ISTANBUL TECHNICAL UNIVERSITY ★ INSTITUTE OF SCIENCE AND TECHNOLOGY

A DESIGN TOOL FOR HUMAN-CENTERED INTELLIGENT BUILDINGS

Ph.D. Thesis by
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Department : Architecture

Programme : Architectural Design

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<u>İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ</u>

İNSAN-MERKEZLİ AKILLI BİNALAR İÇİN BİR TASARIM ARACI

DOKTORA TEZİ

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FOREWORD

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Senior Architect

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ABBREVIATIONS

AI : Artificial Intelligence
ANNs : Artificial Neural Networks
BA : Building Automation
BACNET : Building Automation Control Network
BAS : Building Automation System
BMS : Building Management System
BRE : Building Research Establishment
BRM : Building Rating Method
BQA : Building Quality Assessment
CABA : Continental Automated Buildings Association
CAV : Constant Air Volume
CCTV : Closed Circuit Television
CMS : Communication Management Systems
DDC : Direct Digital Control
EE : Embedded Electronics
EMS : Energy Management Systems
HVAC : Heating, Ventilation and Air Conditioning
IB : Intelligent Building
IBE : Intelligent Buildings in Europe
IBI : Intelligent Building Index
IE : Intelligent Environment
ICT : Information and Communication Technology
II : Intelligent Interfaces
IT : Information Technology
KBS : Knowledge Based Systems
LAN : Local Area Network
LEED : Leadership in Energy and Environment Design
LONWORKS: Local Operating Networks
NI : Natural Intelligence
OA : Office Automation
ORBIT : Organizations, Building and Information Technology
PABX : Private Automated Branch Exchange
PV : Photovoltaic
TCP/IP : Transmission Control Protocol/Internet Protocol
UPS : Uninterrupted Power Systems
VAV : Variable Air Volume

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A DESIGN TOOL FOR HUMAN-CENTERED INTELLIGENT BUILDINGS

SUMMARY

There is a radical change in physical, social, psychological and economic needs of the users in global scale by the impact of pervasive “information technologies”, “communication networks” and “digital technologies”. People can communicate with each other by using electronic mails in virtual environments, attend meetings in different regions of the world by tele-conferencing over internet, or participate a web-based education with interactive information sharing.

Developments in technology and communication changed the social and cultural behavior patterns of the user together with the physical environments. Intelligent environments (IEs) can gain social behavioral patterns by observing and learning from their users through embedded intelligent systems. As the researchers develop more realistic models for information processing capacity of human-brain, the intelligent environments will display behaviors more akin to human beings. Some future life scenarios, changing work patterns and visionary studies reflecting the above facts are discussed in the thesis as well.

As a result of these developments in communication and information technologies, there is a radical transformation ongoing in working patterns and organization structures. These changes have a direct impact on the emergence of “technology-oriented Intelligent Building (IB) design criteria consisting of intelligent building “systems”, “services” and “materials”. But, most of the first generation IBs failed as there was no integration between the “the user needs”, “technology-oriented”, and “environment-oriented” design criteria. This problem can be prevented by establishing an integrated design criteria approach for Human-centered IB. The thesis study is based on this hypothesis. In this proposed integrated design approach, Human-centered IB design which is adaptive, responsive and flexible to cope with changing “user needs” are supported by passive design criteria (environment-oriented) and active building systems design criteria (technology-oriented).

While formulating the integrated design criteria for Human-centered IBs, technology-oriented active design criteria (i.e. systems, services and materials) and environment-oriented passive design parameters (i.e. building orientation and climate, building skin and building shell) can be reconciled to maximize the cost effectiveness, work productivity, and human comfort. The user should be given a certain level of control in their activity area for their physical, social, psychological and economy comfort adjustments.

Main goal of this research study is to integrate the major components of a Human-centered IB design which are; “user-oriented”, “environment-oriented” and “technology-oriented” design criteria in order to develop a design tool for Human-centered IB design which has learning, adaptive, responsive skills to cope with changing user requirements. The static and passive role of the buildings has changed and the buildings act like a living body with their responsive and adaptive structures

to changing spaces and needs, which is one of the main concerns of interactive buildings of the future.

In this thesis study, theoretical model is based on the integrated design criteria approach for Human-centered IBs consisting of three major components: “user”, “environment” and “technology”. In the proposed integrated design approach, “user-oriented design criteria” is taken as a focal point, and supported by “environment” and “technology” oriented design criteria. There are four parameters defined for the “user-oriented design criteria” which are “physical”, “psychological and social”, and “economical” needs of the user. Increasing the productivity and effectiveness of the user are the main goals to be achieved in IBs. For reaching to this target, user requirements shall be effectively integrated into selected design parameters list from the beginning stage of the design as the user-oriented design criteria have direct impact on the selection of the most appropriate “environment-oriented” and “technology-oriented” design criteria.

The second major component identified for the integrated design approach of Human-centered IBs is; “environment-oriented design criteria”. There are three design parameters defined for environment-oriented criteria which are; “building orientation and climate”, “building shell”, and “building skin”. In this thesis study, the selected seven sample buildings are reviewed in order to formulate the design basis parameters for “environment-oriented” design criteria of Human-centered IBs. The selected passive design parameters (i.e. climate, building form, core location, natural ventilation, natural lighting, floor plate area, type and shape, structural planning, and plan type) are converted into a checklist to which new design parameters can be added and/or some existing ones removed based on the requirements of different projects. Also, these “environment-oriented design criteria” have a direct impact on the “user-oriented design criteria”, and this correlation matrix is given in the thesis by selecting one of the sample buildings.

The third major component identified for integrated design approach of Human-centered IBs is; “technology-oriented design criteria”. There are three design parameters defined for technology-oriented design criteria which are; building “services”, “systems” and “materials”. Human-centered IBs must be able to respond to the individual, organizational and environmental requirements, and be flexible to cope with the dynamic interaction between changing user needs and technological progression. In order to respond to these changing user needs, IBs should have an ability to learn, decide, respond and adapt through intelligent technologies used in the building.

During the research studies, it is also realized that there is no integrated design tool to be taken as a common design basis before starting the design of IBs. In these checklists, different parameters belonging to “user-oriented”, “environment-oriented”, and “technology-oriented” design criteria are correlated with each other. By formulating checklists as a tool for the design of Human-centered IBs, some generalizations can be developed to reach a common design basis for IBs. For this reason, the researcher creates some sample checklists displaying the integrated design criteria approach for Human-centered IBs. The correlations between these three main design criteria of Human-centered IB and evidences of the checklists are discussed in the thesis. The solutions and generalizations reached through this design tool are explained in the Conclusion part of the thesis.

In this thesis study, an integrated design approach between the “user-oriented”, “environment-oriented” and “technology-oriented” design criteria is proposed for reaching a Human-centered IB. As a method, checklists consisting of correlation matrices are formulated to establish a common design tool for IB design. Through this Human-centered IB design tool, other architects/designers can create various design combinations based on the requirements of different projects. Also, the architects/designers can use this proposed tool for the evaluation and comparison studies of the existing IB designs.

İNSAN-MERKEZLİ AKILLI BİNALAR İÇİN BİR TASARIM ARACI

ÖZET

"Bilgi teknolojilerinin", "iletişim ağlarının" ve "digital teknolojilerin" yayılan etkisiyle kullanıcıların fiziksel, sosyal, psikolojik ve ekonomik gereksinimlerinde radikal bir değişim yaşanmaktadır. İnsanlar birbirleriyle sanal ortamda e-posta ile iletişim kurabilmekte, internet üzerinden tele-konferans aracılığıyla farklı bölgelerden toplantılara katılabilmekte veya etkileşimli bilgi paylaşımı aracılığıyla web tabanlı eğitime katılabilmektedirler.

Teknoloji ve iletişimdeki gelişmeler kullanıcıların sosyal ve kültürel alışkanlıkları ile beraberinde fiziksel ortamı da değiştirmiştir. Akıllı ortamlar, gömülü akılllı sistemler aracılığı ile kullanıcıları gözlemleyerek ve onlardan öğrenerek sosyal davranış kalıpları edinebilirler. Araştırmacılar insan beyninin bilgi işleme kapasitesinin daha iyi modellerini geliştirdikçe akıllı ortamlar insana daha benzer davranışlar gösterecektir. Tezde; yukarida bahsedilen gerçekleri yansıtan bazı gelecek yaşam senaryoları, değisen çalışma şekilleri ve ileri görüşlü çalismalar da tartışılmıştır.

İletişim ve bilgi teknolojilerindeki bu gelişmeler sonucunda çalışma kalıpları ve organizasyonel yapılarda radikal değişimler yaşanmaktadır. Bu değişimler akıllı bina "sistemleri", "servisleri" ve "malzemeleri" kullanan teknoloji-yönelimli Akıllı Bina tasarim kriterlerinin ortaya çıkışı üzerinde doğrudan etkiye sahiptir. Ancak birinci nesil akıllı binaların çoğu, "kullanıcı gereksinimleri", "teknoloji-yönelimli" ve "çevre-yönelimli" tasarım ölçütleri arasında bütünleşme sağlanamadiğindan beklenen başarıyı gösterememiştir. Bu problem İnsan-merkezli bir akıllı bina için bütünleşik tasarim ölçütleri yaklaşımı benimsenerek önlenebilir. Tez bu varsayım üzerine inşa edilmiştir. Tezde önerilen bütünleşik tasarım yaklaşiminda, değişen kullanıcı ihtiyaçlarına uyumlu, tepki verebilen ve esnek bir İnsan-merkezli akıllı bina tasarımı; pasif tasarım ölçütleri (çevre-yönelimli) ve aktif bina sistemleri (teknoloji-yönelimli) tarafından desteklenir.

İnsan-merkezli akıllı binalar için bütünleşik tasarım ölçütlerini ortaya koyarken teknoloji-yönelimli aktif tasarım ölçütleri (bina sistemleri, servisleri, ve malzemeler) ve çevre-yönelimli pasif tasarım ölçütleri (bina yönelimi ve iklim, bina kabuğu ve bina strüktürü) uzlaştırılarak maliyet etkinliği, verimlilik, ve insan konforu maksimize edilebilir. Kullanıcıya, fiziksel, sosyal, psikolojik ve ekonomik anlamda konfor ayarlamalarını yapabilmesi için kendi kullanım alanı içerisinde belli bir seviyeye kadar kontrole sahip olmalıdır.

Bu araştırmanın ana amacı; İnsan-merkezli bir akıllı bina kavramının ana unsurları olan "kullanıcı- yönelimli", "çevre-yönelimli" ve "teknoloji-yönelimli" tasarım ölçütlerini bütünleştirip, değişen kullanıcı ihtiyaçlarını öğrenebilen, uyum sağlayabilen, tepki verme yeteneğine sahip bir insan merkezli bir akıllı bina tasarım aracı geliştirmektir. Binaların durağan ve pasif rolleri değişmiş, binalar tepkisel, ortama ve değişen ihtiyaçlara uyum gösterebilen yapıları ile canlı bir vücut gibi davranabilmektedir ki bu da geleceğin etkileşimli binalarıyla ilgili ana konulardan biridir.

Bu çalışmada “İnsan-merkezli Akıllı Bina” kavramı üç tasarım ölçütünün bütünleşmesi olarak incelenmiştir: “kullanıcı-yönelimli ölçütler”, “çevresel-yönelimli ölçütler” ve “teknoloji-yönelimli ölçütler”.

Bu çalışmada teorik model; "kullanıcı", "çevre" ve "teknoloji" üç ana bileşeninden oluşan insan-merkezli akıllı binalar için bütünleşik tasarım ölçütleri yaklaşımına dayanmaktadır. Önerilen bütünleşik tasarım yaklaşımında, "kullanıcı-yönelimli” tasarım ölçütleri, odak noktası olarak ele alınip, "çevre" ve "teknoloji" yönelimli tasarim ölçütleri tarafından desteklenmiştir. “Kullanıcı-yönelimli tasarım ölçütleri” için; kullanıcının "fiziksel", "psikolojik ve sosyal", ve "ekonomik" ihtiyaçları olarak tanımlanmış dört parametre vardır. Akıllı binalarda kullanıcının verimlilik ve etkinliğini arttırmak başarılması gereken temel hedeflerdir. Bu hedefe ulaşmak için; kullanıcı ihtiyaçları, seçilen tasarım parametreleri listesine tasarımın ilk aşamasından itibaren etkin bir şekilde bütünleştirilmelidir, çünkü kullanıcı-yönelimli tasarım ölçütleri en uygun “çevre-yönelimli” ve “teknoloji-yönelimli” tasarım ölçütlerinin seçiminde doğrudan etkiye sahiptir.

İnsan-merkezli akıllı binaların bütünleşik tasarım yaklaşımı için belirlenen ikinci önemli bileşen, “çevre-yönelimli” tasarım ölçütleridir. “Çevre-yönelimli” ölçütler için üç tasarım parametresi tanımlanmıştır: “bina yönlenmesi ve iklim”, “bina strüktürü” ve “bina kabuğu”. Bu tez çalışmasında seçilen yedi örnek bina, İnsan-merkezli akıllı binaların “çevre-yönelimli” tasarım ölçütlerinin temel tasarım parametrelerinin oluşturulması için incelenmiştir. Seçilen pasif tasarım parametreleri (iklim, binanın şekli, çekirdeğin yerleşimi, doğal havalandırma, doğal aydınlatma, döşeme alanı, tipi ve şekli, stüktürel planlama, ve plan tipi) başka projelerin gereksinimlerine dayanarak, yeni tasarım parametrelerinin eklenebileceği ve/veya mevcutların çıkarılabileceği bir kontrol listesine dönüştürülmüştür.

Ayrıca, bu “çevre-yönelimli tasarım ölçütlerinin” “kullanıcı-yönelimli tasarım ölçütleri” üzerinde doğrudan etkisi vardır ve bu bağıntı (korelasyon) matrisi örnek binalarından biri seçilerek verilir.

İnsan-merkezli akıllı binaların bütünleşik tasarım yaklaşımı için belirlenen üçüncü önemli bileşen ise “teknoloji-yönelimli” tasarım ölçütleridir. “Teknoloji-yönelimli” tasarım ölçütü için üç tasarım parametresi tanımlanmıştır: bina “servisleri”, “sistemleri” ve “malzemeler”. İnsan-merkezli akıllı binalar; bireysel, örgütsel ve çevresel ihtiyaçlara cevap verebilmeli, ve değişen kullanıcı ihtiyaçlarıyla teknolojik ilerleme arasında dinamik etkileşimle başa çıkabilmek için esnek olması gerekmektedir. Bu değişen kullanıcı ihtiyaçlarına yanıt vermek için, binada kullanılan akıllı teknolojiler aracılığıyla, akıllı binaların öğrenme, karar verme, tepki verme ve uyum sağlama yeteneğine sahip olmalıdır.

Araştırma çalışmaları sırasında, Akıllı bina tasarımına başlamadan önce ortak bir tasarım temeli olarak alınabilecek bütünleşik bir tasarım aracı olmadığının farkına varılmıştır. Bu nedenle, tezin yazarı insan-merkezli akıllı binalar için bütünleşik tasarım ölçütleri yaklaşımını gösteren bazı örnek kontrol listeleri oluşturmuştur. Bu kontrol listelerinde; “kullanıcı-yönelimli”, “çevre-yönelimli” ve “teknoloji-yönelimli” tasarım ölçütlerine ait farklı parametreler birbirleriyle ilişkilendirilmiştir. İnsan-merkezli akıllı binaların tasarımı için araç olacak şekilde Kontrol listeleri oluşturarak, akıllı binalar için ortak bir tasarım temeline ulaşmak için bazı genellemeler geliştirilebilir. Bu tez çalışmasında, Akıllı binaların üç ana tasarım ölçütünün arasındaki bağıntı ve kontrol listelerinin bulguları tartışılır. Bu tasarım aracı ile ulaşılan çözümler ve genellemeler tezin Sonuç bölümünde açıklanmıştır.

Bu tezde; İnsan-merkezli bir akıllı bina tasarımına ulaşmak için “kullanıcı-yönelimli” “çevre-yönelimli” ve “teknoloji-yönelimli” tasarım ölçütlerini bütünleştiren bir yaklasim önerilmiştir. Metod olarak ise; akıllı bina tasarımı için ortak bir tasarım aracı oluşturmak üzere bağıntı matrislerinden oluşan kontrol listeleri hazırlanmıştır. Bu akıllı tasarım aracını kullanarak diğer mimarlar/tasarımcılar farklı proje gereksinimlerine göre çeşitli tasarım birleşimleri yaratabilirler. Mimarlar/tasarımcılar önerilen bu tasairm aracını varolan akıllı bina tasarımlarının değerlendirmesi ve karşılaştırmasında kullanabilirler.

1. INTRODUCTION

There is a radical change in the social needs and behavior patterns of the users in global scale by the impact of pervasive "information technologies" and "communication networks". We are moving towards an era of ubiquitous computing in which anyone can get any document anytime and anywhere (anyone, anything, anytime, anywhere) (Flanagan et al., 1997). This new creative environments and knowledge/communication based intelligent infrastructures provide the necessary means for the user in order to support activities that were not possible beforehand. For example, people can communicate with each other by using electronic mails in virtual environments, attend meetings in different regions of the world by tele-conferencing over internet, or participate a web-based education with interactive information sharing. Developments in technology and communication changed the social and cultural behavior patterns of the user together with the physical environments.

During these technological developments, the relation between man and nature is passing through evolutionary stages reflections of which can be seen in the built environment. We are surrounded by information flood of digital technology. The Internet is the most widespread information-processing tool. It spreads out the information over the surface of the world through "distributed intelligent network". During this process, millions of computers are connected to each other and exchange data to reach into other information. The Internet functions like a *"gigantic worldwide brain structure"* (Ooesterhuis, 2002: 94). The connected computers through the Internet are compared to the millions of the neurons cells of the human brain communicating with each other. Information processing capacity of natural intelligence (brain) and its highly adaptable structure developed through learning is taken as a major model for interdisciplinary studies changing from computer science to architecture.

In this digital era, information is everything and there is continuous data flow from both living and non-living bodies. Just like the networks of computers, information can enter the buildings through the wires of the building connecting it into different networks. Wireless technology will be processed by the body of the building, transformed into another state, and then released again through its output channels (Ooesterhuis, 2002: 98). These buildings enriched with IT and intelligent systems process the information and response to their users' needs. These buildings are becoming more responsive and adaptive to changing human needs and tasks, but at the same time they are losing their integration with natural and environmental concerns. As a result of this alienation from environmental context, we are facing with the problems of sustainability in social, environmental and economic life.

By the year 2015, the estimated world population will be 8,5 billion and %70 percent will live in cities (Yeang, 2003). This will bring forth the development of cities in vertical dimension rather than horizontal ground, which means that the high-rise building type will prevail in the future as well. But, %50 of the total energy consumption belongs to the buildings and we have to be conscious about our built environments (Yeang, 2003). As the buildings become more responsive to human needs, they consume more energy for establishing the tasks through intelligent systems. In fact, what makes the buildings intelligent are not the intelligent systems that are used but the intelligent design criteria supporting the balance between building systems, services, materials and nature for providing a healthy and productive environment for human beings.

The danger of exhausting the limited natural sources and waste pollution together with the global warming are the urgent environmental problems to be solved for the sustainability of the future generations. This is one of the most critical environmental problems that have to be handled together with technological developments of the digital era. These technological developments are highly responsive and adaptive to the future life scenarios, but weak in terms of environmental responsiveness. In general, the buildings are the most energy consuming entities of the artificial environment created by human beings. This energy load has increased with the addition of intelligent systems within the information society.

Before giving the definition of Intelligent Building (IB) concept, it is relevant to explain what is meant by environmental responsiveness. The environment issue has two sides defining the climate on one side it; and defines the action of man on his environment on the other side. There exists a symbiotic relation between man and his environment. Human need to find a way to live together with his environment

(Gratia et al., 2003). If we can establish a similar type of symbiotic relation between the man-made artifacts (buildings) and nature (environmental context), then the destructive effects of the buildings can be minimized. As a result of this, the energy and material consumption will be reduced.

With the idea of environmental responsiveness, there have been built zero energy consuming domestic buildings. But it is not possible to mention the same developments for Intelligent Office buildings because of their more complex use and dynamic changing work patterns. Whereas, there are some examples for environmentally responsive high-rise office buildings that can use energy, water, and other resources more efficiently while protecting the users' health and improving their productivity. They reduce the overall impact of high-rise building to its environment. Ken Yeang emphasizes the fact that, high-rise building type will not simply go away in the next millennium in most of the World's cities. It will continue to exist until another more economical alternative is invented (Yeang, 1994). While designing intelligent high-rise buildings, Environment-oriented design criteria need to be integrated with "User-oriented" and "Technology-oriented" design criteria. By this way, the reverse effects on the environment can be mitigated.

It is relevant to continue with the definition of "IB" concept. The IB Institute in Washington, D.C., defines the IB as follows: *"An IB is the one which integrates various systems to effectively manage resources in a coordinated mode to maximize occupant performance, investment and operating cost savings and flexibility"* (McClelland, 1988: 10). As it can be understood from this definition, the design of the IBs should be both cost saving and energy efficient while providing maximum comfort conditions to its users. In order to achieve this target, there can be produced a design tool to establish a common basis for the design of IBs.

By establishing IB design parameters through a design tool, there can be reached reconciliation between "environment" and "technology" centralizing the "user" requirements. This will bring forth the implementation of an IB design tool in which environment-oriented, technology-oriented (building systems, services, materials) and user-oriented design criteria are integrated into each other from the initial design stage of the project.

The IB design principles should also support environmental, social, cultural and economic sustainability. There are various definitions for IBs, some of which explain merely technical properties; whereas the others emphasize the importance of human-machine interaction through these integrated intelligent systems.

In this thesis study, the definition of IB established by Yang et al., will be taken as a major source:

> "An IB must be able to respond to individual, organizational and environmental requirement and to cope with changes. It is also believed that a truly IB should also be able to learn and adjust its performance from its occupancy and environment" (Yang et al., 2001).

The term intelligence includes higher levels of adaptability to changing conditions, and learning. An IB can only prevail if it is able to cope with the changes in social, technological and economic life. This requires adaptability, learning, flexibility and responsiveness to the requirements of the user and the environment.

Whenever the architecture of IB is disconnected from the environmental, human-centered and user oriented design criteria of the IBs, the interaction between the user and the building will diminish. As a result of this weak interaction, most of today's IBs are "electronically enhanced architectural forms, which are essentially containers of smart technologies and disenfranchised occupants" (Kroner, 1997: 385). IBs need to improve the comfort conditions of the user rather than converting them into passive actors of the created intelligent environments. In this thesis study, the user has been given a centralized role supported by Environment-oriented design criteria (building orientation and climate, building skin, and shell), and Technology-oriented design criteria (building services, systems and materials) in order to reach a responsive, adaptive and flexible design for IBs. IBs will start to display responsive, adaptive and flexible skills by analyzing the social behavior patterns of the user, learning through this process, and adapting itself.

Human-centered IB design should provide the appropriate responsiveness and adaptation skills to satisfy the changing user needs. The user should be given a certain level of control in their environment for their physical, psychological and social needs. The developments in communication technology affect the social interaction patterns among people. Also the cultural background of the user is effective in human interaction and its reflection to physical space. For example, some cultures like American, British and Dutch are individualistic, and they have a tendency towards social independence. The virtual office might be a good alternative for these individualistic cultures (Meel et al., 1997).

Human are social beings, and they do not just live as independent individuals working and living alone. They belong to different social groups, organizations and communities. They interact and participate in activities with other groups, teams, organizations and communities. During these activities, they learn and adapt to changing circumstances. Hence, in order to cope with the changing user needs, Human-centered IB designs should possess this learning and adaptation skills to interact with the user. These designs should correlate with human skills not only in technological terms, but also in environmental and user requirements. Human-centered IB design should support and satisfy the physical, psychological, social and economic requirements of the user by implementing a responsive, adaptive and flexible approach.

As it has been stated by W. Kroner, an intelligent architecture evolves as a result of three universal design challenges; (i) "healthy sustainable and culturally diverse forms of architecture"; (ii) "smart materials technologies incorporating Artificial Intelligence", and (iii) "expanded design team supporting the intellectual and creative potential of human source together with the economically enhanced machine". The use of technological developments in smart materials, artificial intelligence and intelligent technologies has resulted in significant progress in many building systems. Some of the needs of the user can be responded with the developments in computing, telecommunications, IT, virtual reality and data processing. The most critical point in the design of the IB is to create environments, which are more responsible to human and nature (Kroner, 1997). A responsive Human-centered IB design needs to satisfy user needs in a balanced manner by integrating environment and technology-oriented design criteria.

One of the most problematic issues in the design of IBs is their sealed and disengaged indoor space independent from climatic and environmental context of the local requirements. They use only active building systems, services and smart materials for the provision of indoor comfort conditions. This type of IBs is merely designed with technology-oriented approach by disregarding the environmental and user needs. This thesis study is focused on reaching a common design basis for Human-centered IBs which can respond to user requirements (physical, psychological, social and economic) in a responsive, adaptive and flexible manner by establishing a balance between the use of Environment-oriented design criteria (building orientation and climate, building skin and shell) and technology-oriented design criteria (building services, systems and materials).

The seamless integration of environmental design criteria with technological ones for satisfying user requirements can minimize the risk of ending up merely technology-oriented IBs by enriching them with social and environmental responsiveness.

1.1 Aim of the Thesis

The aim of this research study is firstly to integrate the missing links between the major components of IB design, which are; “user-oriented criteria”, “environment-oriented design criteria”, and “technology-oriented criteria”. The researcher aims to develop a design tool for a Human-centered IB that can be used by the designers/architects at the preliminary design stage of different projects. By this way, the user requirements (physical, psychological and social, economic) are integrated into IB design from the initial phase of design, and the user will not be the passive actor of the work space. The comfort conditions and productivity of the user increase by providing a responsive, adaptive and flexible Human-centered IB.

During literature survey, it has been realized that there is no universally agreed IB definition, and a detailed study displaying the design parameters of IBs. Most of the IB research studies are done by computer science, mechanical and electrical disciplines which are mostly related to intelligent systems and technologies. In the thesis, human intelligence is taken as the driving force for the definition of IB criteria through which the “user”; “environment”, and “technology” components are integrated to reach a Human-centered IB (Figure 1.1).

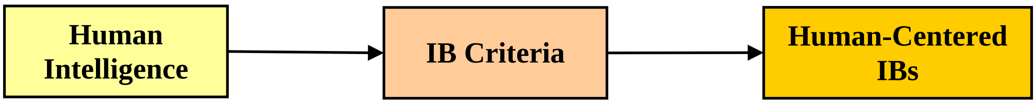


Figure 1.1 : Human Intelligence leading to IB concept and Human-centered IBs.

At the end of this study, the aim is to develop a design tool which can become a common design basis for IB designers/architects. As a design tool, checklists will be used displaying the correlation of relevant design parameters for the “user”, “environment” and “technology” criteria. It is important to define an integrated approach for design criteria of Human-centered IBs for having a common design basis that can be adjusted according to changing user needs. This research study hopes to open new perspectives for the design of IBs by establishing an integrated design basis approach which is flexible and open to new additions and omissions based on the requirements of each IB project.

In this study, the user-oriented criteria (physical, psychological, social and economic requirements) are taken as the focal point which is supported by technology and environment-oriented design criteria in a responsive, adaptive and flexible manner. The design parameters for Human-centered IBs can be developed in a responsive, adaptive and flexible manner if the user requirements (physical, social, psychological and economic) are properly integrated in to IB design from the initial stage and supported by the most appropriate "technology-oriented" and "environment-oriented" criteria for achieving these requirements.

In this thesis, by using checklists as a tool for displaying various combinations of correlated design parameters for "user-oriented", "environment-oriented" and "technology-oriented criteria", the designer/architect is given the option of developing IB design parameters specific to that building. The designer/architect can select among several layers of correlations established for IB design criteria by opening and/or closing the relevant parameters.

In order to formulate the design parameters for IBs, seven buildings are selected and reviewed according to "User-oriented", "Environment-oriented", and "Technology-oriented" design criteria. As a result of this study; these design parameters will be generalized to provide a common design basis for IBs. But, it will be an open ended generic design tool rather than a rigid, closed model consisting of stable parameters.

1.2 Organization of the Thesis and Methodology

The organization of thesis is summarized in Figure 1.3 in which integration of three major criteria for Human-oriented IB; "user", "environment" and "technology" can be followed. After the statement of the problem, objectives and research method in Chapter 1 (Introduction), AI paradigms and applications are briefly explained after the description of the term intelligence in Chapter 2 before passing to the emergence of IB concept.

1. INTRODUCTION

PROBLEM STATEMENT
- Developing a design tool for Human-centered IBs

METHODOLOGY
- Checklists as a design tool

2. INTELLIGENCE CONCEPT & INTELLIGENT BUILDINGS

- **USER-ORIENTED DESIGN CRITERIA OF IBs**

- **Theoretical Model of Research: Integrated Design Approach for IBs**

3. ENVIRONMENT-ORIENTED DESIGN CRITERIA OF IBs

- Building Orientation and Climate
- Building Shell
- Building Skin

- Evaluating Environment-oriented Design Criteria on Seven IBs

4. TECHNOLOGY-ORIENTED DESIGN CRITERIA OF IBs

- Systems-Oriented Criteria
- Services-Oriented Criteria
- Materials -Oriented Criteria

5. A DESIGN TOOL FOR HUMAN-CENTERED IBs

- Generalized **Checklists** proposed as a decision support tool for Human-centered IB design

6. CONCLUSION & EVALUATIONS

Figure 1.2 : The Organization of Thesis.

In Chapter 2, after introducing the definition of various IB concepts, future projections for intelligent environments are given in which some future life scenarios and visionary studies have been examined. In the same chapter, theoretical model based on the integrated design criteria approach for Human-centered IB is explained in which three components are highlighted which are: “user”, “environment” and “technology”. The major component of this approach is “User-oriented design criteria” taken as a focal point, explained by referring to the “physical”, “psychological and social”, and “economical” needs of the user. Increasing the productivity and effectiveness are the main goals to be achieved by IBs, and for this reason user requirements shall be properly integrated into design from the beginning stage of the design. In Chapter 2, the “physical”, “psychological and social”, and “economic needs” of the users have been defined by reviewing the changing working patterns and organization structure of IBs. While displaying the physical needs of the user; “spatial quality”, “thermal quality”, “air quality”, “aural quality”, and “visual quality” parameters are examined. For explaining the psychological and social needs of the user; “privacy/autonomy relation”, “interaction”, “habitability”, “mental health/stress”, and “security/territoriality” parameters are discussed. For the economic needs of the user; “space”, “material”, “energy”, and “investment” conservation parameters are discussed.

In Chapter 3, after providing brief information about the sustainability and ecological design, the second major component of Human-centered IB design approach; “Environment-oriented design criteria” is described. Three design parameters are specified for environment-oriented criteria which are; “building orientation and climate”, “building shell” and “building skin”. Environment-oriented design criteria for IBs have been analyzed through seven selected IBs for displaying the passive design parameters (i.e. climate, building form, core location, natural ventilation, natural lighting, floor plate area, type and shape, structural planning, and plan type) to prepare the checklists. These passive design parameters have a direct impact to the “user needs” which will be displayed through checklists for one of the selected buildings in the following sections (Chapter 5).

In Chapter 4, the third major component of Human-centered IB design approach; “Technology-oriented design criteria” is described. Three design parameters are specified for technology-oriented criteria which are: “services”, “systems” and “materials”. Developments in technology and communication changed the social and cultural behavior patterns of the user together with the physical environments. Intelligent environments can gain social behavioral patterns by observing and learning from the users through embedded intelligent systems. As the researchers develop more realistic models for information processing capacity of human-brain, the intelligent environments will display behaviors more akin to human beings and become more human-centered.

During the research studies, it is realized that there is no integrated design tool to be taken as a common design basis before starting the design of IBs. In Chapter 5, the researcher creates some sample checklists displaying the integrated design criteria approach for Human-centered IBs. In these checklists, different parameters belonging to “user-oriented”, “environment-oriented”, and “technology-oriented” design criteria are correlated with each other. By formulating checklists as a tool for the design of Human-centered IBs, some generalizations can be developed to reach a common design basis for IBs. The correlations between parameters and evidences of the checklists are discussed in Chapter 5. The solutions and generalizations reached by using this tool are explained in the Conclusion and Evaluations part, in Chapter 6.

Methodology

The methodology of the thesis displaying an integrated design criteria approach for Human-centered IBs is given in Figure 1.3. There are three main design criteria that need to be integrated to each other which are “user-oriented”, “environment-oriented” and “technology-oriented” ones.

The aim of the proposed checklists is to create a common design tool that can be used by the designers/architects for the design of Human-centered IB which may provide more responsive, adaptive and flexible IBs that can cope with the changing user needs. Some of these parameters can be closed and opened in each IB design project according to the requirements of the new building program. Depending on the requirements of the new project, the user of this design tool can search for many combinations between already specified design parameters which can be expanded or omitted.

For example, “technology-oriented” design criteria can be correlated to “environment-oriented” design criteria based on the requirements of the user. If the natural ventilation design criteria consisting of specified parameters like cross ventilation, sky-courts, atriums, double skin, and operable windows are taken and correlated with HVAC parameter of services-oriented criteria, by considering the climate zone and orientation of the building, some of the natural ventilation parameters can be used in collaboration with HVAC to increase the user comfort conditions and productivity in physical, social, psychological and economic terms The architect/designer can develop several combinations by closing and opening the selected parameters for "user", "environment" and "technology" to reach an integrated Human-centered IB design.

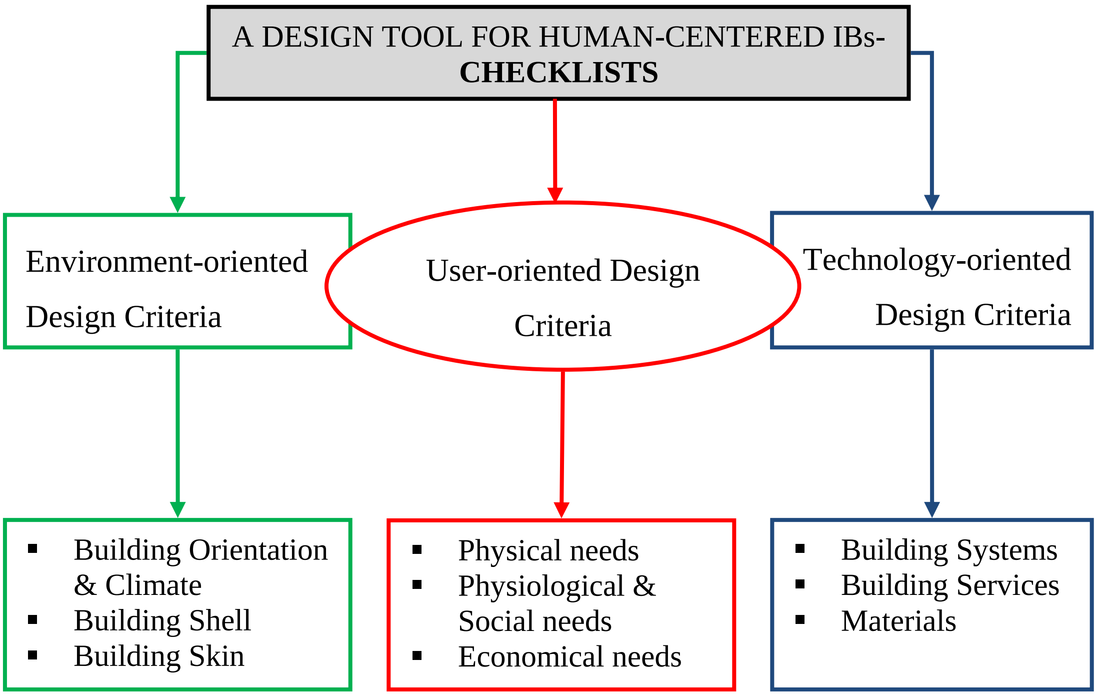


Figure 1.3 : Methodological structure of the thesis displaying the integrated design approach for Human-centered IB.

In this thesis study, there is a search for a more responsive, adaptive, and flexible Human-centered IB design approach. For achieving this target, integration of the "user-oriented", "environment-oriented", and "technology-oriented" design criteria is proposed rather than seeing technology-oriented criteria as the resolution to intelligent design which is the prevailing condition in most of the existing IBs.

The proposed design tool (checklists) can be adapted to different cultures and different contexts in different forms. The IBs of the future should provide the appropriate responsiveness and adaptation skills in relation to changing user needs and changing environments. This type of IB can be achieved by using an integrated design approach between “user”, “environment”, and “technology” criteria. In the proposed Human-centered IB design approach, user-oriented criteria is the focal point for a highly responsive, adaptive and flexible design, and it will be supported by “technology-oriented” and “environment-oriented” design criteria

2. INTELLIGENCE CONCEPT AND IBS

It is relevant to start with the definition of the term "intelligence" before passing to IB. Most of the time "reason" *(usa vurma)* and "intelligence" *(zeka)* terms are confused and misused. **Intelligence**: ***"****is an inferred ability to perceive and comprehend meaning, and apply this acquired knowledge, through the thinking process of reasoning"* (Harris et al.., 2002:17) whereas **reason**: *"is the power of mind to think, understand and form judgments by a process of logic* (The New Oxford Dictionary, 1998: 948).

According to J. Piaget, Swiss biologist and child psychologist, intelligence is: "a complex hierarchy of information processing skills, underlying an adaptive equilibrium between the individual and their environment" (Piaget, 1980). Piaget's definition can be explanatory for understanding; how people work or live in buildings and how they interact with their microclimate and the external environment.

Intelligent environments should perceive, learn and adapt to changing conditions in order to survive with their users. While explaining the concept of intelligence, J. Piaget emphasizes the information processing ability of human mind and its highly 'adaptive' and 'learning' character. These properties can be developed in a sense. There are ongoing research and development studies for improving the adaptation and learning skills of intelligent environments. If we continue with the definition Piaget, he says:

> "Intelligence is an adaptation…To say that intelligence is a particular instance of biological adaptation is thus to suppose that it is essentially an organization and that its function is to structure the universe just as the organism structures its immediate environment" (Piaget, 1963: 3-4).

People adapt to their environments both physiologically and psychologically, and previous experiences are effective during this interaction. The IB should be responsive to the user needs and to acquire this, it has to learn and adapt some social behavioral patterns of the people. In his book, "*The Sciences of the Artificial"*, in 1996, Herbert A. Simon explains the adaptive human behavior as follows:

> "…A thinking human-being is an adaptive system; men's goals define the interface between their inner and outer environments, including their memory stores in the outer environments. To the extent that they are effectively adaptive, their behavior will reflect characteristics largely of the outer environment and will reveal only a few limiting properties of the inner environment – of the physiological machinery that enables a person to think" (Simon, 1996: 53).

If the IB system adapts to its environment in a similar way, it will respond the requirements of the user in a flexible manner. Natural Intelligence is related to faculties found in living beings in order to preserve their existence, and it should include the *adaptive* and *responsive* systems found in the nature. There are many expert systems produced by using artificial intelligence, but they haven't been able to reach the true intelligence level of cognitive thought.

It is relevant to briefly summarize the Artificial Paradigms and AI applications before starting the definition of IB as these applications support the learning process and development of responsive behavior of IBs. AI studies are especially important for the IBs gaining social behavioral patterns by observing, learning, adapting and responding to the user in the intelligent environment.

AI paradigms and applications are also important for the intelligent building systems which are one of the parameters of technology-oriented IB design criteria.

2.1 Artificial Intelligence, Paradigms and Applications

AI tries to imitate the learning methods of the brain and tries to reach the true intelligence level of human brain. The scientist aim to model the human brain in computers in order to solve its functioning mechanism to develop AI, that is more akin to human brain processing. For example, Lloyd Watts, collected models of specific types of neurons and wiring information about how the internal connections are wired in different regions of the brain. A detailed model of about 15 regions that deal with auditory processing has been prepared, and he has applied psycho-acoustic tests of the model, comparing it to human auditory perception. This technology is now being used as a front end for speech recognition software (Kurzweil, 2002). Human intelligence is complicated, and hard to decipher, but there are experts modeling these complicated issues to reveal the processing of the brain.

2.1.1 Artificial paradigms

As stated by A. Caplinkas, there are at least three paradigms that can be used in AI which are: “the behaviorist paradigm”, “the agent paradigm”, and “the artificial life paradigm” (Caplinskas, 1998). These paradigms are briefly explained in the following paragraphs.

Behaviorist paradigm; sees AI as “the study of intelligent behavior and construction of systems that act like a human being. In the behaviorist paradigm, the intelligence is seen as collection of behaviors, and each behavior can be studied and implemented separately. This paradigm is based on Turing Test (1950) and aims to define intelligence in a way that can be applied to anything that is intelligent, including human beings and machines” (Caplinskas, 1998: 493). In the famous Turing test, the interrogator in one room communicates with a system in a second room, and a man in a third room. The system is intelligent if the interrogator cannot tell the difference between the human and the system (Caplinskas, 1998). In the Turing test, the standard is a human being in general, but this is also contradictory as different people have different degree of intelligences.

Agent paradigm; views intelligence as the ability to behave reasonably in appropriate environments. Integration is the key term for agent paradigm. Agent is “an entity that integrates and manages separate behaviors. It can perceive its environment through “sensors” and acting to environment through “effectors”. Agents should be reactive and autonomous. Agents should perceive their environments and respond to changes. They have data-oriented architecture, concentrating on algorithms to implement behaviors. (Caplinskas, 1998)

Agent paradigm of AI views the systems abilities as skills and an agent can learn these skills. New skills can be embedded into agents by adding new sensors or effectors. According to Caplinkas, the next intelligence level of agents will be defined by “social ability” and “adaptivity” (Caplinskas, 1998).

Artificial life paradigm; suggests that the “logical form” of an organism can be separated from its material basis of construction and “aliveness” will be the property of former, not the material basis. It aims to build a general purpose, robotic agent that works and communicates with human beings in their natural environments (Caplinskas, 1998).

2.1.2 AI applications

There are different types of AI applications such as; “Expert Systems”, “Knowledge-Based Systems”, “Robotic”, and “Natural Languages”. Among these systems, Artificial Neural Networks (ANNs) are more akin to human brain than computers. But still, the neural networks cannot be designed as complicated as human brain, and the layering of these networks and the nodes are more simple in order to imitate the brain connections in a reasonable time period. ANNs high capacity of learning and adaptability can provide an interactive relation between the user and intelligent environments.

Artificial Neural Networks (ANNs)

ANNs are able to deal with complex problems that cannot be simply solved by predefined rules and behavior patterns. The neural network tries to recreate biological networks by imitating the information processing functions of brain cells. The network consists of artificial neurons performing activation functions to determine output.

The intelligent systems try to reach the true complexity of intelligence through *“Artificial Neural Networks (ANNs)”*. The neural network tries to recreate biological networks by imitating the information processing functions of brain cells (Harris et al., 2002).

ANNs are being developed for simulating some learning methods of human brain in order to solve the complicated problems that cannot be achieved by computers. ANNs provide abilities such as learning, making generalizations, and dexterity to cope with minor errors and incomplete (uncertain) inputs. This system can adapt different solutions in relation to changing circumstances (Doğan, 2002).

In order to cope with the complicated issues of uncertain cases, ANNs use the concept of Fuzzy Logic. It can be defined as a rigid mathematical system to explain and work with uncertain cases. Fuzzy Logic provides the modeling and mathematical expression of learning by experience that is specific to human-being (Dogan, 2002). This kind of approach tries to imitate the cognitive capabilities of human mind such as knowing, reasoning, judging, thinking, deciding, responding and perception. But, it should be kept in mind that it is not possible to reach the true cognitive level of human mind by advanced computer systems.

There are some studies on the development of neural links that will allow the user commands to be given with muscle impulses, eye movements, and brain waves by improving human-machine interaction level. (Lusted et al., 1996) The technological developments in information and computer technology open the way of the new interaction modes between the user and the machine. But technology should be used for serving people, not to be served by user.

Expert Systems

The AI techniques (i.e. Expert systems, Knowledge-Based systems, Rule-Based Systems) which can model human reasoning have been implemented into various aspects of the building design and construction. They do not stem from imitation of the way of thinking of people, but from the development of computer programs adding the new information gained through experience of practice.

Expert systems are computer programs that act like an expert consultant in predicting the outcomes of events or diagnosing problems. It does this by manipulating large knowledge using structured rules to draw its conclusions

Cornick (1988) emphasizes the importance of producing a computer model which will include all the information related to a building from its conception stage to its operation and maintenance. By integrating these databases with CAD graphics and by adding necessary "expert modules", a user friendly interface can be created.

Knowledge-Based Systems (KBS)

Knowledge-based Systems (KBS) are one form of AI technology in which knowledge is captured from the experts and stored as a knowledge base. A KBS diagnose the problem by accessing its data-base and suggest the best action for each case. KBS can be used for integrating the building services and systems in IBs.

Yang et al., emphasize the significance of a Knowledge-Based System (KBS) that can be used for solving complex decision-making problems faced in the selection, evaluation, and comparisons of intelligent building technologies. The researchers explain the objective of this paper as follows: *"The on*-going *system development introduced here attempts to fill in the gap between increasing demand and the lack of tools in tackling the complex issues of selecting the most appropriate design alternatives, when clients and consultants work with other construction professionals for IB applications"* (Yang et al., 2001, 67-77).

Robotics

If the buildings are considered as long term investments that are capable of adapting to changing needs, it is worth to develop an integrated AI and Robotics system in intelligent buildings. The Robotics gives automatic reaction to changing conditions through sensors. When these two systems are integrated, the IB will have an advanced knowledge-base. It includes all design and development stages with the robotic sensing monitoring and demands correction whenever necessary against the knowledge-base of every elemental part of the building (Cornick, 1988).

After a brief introduction about AI applications, the thesis continues with the definition of IB concept and its emergence in architecture.

2.2 The Emergence of IB Concept: Definitions and Theory

Before displaying the various definitions of IBs, it is appropriate to start with the emergence of this concept in architecture. The evolution of high-rise buildings can be defined as an important preparatory stage in IB design. The technological developments in structural systems and building materials provided the necessary tools for the development of high-rise buildings. The designer of high-rise buildings tried to meet both the commercial objectives of the developers' and requirements of this new building typology. The first high-rise building was built in America in 1880s, and the next step has been its transformation into IB. The world's first IB "City Place", is in Hartford, Connecticut in the USA, built between 1981 and 1983 (Figure 2.1). But, the intelligence of this building was limited to electrical controls rather than the integrated intelligence of design and systems (Duffy, 1983).

In the past, IBs were used to define office buildings, but today the intelligent architecture includes: homes, apartments, offices, hospitals, libraries, factories, and educational institutions etc.

IB design is a dynamic concept that can be created in various combinations in relation to occupant needs, environmental and technological conditions for maximizing the user productivity and efficiency. The most critical tool in the achievement of IB design is integration between buildings' service systems, environments and the user. IBs should be designed to cope with social and technological changes and should be adaptable to changing human needs.

According to Mill et al., there are three basic approaches to the design of intelligent office: "using technology as controller", "using the environment as controller", and "enabling the individual user to be the controller of interior office environments". The critical issue about the technology and environment-oriented approaches is that they ignore the most important actor of the IB design: "the user". Even though they are designed to increase the work efficiency and energy efficiency, they do not serve for user comfort in physical, psychological, social and economic terms.

In this thesis study, the integration between the "user", "environment" and "technology" oriented design criteria have been discussed for reaching an adaptive, responsive and flexible Human-centered IB design.

Figure 2.1 : The world's first IB, City Place Hartford, adapted from Duffy (1983).

IB Definitions

Before giving the definition of Human-centered IB described in this thesis study, some major IB definitions are explained. At the end of this section, the definition of IB for this thesis study is provided.

Definition of the IB Institute (IBI):

> "An IB is one that provides a productive and cost effective environment through optimization of its four basic elements: Structures, Systems, Services,

> Management, and the interrelation between them… the only characteristic that all IBs must have in common is a structure designed to accommodate change in a convenient, cost effective manner" (Arkin et al., 1997: 472).

The definition of IB institute mainly emphasizes the optimization of "structure", "systems", "services" and "management". In this definition, the priority is given to the flexibility of structure to accommodate changes which are a very limited common base to share for all IBs.

Definition of the European IB Group (EIBG), in:

> "An IB creates an environment that allows organizations to achieve their business objectives and maximizes the effectiveness of its occupants while at the same time allowing efficient management of resources with minimum life-time cost" (Arkin et al., 1997: 472).

The definition of EIBG is giving the priority to organizational needs of the user and requirement of an efficient resource management rather than emphasizing some physical criteria.

The National Research Council, in Washington DC; calls an IB as electronically enhanced office buildings and defines them as:

> "Buildings (which are) equipped with the electronic and physical infrastructure to support the use of advanced communication, data processing and control technologies by its occupants and operating personnel. Such a building is equipped with the necessary wires, cables, ducts, power supply, heating, ventilating, cooling, illumination, noise suppression and security systems to support the performance requirements of today's office environment" (Kroner, 1997).
>
> "An IB is a dynamic and responsive architecture that provides every occupant with productive, cost effective and environmentally approved conditions through a continuous interaction among its four basic elements: Places (fabric; structure; facilities): Processes (automation control; systems): People (services; users) and Management (maintenance; performance) and the interrelation between them" (Clements-Croome et.al., 1997: 396).

The definition of The National Research Council is more oriented to technology and intelligent systems use which is reflecting the common perception of IBs. In 1992, DEWG/Teknibank research project, the Intelligent Building in Europe (IBE), examined the relation between organizations, buildings and information technology. An intelligent building was defined as any building which:

> "…provides a responsive, effective and supportive intelligent environment within which the organization can achieve its business objectives".

An internationally renowned designer of an Intelligent Buildings, Francis Duffy defines the four dimensions of building intelligence as follows: “Office Automation”, “Advanced Telecommunications”, “Building Automation”, “Responsiveness to change”. There are some other definitions of the professionals working on IBs which are as follows:

Hartkopf et al., define IB as follows:

> “The intelligent office buildings will provide for unique and changing assemblies of recent technologies in appropriate physical, environmental, and organizational settings, to enhance worker effectiveness, communication, and overall satisfaction” (Hartkopf et al., 1997: 402).

Sherbini et al., emphasize the ability of strong communication among building systems which can be adjusted according to different needs, and define IB as:

> “….the strongest level of communication among a building’s systems….The IB concept presents control and management by a building’s system and users using computer abilities to achieve users’ needs, which may include productivity, efficiency, energy savings, entertainment, delight, and comfort, return investment, and low life cost. So defining IB should not be related to specific achievement because required achievement can be changed from party to party. The IB should have the same operation concept that has the ability to be adjusted according to the different needs” (Sherbini et al., 2004: 138).

Clements-Croome D. et. al., defines IB as follows:

> “An IB must be able to respond to individual, organizational and environmental requirement and to cope with changes. It is also believed that a truly IB should also be able to learn and adjust its performance from its occupancy and the environment.”
>
> “…Flexibility, adaptability, service integration and high standards of finishes offer an intelligence threshold. An IB can be described as the one that will provide for innovative and adaptable assemblies of technologies in appropriate physical, environmental and organizational settings, to enhance worker productivity, communication and overall satisfaction” (Clements-Croome, 1997:395-400).
>
> “An IB is one which integrates various systems to effectively manage resources in a coordinated mode to maximise: technical performance; investment and operating cost savings; flexibility” (Clements-Croome et. al, 1997: 396).

Clements Croome’s IB definition is more close to the definition that is proposed in this thesis study with its learning, adaptable, responsive and flexible skills to cope with the user and the organization.

IB definition also varies according to the requirements of different countries. For example, the IB definition of UK is more focused on users' requirements, whereas US definition is more concentrated on technologies. Some of the IB definitions for different countries are as follows:

Japanese IBs:

> The Japanese office buildings are firmly stacked on operational efficiency, which emphasize collectivity and teamwork. The Japanese IBs express interactive networks of communications overcoming geographical dispersal. They also perceive IBs as a product and extend the concept into much larger scale (Duffy, 1988).

US IBs:

> The most common concern about IBs is Shared Tenant Services (STS) in USA, in which automation and advanced communications are integrated into office building. The major contribution of STS is the integration of real estate and telecommunications (Duffy, 1988).

European IBs:

> European offices tend to be custom-built as they are different in terms of organizational aspects. They prefer highly individualized, cellular offices rather than open plans. They think more about increasing the building's responsiveness to change (Duffy, 1988).

The definition of the IB extended from their ability to change and react according to individual and organizational requirements to capability of "learning" and "adjusting performance from its occupancy and the environment". In this thesis study, a Human-centered IB definition is given and taken a base for the definition of IBs.

Human-centered IB Definition of the Thesis

In this thesis, the IB concept is defined to display highly adaptive, responsive, and flexible features to cope with the changing requirements of the user/client. A human-centered IB design is proposed which can be achieved by an integrated design approach between the "user", "environment", and "technology" criteria.

Human-centered IBs should have learning, adaptability, responsiveness and flexibility skills in order to respond to the changing requirements and provide a comfortable environment for its users. In order to provide an effective and productive IB design, both "environment-oriented design criteria" and "technology-oriented design criteria" need to support the user requirements in physical, social, psychological and economic terms rather than trying to dominate the user.

Advances in IT, computing, knowledge representation, learning, communications, and the behavioral and social sciences, offer unprecedented new opportunities for the design of Human-centered IBs that can support new working patterns of the office organizations and knowledge workers. Tomorrow's IBs are expected to involve the dynamic interaction of building and information systems. Building materials and systems would sense internal and external environments, anticipate changes, and automatically make corresponding adjustments to maintain an optimized environment. Space lighting would be adjusted for differing daylight exposures and window control devices—blinds, louvers, environmentally reactive glass—would respond automatically. They will be more akin to human behavioral patterns, way of thinking and responding as a result of continuous learning process.

In the following section, some future projections and ongoing studies are explained before explaining the integrated design approach proposed for Human-centered IBs. As per definition of adaptive, responsive and flexible Human-centered IB, it is crucial to make future projections for the changing user needs and social life.

2.2.1 Future projections for Intelligent Environments(IEs)

There are fundamental changes in the social life of human together with the environmental and technological ones. In the future, the traditional understanding of “space” and “time” will lose their importance and physical boundaries will dissolve. People will control their business from their home-offices more widely, by using different communication systems, installed into their house. Their working hours will increase but by this way they can spend more time in their home and share their work with their team partners via Internet.

The social interaction between people will be provided through tools of IT rather than face-to-face communication; and people will meet in the digital environments rather than physical world. Moreover, microchips will be installed in human body and by using these microchips personal information, such as identity, credit card information and entrances and exits to his/her workplace will be controlled (Url-1). Future life scenarios like this are prevailing in contemporary movie industry and some examples will be examined in relation to intelligent environments of the future in the coming section.

In the future Intelligent Environment (EI) scenarios, passive building design understanding of the conventional architecture is replaced by a highly "responsive" "adaptive" and "flexible"one, which can establish an interactive relationship with its user. These intelligent environments will define a new behavioral pattern by attributing new social roles to the buildings. Nevertheless, these behaviours can not include the cognitive human behaviours, but these intelligent environments will be able to observe human behaviours through sensors and learn from them and guess some future actions of the user. But, while defining these social behaviours of the IBs, the inhabitants of the buildings should be properly defined from the beginning of IB design.

There are some visionary studies providing predictions about "what the future will bring forth?". In his visionary book, "*The Age of Intelligent Machines"*, Ray Kurzweil predicted the development of a "worldwide computer network" and a computer that could beat a chess champion. This all happened, the computer system, Deep Blue defeated a reigning world champion Kasparov in chess match in 1997 and the worldwide computer network has been established changing the social, economic, cultural and environmental aspects of daily life.

Kurzweil claims that, there is a methodology and mathematical calculations behind these future visions. It would be interesting to give some quotations from *"What the future will bring"* titled speech at Worcester Polytechnic Institute, May 2005, in which he summarizes the ongoing and futuristic revolutions and two topic is directly related to technological developments ongoing in IB design: "nano-technology" and "robotics". He stated that:

> "…I began to try to model technology trends attempting to anticipate where technology will be. This has taken on a life of its own. I have a team of 10 people that gathers data in many different fields and we try to build mathematical models of what the future will look like…
>
> …The next revolution is **nano-technology**, where we're applying information technology to matter and energy. We'll be able to overcome major problems that human civilization has struggled with. For example, energy: We have a little bit of sunlight here today. If we captured 0.3 percent, that's three ten-thousandths of the sunlight that falls on the Earth, we could meet all of our energy needs. We can't do that today because solar panels are very heavy, expensive and inefficient. New nano-engineered designs, designing them at the molecular level will enable us to create very inexpensive, very efficient, light-weight solar panels, store the energy in nano-engineered fuel cells, which are highly decentralized, and meet all of our energy needs.

.....And finally **robotics**, which is really artificial intelligence at the human level, we'll see that in the late 2020s. By that time this exponential growth of computation will provide computer systems that are more powerful than the human brain. We'll have completed the reverse engineering of the human brain to get the software algorithms, the secrets, the principles of operation of how human intelligence works. A side benefit of that is we'll have greater insight into ourselves, how human intelligence works, how our emotional intelligence works, what human dysfunction is all about. We'll be able to correct, for example, neurological diseases and also expand human intelligence. And this is not going to be an alien invasion of intelligent machines. We already routinely do things in our civilization that would be impossible without our computer intelligence. If all the AI programs, narrow AI, that's embedded in our economic infrastructure, were to stop today, our human civilization would grind to a halt. So we're already very integrated with our technology.

…And this technology will also expand our opportunities, expand our ability to create and appreciate knowledge. And creating knowledge is what the human species is all about. We are the only species that has knowledge that we pass down from generation to generation" (Url-2).

As it can be followed from Kurzweil's statements, there are serious research studies for realizing the visionary projects of the future, some of which have been already achieved. The same projections can be done for architectural spaces by using the revolutionary progress in technological and social behavioral patterns. There are visionary architects like Greg Lynn and Kas Ooesterhuis trying to reconcile the digital revolutions with the architectural spaces.

Greg Lynn claims that, architects should develop an intuition by searching the behavior of computer-driven design systems and mathematics behind them. But, the intelligence of computer shall not be mixed with human intelligence. The computer can never develop the same type of consciousness and insight as human beings, and it will only simulate the insight of that kind in order to communicate with people (Ooesterhuis, 2002)

Kas Ooesterhuis is among these visionary architects, who are more interested in information processing and programmable aspects of architecture. He defines the interactive architecture of the future as follows:

"The Architecture of the future will calculate its construction in real time, determine its position in relation to other constructions, and continually adjust its relation to its users on the basis of a constant flow of new data from the database that upgrades itself in real time. The building sets out on a course of its own, and is steered by its users. The building knows its users, it is aware of their individual differences and preferences. These play the building like an instrument. Now the instrument becomes programmable and its operation so complex that its behavior becomes unpredictable" (Ooesterhuis, 2002: 109).

In the conventional architecture, the doors and windows are opened to let people and fresh air, and the buildings have always exchanged information with their environments. With the digital revolution, the new digital technologies invaded the buildings and exchange of information will be done on a digital platform. There are sensory equipments attached to the building, and doors will open and close after receiving the signals from their user to do so. The windows will open/close according to the data received from weather stations. Firstly, the information will be received by the building and then sent to processing unit (building's brain) where it will be processed and transferred into specific action. Here, the building body acts as an input-output device (Ooesterhuis, 2002). In this Digital area, information stands in everywhere and embedded in everybody. The information will be processed in both natural and artificial environments. Architecture is one of the most effective tools for the transformation of this information.

The planning of the IB of the future requires establishing both a long-term strategy and flexibility for spontaneous needs. Generally, an IB design starts with a forecast, and anticipates technological changes and possible future problems to be solved. As stated by Klein, the three most significant characteristics of the IB of the future should be *"efficiency", "flexibility"*, and *"effectiveness"*. The IB should provide a more productive environment for the worker through its integrated building automation, telecommunication, and data processing systems (Klein, 1988).

In the future, intelligent environments can forecast their users' requests by evaluating sensed data generated in the physical environment. By using computer based reasoning and image definition techniques, the behaviors of the user will be observed through sensors in the environment. Also by observing users' actions in intelligent environments, learning action can be developed. One further step will be the prediction and generation of requests or needs of the user. For example, there are some studies about intelligent environments for the people entering and exiting the house which can be tracked by sensors placed in the house. Also, the consumed goods can be ordered by the intelligent agents connecting to the manufacturers' web-site i.e. Mav House Project in University of Texas at Arlington (Url-3).This will generate new horizons in order to design products with a user-friendly interface.

By observing the changing behavioral patterns of users in relation to their needs and tasks in different contexts, highly adaptable IB systems will take hints about how to react to the user in the future. It takes all the necessary data from the reporting sensors placed in that environment and training signals coming from the tools. At one further step, by forecasting his/her needs, frees the user from the manual control of the environment. For example, it can observe user's attitudes, like which music he/she listens while eating dinner or in which light he/she uses while reading a book or working, between which hours he/she watches TV news, adjusting room temperature based on his/her clothes, and generates new environmental adjustments (Mozer, 1999). This type of a highly adaptive and responsive environment tries to generate appropriate environmental conditions required by the user through "intelligent agents". But these intelligent systems, which can analyze and learn the user's behaviors and trends in such adaptation level, are still at the stage of experimental research studies. The user of intelligent environments, by using Internet or a phone, can reach his/her house can activate machines or the machines can send auditory signal to the user when they complete any task (Mozer, 1999).

Figure 2.2 : The vertical circulation in the future intelligent house in "Minority Report" movie, adapted from Null (2002).

In the intelligent environments, microchips will be embedded into every tool and they will to communicate among themselves and the user. This automation system requires a serious programming effort and the most difficult part is to "adapt", "respond" and be "flexible" enough to renew itself according to user's changing life style". As far as it can be understood, highly adaptive and responsive environments, which supports an effective customization and social interaction between the user, environment and technology will be helpful in reaching a truly Human-centered IB design. Today, research studies about the future of intelligent environments have been subject to various fields such as architecture, nano-technology, computer science, 3d animation programs, games and movie industry. Before getting realized in our physical environment, futuristic life scenarios were projected into the movies.

New softwares have been developed with the advancements in digital technology, which can re-present these Intelligent Environments (IEs) of the future. In the movies like, *"2001: Space Odyssey"*, "*Star Wars"*, "*Fifth Element"*, "*Matrix"*, "*Artificial Intelligence",* and *"Minority Report"*(Figure 2.2 and Figure 2.3), IEs have been visualized by software programs designed for animating the future life scenarios.

Figure 2.3 : The dynamic interaction between IBs of the future in "Minority Report" movie, adapted from Null (2002).

For example, if we compare the futuristic IEs of the "Minority Report" (Figure 2.3) movie with "The Elephant and Castle Eco-Tower Project" in London (Figure 3.47) designed by Ken Yeang, there can be found some similarities regarding basic design criteria such as sky-courts, plug-in structure of the building, and cities developing in vertical direction connected into each other.

The movie of "*Minority Report*" visualized IEs of the future with its "user-friendly", highly "adaptable", "responsive" and "flexible" behavioral patterns. IEs of the future (including houses, roads, automobiles, shopping centers, intelligent portable and wearable devices, transparent communication devices, computers etc.) can sense the users' visual and spoken orders. Also, there exists a central database controlling all of the information transferred through devices such as sensors, actuators, agents etc., to track the individual identification by using technologies like finger print, and retina scan. In all of these future life scenarios; the main target is to increase the communication between the IEs and the users in order to create a highly interactive, learning, responsive and adaptive environments increasing user comfort.

In the movie “2001: A Space Odyssey”, a computer named ‘HAL’ has high level of intelligence, which can observe human’s activity with its distributed cameras, and control the subordinate systems through expanded actuators of it. The IEs are able to; “watch what is happening in them”, “build a model of them”, “communicate with their inhabitants”, and “act based on decisions they make” (Lee et al., 2002). In IEs of the future, the most important criteria of design will be “user”. The hardware can be installed in some centers in the building as well as they can be portable to be carried or weared by the user according to his/her needs (Callaghan et al., 1998).

The radical transformations and changes in the user behaviors can be best perceived in the work space and user relation. In the following part, some major changes in the working patterns and research studies for adaptable, responsive and flexible workspace are reviewed.

2.2.1.1 Changing Work Patterns

The communication between intelligent computers extended to intelligent office environments. The office space should be designed in a manner to improve flexibility of use, enhance individual work and increase work effectiveness (Harrison et al., 1998). The whole space can be wired like a network and the IB can become more adaptive and responsive to human needs.

Most of the people believe that, with the explosion of the Internet and new Communication Technologies, people are free to work from anywhere and anyplace, which will demolish the office building type. As a result of the digital revolution, the space understanding has passed through radical transformations. Worldwide computer and communication network redefine the communal life and spatial relations. K. Yeang explains this fact as follows:

> “…We need to design for the digital community as our cities become by nature anti-spatial. The worldwide computer network and the digital revolution subvert, displace and radically redefine our notions of community life and urban life and the concept of gathering place. Our new place-in-the-sky may in effect be an electronic agora” (Yeang, 2002:113). “..the digital revolution not only accelerates the speed with which information is processed and disseminated, it also relates the relationship of space and time within our communities. Work will be globally time-driven, as distance will no longer determine the cost of communication electronically.” (Yeang, 2002: 194-195).

A new sense of social consciousness started to emerge in intelligent office environments. People living on different continents can be physically inserted into the "global brain" (Internet) for meetings and working groups. The physical boundaries and limits are exceeded through interactive intelligent environments. The building knows about you through the sensors, which may include active and passive cameras, microphones, and tactile sensors. It responds to the user according to previous information flow and observations attained by these sensors in the space.

There are also actuators, which provide information and physical support to the inhabitants. The IEs become actors of the space, just like the people; talking back the user and other tools (Lee et al., 2002).

It is relevant to continue by reviewing some workspace projects displaying the changes in the working pattern and social behavior of the user as a result of digital technologies.

- **Intelligent Workspace Projects**

The previous IB concept of sealed, merely technological approach is now being replaced by a building concept that is breathing and animate. The environmental concerns compelled the use of the ecologically responsive features in balance with the intelligent systems. The ecologically adverse effects of the computers and digital tools have been reduced as a result of the "connectivity" in contemporary offices. As a result of the developments in IT and communication technology, the workspaces became "invisible panopticon" in which every behavior of the worker can be tracked (Bullivant, 2005b). This will exert psychological pressure on the workers and in fact their so-called freedom caused by wireless technology is more limited than the conventional workplaces.

In the design of workspaces, the technological developments became the driving force, but one has to be careful about the social aspects such as the psychological satisfaction of the user needs and factors affecting the work performance. There are some research projects for creating intelligent and responsive workspaces. One of the recent projects is a next generation workspace solution including multiple software and hardware components that integrate sensors, actuators, displays and wireless networks into architectural elements (Bullivant, 2005b). There are three intelligent workspace projects selected which are briefly explained in the following part.

1. The iRoom - Interactive Workspaces Project, Standford University, 2000

The Stanford Interactive Workspaces Project has started at Stanford University in mid-1999 for exploring new possibilities for people to work together in technology-rich spaces with computing and interaction devices on many different scales.

The iRoom (Figure 2.4) within the scope of the Interactive Workspaces Project, is a second generation prototype interactive workspace that contains three touch sensitive white-board sized displays along the side wall, and a custom-built 9 mega-pixel, 6' diagonal display with pen interaction called the interactive mural built into the front wall. In addition, there is a table with a built in 3' x 4' display that was custom designed to look like a standard conference room table. The room also has cameras, microphones, wireless LAN support, and a variety of wireless buttons and other interaction devices (Winograd, 1999).

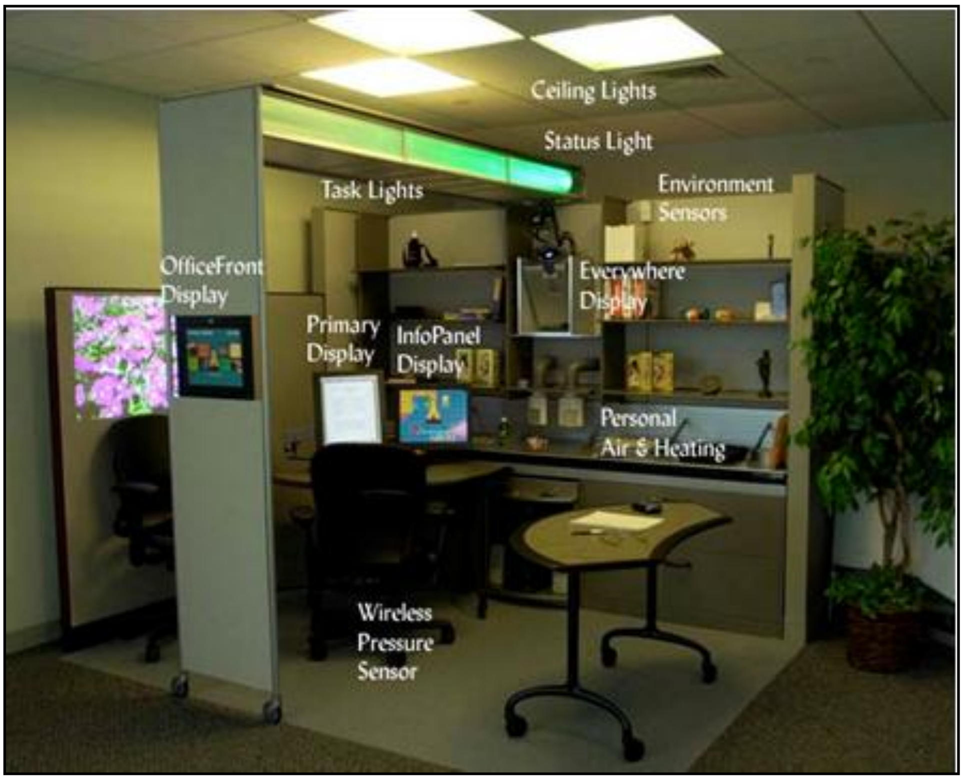


Figure 2.4 : A view of the Interactive Room (iRoom) 2000, Stanford University, adapted from Winograd (1999).

2. The Intelligent Workplace, Carnegie Mellon University, 1998

This Intelligent Workplace (Figure 2.5) project has been developed for improving user satisfaction, organizational flexibility, technological adaptability and maximizing energy and environmental effectiveness. At the Intelligent Workplace, in

Carnegie Mellon University, teachers, office managers and administrative staff evaluate how integrated building components, systems and assemblies affect building and staff performance.

Figure 2.5 : The Intelligent Workplace Project, adapted from Url-4.

The features of the Intelligent Workplace Project can be summarized as follows:

- The operable windows aligning on each side of the building will maximize the natural ventilation and natural lighting. The workplace's layout gives everyone a window, because studies have shown that access to daylight is a key factor for worker satisfaction. The use of natural heating, cooling and ventilation reduces the energy expenditure to one-twentieth of the U.S. average (Url-4).
- Rooftop ventilators facing the stack effect are used for natural ventilation and cooling. There are light direction louvers to control the lights and reduce solar heating.
- Fluorescent lamps with "occupancy sensors" provide more light when someone is in the office, but turn themselves off when nobody's there. There are various cubicle designs to provide more of an open or closed look to personal space.
- The indoor temperature, air flow and lighting can be controlled by the user through a slider-bar control located in each desk and local controls achieved through Personal Environmental Module (PEM) that is re-locatable in case of moving.
- For privacy, one can turn up a "white noise" generator to mask out conversations or other sounds from other areas in the room.

- The steel construction column-free interiors, re-configurable modular components provide spatial adaptability (Url-4).

3. BlueSpace Project, IBM and Steelcase Corporation

BlueSpace (Figure 2.6) is a joint project that combines IBM's technology expertise with Steelcase's workplace knowledge to create a new office environment that integrates the physical workspace with advanced computer, sensor, display and wireless technologies.

Figure 2.6 : “BlueSpace” Project developed by IBM and Steelcase, adapted from Url-5.

This collaborative study aims to display the changing technological, physical and psychological needs that knowledge workers face. The major goal is to increase the workers’ productivity by preventing undesired interruptions, improving awareness and continuous communication among team members, and improving individual comfort conditions by providing personalized environmental settings. This fully Internet-enabled, IBM-Steelcase smart office includes: “Bluescreen”, “Monitor rail”, “Everywhere Display”, and “Threshold” (Url-5).

2.2.1.2 Interactive architecture – Architecture as information processing

In his book "Architecture Goes Wild", Kas Ooesterhuis defines a building as, "a set of fixed and moving components, a totality giving form and substance to the flow of information passing through it" (Ooesterhuis, 2002: 39). He emphasizes the information transformation capacity of a building and defines architecture as information processing.

The information is fluid, changeable, and dynamic, and it is included in every animate and inanimate body. The building body is a vehicle for processing "information" and it is "programmable". As a result of intelligent features, the building services can be adjusted by remote control. At this point, he gives an example of buildings' themselves measuring their temperature and humidity levels in real time. He asserts that, there is no ideal climate temperature concept; as such a thing doesn't exist in reality. In a programmable building both the architect and the users can experience their own particular climates. K. Ooesterhuis explains this dynamic and continuously changing programmable building body in real time as "hyperbody" (Ooesterhuis, 2002). He explains the possible evolution of a programmable building by sharing the vision of Ray Kurzweil, the scientist, software producer and visionary. In his book, "The Age of Spiritual Machines," published in 1999, he predicts that:

> "…in about 2010, a personal computer will have the calculation power of a mouse's brain, and in 2030 that of a human brain measured in calculations per second. It means that in the year 2060 a single consumer PC will have the calculation power of the entire world population" (Ooesterhuis, 2002: 46).

Then he asks the question of *"how will we communicate with that calculation power?"* At this point, one has to think about the communication between buildings and their users. K. Ooesterhuis believes in an "interactive play" between the user and the building components. The communication between the user and the building environment should be responsive and unpredictable, like playing a game.

In order to cope with the digital technology, the buildings will become members of distributed networks that can communicate with each other and with their users. The buildings will become "dynamic" and "programmable". Kas Ooesterhuis sees architecture as a game in which architects will design buildings as interactive games. He has developed a game called Trans-ports, in which the active building structure responds to the impulses from the Trans-ports web site (www.trans-ports.com). This project is directed through a globally accessible internet-based game that can change shape and content in real time.

The flexible space frame of the Trans-ports (Figure 2.7) is controlled by a computer program that calculates changes in form in real time and then sends the information to pneumatic cylinders acting just like a set of muscles. During the interaction with the player, when forces are modest, it relaxes. When there are strong winds, earthquakes and applied dynamic loads, it changes its shape by shortening and extending through computer controlled pneumatic hydraulic cylinders of the space frame (Ooesterhuis, 2002).

The space frame acts as a spacer between the exterior and interior. The skin must be elastic and flexible enough to follow the formal changes in the space frame. K. Oosterhuis and Ole Bouman developed a truly 3-D membrane concept that can expand and shrink seamlessly. Since the structure, text and visuals of Trans-ports project are programmable, the interior space can adapt to variety of uses such as: “info-mode”, “performance mode”, “disco mode”, “television mode”, “research mode”, “art mode”, and “stand-by mode” (Ooesterhuis, 2002: 97).

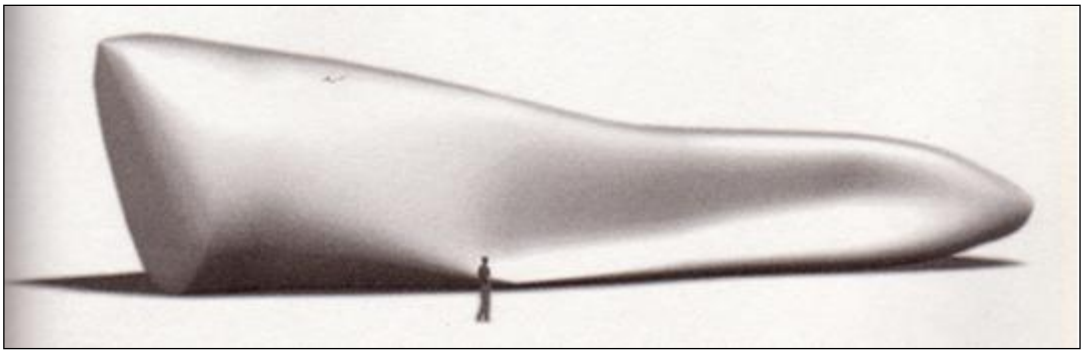


Figure 2.7 : Trans-ports v 2.0, K. Oosterhuis and Ole Bouman, adapted from Oosterhuis (2002).

As it is seen from this project, the static and passive role of the buildings has changed, and the buildings can act like a living body with their responsive and adaptive structures, which is one of the main concerns of interactive buildings of the future.

There are some other attempts to create IEs, which are based on the interactive play between the “user” and the “building”. *“Ada: The Intelligent Room”* is an interactive space created by applying the information processing mechanisms of human brain. It has been developed for Expo 2002, at The Swiss National Exhibition in Switzerland (Figure 2.8). “Ada” was designed by a multi-disciplinary team of 25 people led by psychologist Paul Verschure, working at the Institute of Neuroinformatics. Ada, the intelligent room, has the ability to interact and communicate with her visitors, as she is a project based on the research on “neuroinformatics”. The aim of this project was to start a public debate about the application and implication of brain-based technology on our future society (Bullivant, 2005a).

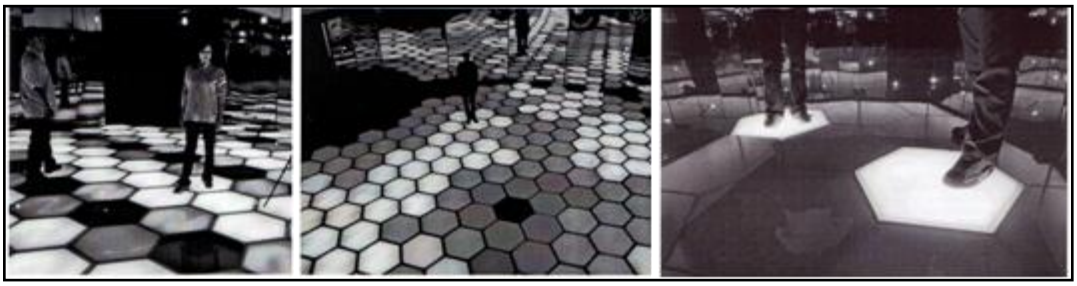


Figure 2.8 : The movable light fingers of Ada Room, adapted from Bullivant (2005a).

Ada displays highly adaptive behavioral patterns. She is programmed to balance visitor density and flow, identify, track and guide specific visitors, and play games with them. The steps of experience are as follows: firstly the visitors approach waiting area (conditioning tunnel) getting information about Ada’s components and their functions and then they enter a 175 m^2 space, an octagonal room where the visitor interacts with Ada. In a corridor around this room, the visitors can observe the activities without interacting. As a third step, the visitors enter the “Brainarium”, a technical room displaying the internal processing states of Ada. On the way out, there exists an “Exploratorium”, a room explaining and discussing the key technologies behind this intelligent room. If the visitor wants see, there exists the Lab area, containing 30 custom-built computers as well (Bullivant, 2005a).

The intelligent room locates and identifies the visitors by using her vision, audition and touch senses. The visual display of Ada will be provided by a 360-degree ring of 12 LCD video projectors. Through these screens, Ada displays her behavioral mode and internal emotional states to visitors. Ada’s skin is made up of 360 tiles and each unit includes pressure sensors, neon tubes (Figure 2.9) and a microcontroller. By using these tiles, Ada can track visitors, test their responsiveness to visual and sensual clues, and interact with them in different games. Ada’s sound effects derive from a synthetic musical composition system called “roboser” that can create 12-voice behavioral mode.

Another property of Ada is her movable light fingers for pointing at individual visitors (Bullivant, 2005a).

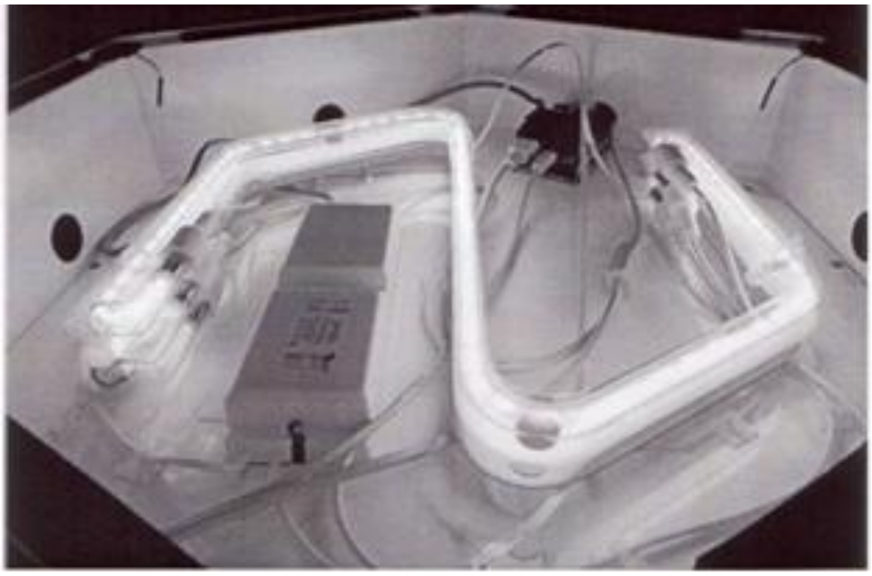


Figure 2.9 : Ada’s patented floor tiles, adapted from Bullivant (2005a).

The design team of Ada tried to give the feeling of a “kind of a basic unitary intelligence” to the visitors. Ada has got four basic behavioral functions; “tracking”, “identifying”, “grouping” and “playing with visitors”. These behaviors are interconnected, independent, simultaneously evolving internal processes. The underlying software of Ada is a mixture of *simulated neural networks, agent-based systems* and *conventional procedural* or *object-oriented software*. By continuous upgrading of the system during the four-month experience, Ada grew like a human being (Bullivant, 2005a). The IEs can gain social behavioral patterns by observing and learning from the users through embedded intelligent systems. As the researchers develop more realistic models for information processing capacity of human-brain, the intelligent environments will display behaviors more akin to human beings.

After discussing the IB concept definitions and future projections for Intelligent Environments, the integrated design criteria approach that is proposed for IBs is explained in the following section.

2.3 Theoretical Model of Research: An Integrated Design Criteria Approach for IBs

In this thesis, an integrated design criteria approach (Figure 2.10) is proposed for a responsive, adaptive and flexible Human-centered IB design. For this approach, there are three major criteria that need to be integrated which are: “user”, “environment”, and “technology”. In the proposed theoretical model, the “user-oriented” design criteria are at the central core of design which is supported by “environment-oriented” and “technology-oriented” design criteria.

In this integrated design approach for IBs, the involvement of the “user/client” from the beginning of the design is crucial to identify the appropriate physical, social, psychological and economic requirements. If these “user-oriented” design criteria are correlated with the appropriate “environment-oriented” and “technology-oriented” design criteria to find the best option serving the user requirements, an adaptive, responsive and flexible Human-centered IB design can be achieved.

2.3.1 Human-centered Intelligent Building Design Approach

The key attributes of IBs which are: “knowing”, “deciding” and “responding” are similar to cognitive properties of human being. But cognitive properties of human beings have various complicated properties, which are shaped by learning through experiences during his/her lifetime. An IB must be able to respond to the individual, organizational and environmental requirements and must be flexible to cope with the dynamic interaction between “*changing user needs”* and “*technological progression”*. In order to respond to these changing human needs, IBs should have an ability to learn, decide, respond and adapt to changes. According to the definition of S. Nolfi, and D. Floreano, learning is a “*set of modifications taking place with each single individual during its own life time.”* It allows an individual to adapt to environmental changes that are unpredictable at the generation level. Learning produces adaptive changes in an individual during its lifetime. The similar learning behavior can be achieved through intelligent agents embedded in IBs which can receive large amount of information from the environment through their sensors. Such information may be used both in determining how to react in different environmental circumstances (Nolfi et al., 1999).

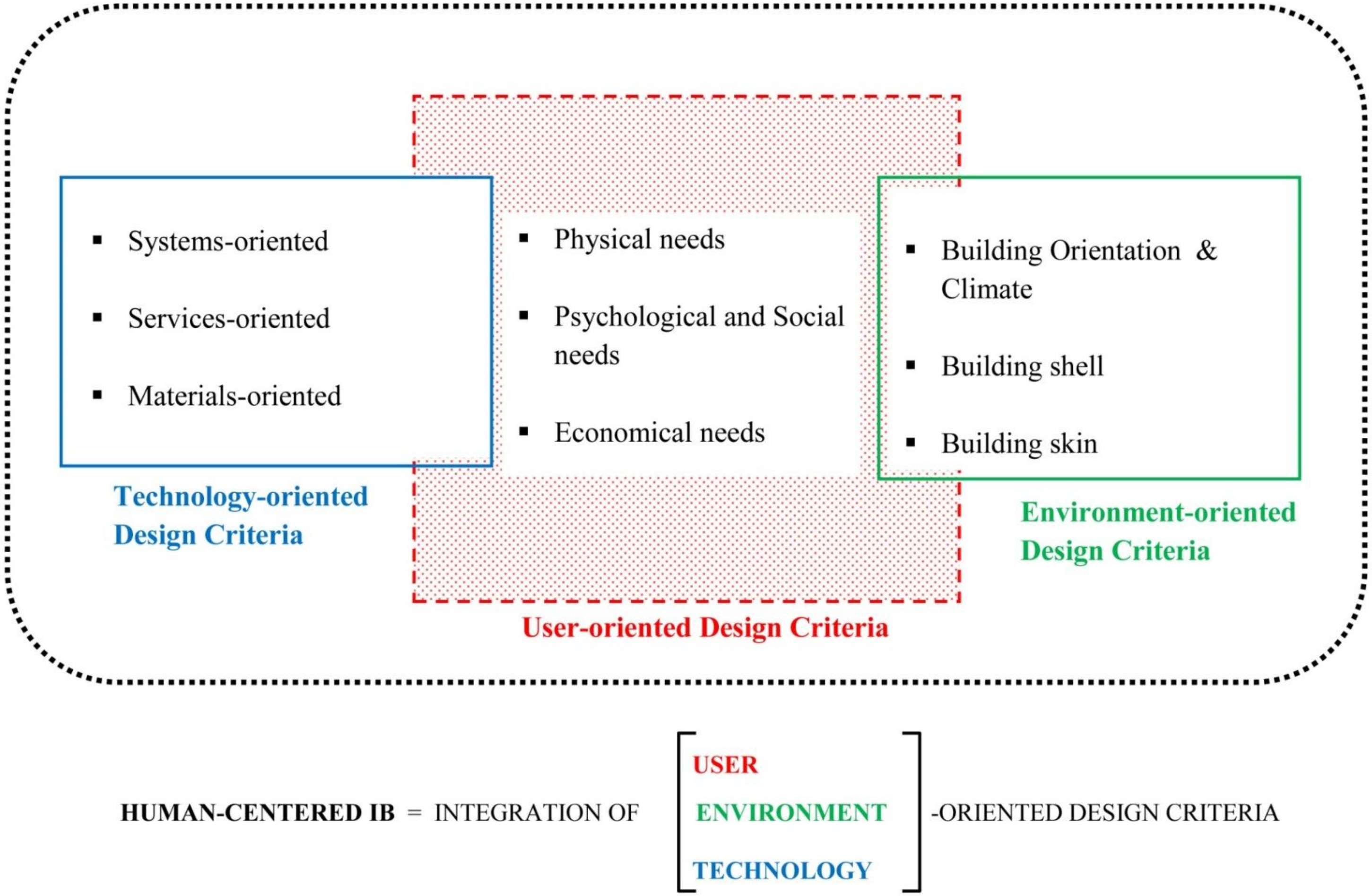


Figure 2.10 : Integrated Design Criteria Approach for Human-centered IB.

The cognitive aspects of human brain will be developed through learning and adaptability skills gained through learning process. Current intelligent buildings often have embedded processors and dedicated information networks. The new generation of IBs started to develop the capability to learn about the buildings circumstances and its occupants needs and change the behavior of its control systems accordingly The use of a large number of sensors within the building will allow it to operate in a responsive manner, rather than using pre-programmed control models as are employed in the first two generations of IBs. The information provided by sensors includes changes in both internal and external environments of a building, such as smoke, temperature and humidity, air quality, air movement, and the number of building occupants as well as a host of other properties. The system will use sensors to identify how a particular person tends to react to particular circumstances and to learn different behaviors for different people (Sharples et al., 1999).

In order to be Human-centered IB, technological systems should support actual practice effectively, be flexible, adaptive, context-sensitive, and open. There are a group of architects searching for an expression of technological evolution in physical and virtual space which is flexible, adaptable and responsive. While searching for this, natural and technological evolutions are compared. Technological evolution is much faster than biological evolution and it has two advantages over natural evolution: first it can produce results that far exceed what ordinary evolution might have produced; second, it allows us parallel evolution, exploring entire regions of the genetic possibility at once. As an example to this first form of evolution, Marcus Novak gives “high speed computation” that is greater than any human brain can manage, but which falls short of overall reasoning ability. In the second form of evolution, we can electively evolve in one direction at one time and in another at another time (Ooesterhuis, 2002). But this second form of evolution hasn’t been achieved yet, which will provide the evolution of ourselves into a possible future state.

As it is explained above, human beings are evolving slower than machines and networks. The human body doesn’t change much, but its extensions can be manipulated. K. Ooesterhuis (2002) defines all the invented equipments in our life as extensions to our body. The computer is an extension of our brains; the drill is an extension of our hands, and the car as an extension of our legs. All invented tools are interfaces to new life forms. He also defines all new designs contributing to the further development of these extensions as “information enhancers” (Ooesterhuis, 2002: 142). There will be a continuous flow of information from human body to building, and the building will output information different from input as a response. The intelligence level of the designed building determines the human-technology interaction and adaptation.

In the design of Human-centered IBs, “user needs” should be taken as the focal point and supported by environment-oriented and technology-oriented design criteria to reach an adaptable, responsive and flexible IB model. According to Marcus Novak (2002), “technology constitutes a form of revolution, and technological products are enmeshed in a reproductive mechanism that includes humans as key component” (Ooesterhuis, 2002: 133). As it can be followed through Novak’s statement, the central key position of the human being should be kept in the design of intelligent environments. The major aim of technological inventions is to increase productivity and comfort conditions of the user evolving with the new life forms. Technological developments can be also used for transforming the ‘static form’ of the built environments into ‘dynamic and interactive forms’ which can be more responsive and adaptive to changing human needs. The aim is to increase the comfort conditions and productivity of the user of IB as a result of its highly adaptive, responsive and flexible dynamic properties.

The work space is important for the productivity and well being of the user. There have been done various Building Performance Evaluation questionnaires for measuring the effects of the work space on user psychology and they supported this fact (Preiser et. al., 2005). Increasing the productivity and effectiveness are the main goals to be achieved by IBs, and for this reason user requirements shall be properly integrated into design from the beginning stage of the design.

In this thesis study, Human-centered IB design approach is structured around the integration of “user-oriented”, “technology-oriented” and “environment-oriented” design criteria to reach an adaptable, responsive and flexible IB. Among these three integrated criteria, “user-oriented design criteria” is taken as a focal point in the proposed integrated IB design approach, that is formulated as: “physical”, “psychological and social”, and “economical” needs of the user.

2.3.2 User-Oriented design criteria of IBs

During this information age, there is a continuous revolution in the working patterns and social life of the user resulting from technological developments. The most convenient environment to track these changes in user requirements and working patterns are office buildings. For this reason, in the thesis study, the user requirements for IBs are examined through office building type even though this integrated design criteria model for IBs is proposed as applicable to all building types.

G. Blachere (1972) classified requirements of the user into four categories which are: “physiological”, “psychological”, “sociological”, and “economic” requirements to meet the comfort conditions. In this thesis study, this classification has been taken as a base while formulating the user-oriented design criteria for IBs as follows:

- “Physiological requirements” aim to provide “physical comfort”, “health”, “safety”, and “functional appropriateness”.
- “Psychological requirements” aim to support “individual mental health” by providing the appropriate “privacy”, “interaction”, “clarity”, “status”.
- “Sociological requirements” aim to support the well-being of the society by relating the needs of the individuals to those of the society.
- “Economic requirements” aim to reserve resources in the most efficient manner in the overall goal through “space, material, time, energy and investment conservation” (Mill et. al., 1988).

The “physical”, “psychological and social”, and “economical” parameters of the user-oriented criteria effecting productivity and work efficiency of human-centered IB design is summarized in Figure 2.11. The physical needs of the user are described under four design parameters which are: “spatial”, “thermal”, “air”, “aural” and “visual” quality which has been based on ABSIC total building performance criteria (Appendix A: 268). The psychological and social needs of the user are categorized under “privacy/autonomy”, “interaction”, “habitability”, “mental health/stress”, “security/territoriality” parameters. The economical needs of the user are described under four design parameters which are: “space conservation”, “material conservation”, “energy conservation” and investment conservation”.

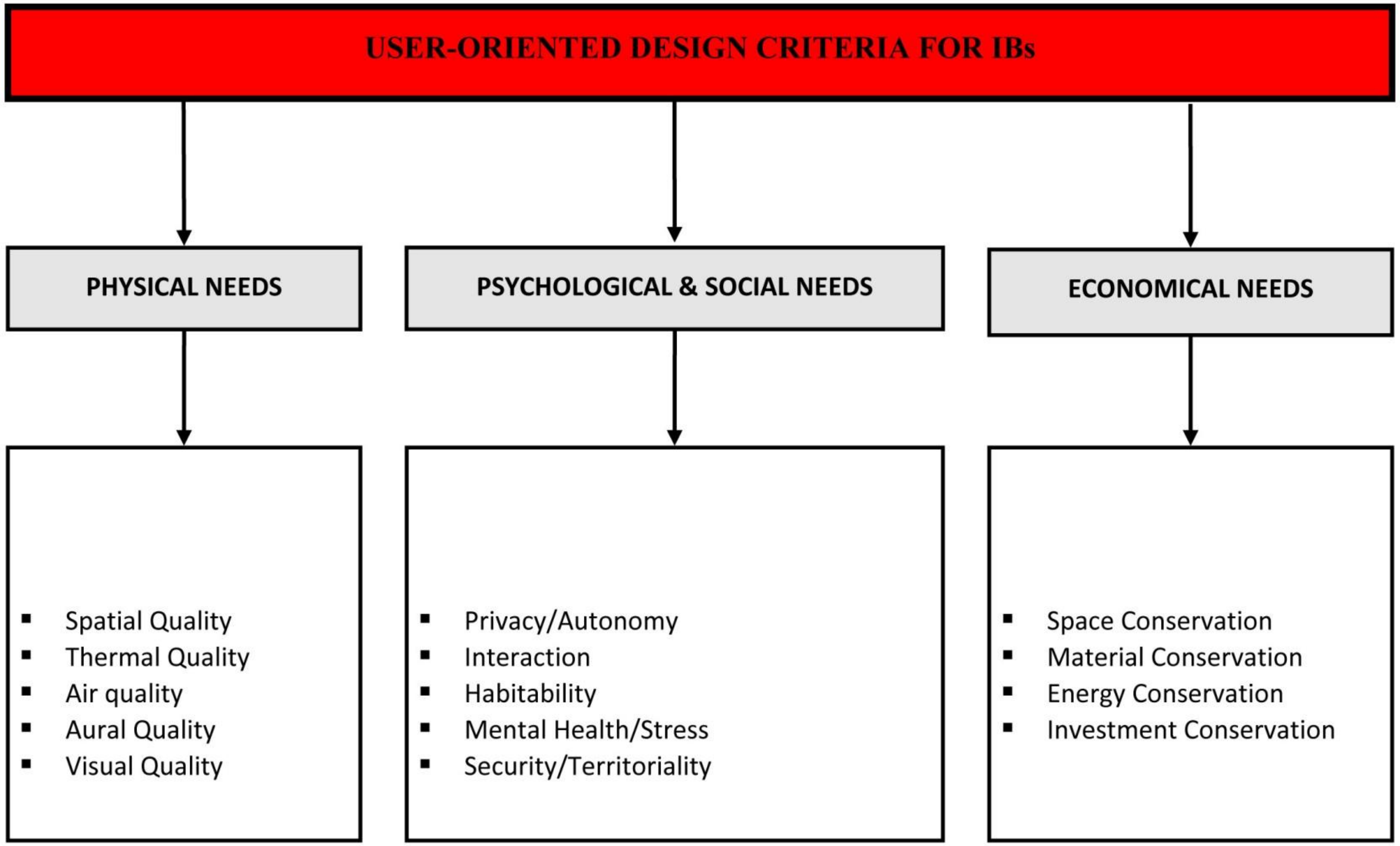


Figure 2.11 : User-oriented Design Criteria for Human-centered IBs.

IBs need to increase the comfort conditions, and productivity of the user and flexible to adapt and response to changing work organizations. While defining the appropriate technologies and passive design requirements, the cultural, social, organizational and individual needs of the user shall be analyzed before establishing user-oriented design criteria. It has been proved through several research projects that the good indoor Environmental Quality (IEQ) can increase productivity and work efficiency. But the environmental conditions required for health and comfort is not the same for every person; there is a wide scale of variations both physically and psychologically changing from one person to another. Through Post Occupancy Evaluation studies done, it has been proved that a mentally and physically satisfying working environment has a positive influence on workers' productivity (Duffy et al., 1997). The physical design criteria like: good spatial arrangement, air quality, temperature level, aural quality, and visual quality have a positive influence on office work performance of the users. The user is the main actor for the success of IBs, and for this reason, user-oriented design criteria are taken as a driving factor for Human-centered IB design approach.

The "user-oriented design criteria" of IBs also focus on the changing working patterns and organizations which is effective on the physical, social, psychological and economical life of the user. The new working patterns appeared as a result of the changes in social and cultural life, and the work can be done across a variety of settings such as: *home, train, airports, hotels, coffee shops* and *cars* in addition to offices with the ongoing technological developments. The new workplace consists of shared open spaces for interaction and communication, shared offices for concentration, project rooms for teamwork, café areas for informal meetings, mobile and modular furniture, and wireless LANs (Bjerrum et al., 2002).

Organizational Changes in the Workplace

The changes in the organizational structure and relationships of the workplace have been supported by transformations in IT, especially the Internet and mobile computing and communication devices. The main organizational changes can be summarized as follows:

- Reduced hierarchical structure: Hierarchies are being replaced by cross unit organizational groupings with fewer layers and more decentralized decision making.

- **Blurred boundaries:** As organizations become more laterally structured, boundaries begin to breakdown. Boundaries between departments as well as between job categories (manager, professional, technical) become looser and there is a greater need for task and knowledge sharing.
- **Teams becoming basic building blocks:** The move toward a team-based organizational structure results from pressures to make rapid decisions, and to continually improve work processes.
- **New management perspective:** The workers are no longer managed to comply with rules and orders, but rather to be committed to organizational goals and mission. The blurring of boundaries also affects organizational roles. As employees gain more decision and latitude, managers become more social supporters and coaches.
- **Continuous change:** Organizations are expected to continue the cycles of reflection and re-organization (Heerwagen et al., 2010).

In the new office building, productivity depends on “good concentration”, “technical competence”, “effective organization and management”, “a responsive environment” and “a good sense of well-being” (Croome, 2000). A good working environment provides the user with a good sense of well-being, inspiration and comfort. For this reason, one of the main targets of Human-centered IB design is to provide this comfort level according to changing requirements of the user by integrating intelligent systems (technology) and passive design parameters (environment).

In 1997, **DEGW** in collaboration with the Building Research Establishment (BRE) conducted a study on the implications of modern working practices. In the “New Environments for Working” study, there has been developed *“a responsible workspace model”* consisting of four alternative office layout typologies by considering the new organizational trends and IT developments in the office space (Duffy and Powell, 1997). In the thesis, these typologies are used as the analyzing parameter for the planning types in selected IBs which are reviewed in Chapter 3.

Organizations are characterized by four kinds of work patterns that combined different levels of *autonomy* and *interaction*: “***hive”,” cell”, “den”***, and “***club”***. Each of them has specific mode of working, which DEGW respectively designated as “individual process work”, “group process”, “concentrated study”, and “transactional knowledge work”. Each of these working modes requires different workspace configuration. The interaction relates to the face-to-face contact required for completing tasks, and autonomy refers to degree of control responsibility and discretion each office worker has over the timing. The shell properties are not considered in these physical arrangements, rather the organizational requirements and work patterns were effective.

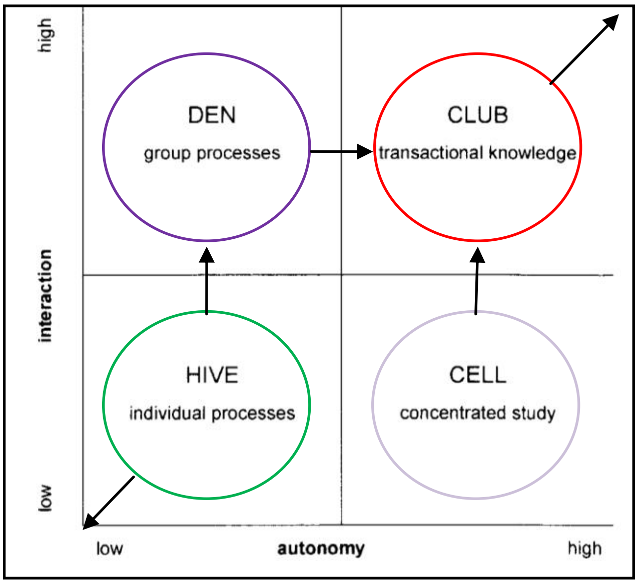


Figure 2.12 : Four major patterns of workspace showing the degrees of autonomy, adapted from Duffy et al. (1997).

According to the responsible workplace model as per Figure 2.12, the *dens* are convenient for group works where there is high level of interaction. The *hive* is convenient for individual processes and the *cell* is for concentrated study. The shared open space such as the *club* is convenient for meeting and knowledge sharing which is one of the main revolutions of the new workspace.

The workplace environment can be split into physical and virtual space. DEGW Distributed Workplace Model (Figure 2.13) attempted to incorporate the increasing correspondence between physical and virtual work environments, displaying the impact of information and communications technologies on individuals and organizations. Each of the physical work environments has a parallel virtual environment sharing some of the same characteristics. The virtual equivalent of the public workplace is the internet, and privileged workplace equivalent is extranets. The virtual equivalents of the private physical workplace is intranets, the private knowledge system belonging to an individual organization that contain the organization's intellectual property (Harrison et al., 2003)

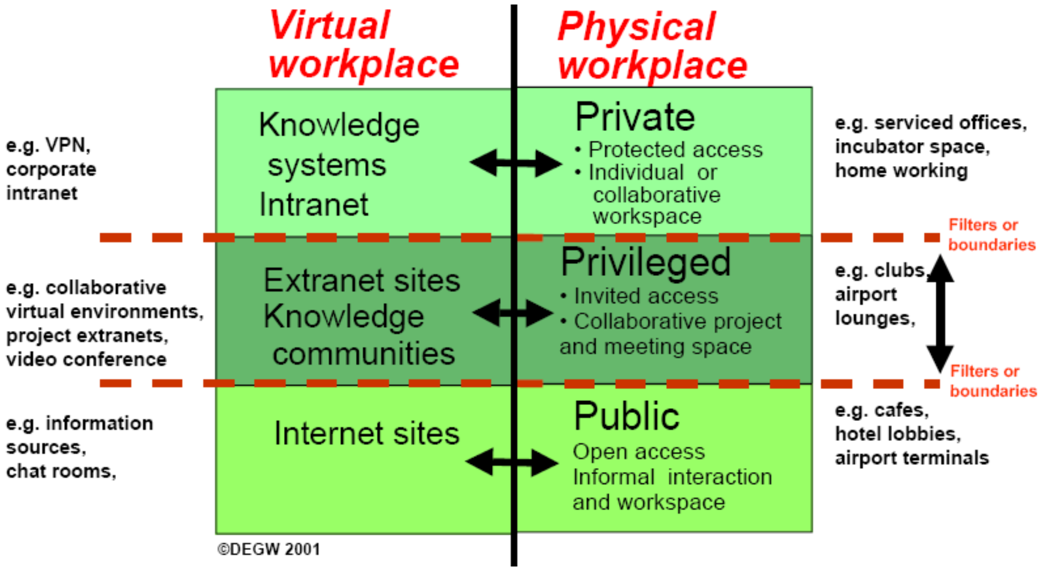


Figure 2.13 : DEGW Distributed Workplace Model, adapted from Harrison et al. (2003).

As stated by Harrison et al., (2004), the office of the future heavily relies on motivated individuals who are enabled by technology to have a high degree of 'autonomy' and who use "face-to face communication" to increase the richness of their business transactions. The user of the future office space should be given flexibility to communicate and work in different levels and this can be achieved by the integrated design approach of Human-centered IB design.

In the thesis, office workspace is selected for reviewing the physical, social, psychological and economical needs of the user because of the extensive information available through post-occupancy evaluations and classifications.

2.3.2.1 Physical needs of the occupants

In order to reach a comfortable living environment, the buildings should be designed to provide a certain level of thermal, acoustic as well as indoor air quality for their users. Some energy is required for controlling this indoor climate and good environmental quality can be reached with a reasonable amount of energy and with a low environmental impact (Roulet, 2001).

The goal of the Indoor Environmental Quality (IEQ) is to provide comfort and well-being of the users and to prevent sicknesses and health problems. There are many health problems in modern buildings and the symptoms are commonly attributed to IEQ problems which include headache, fatigue, sinus congestion, dizziness, and nausea (Url-6).

The office environment has direct impact on the well-being and productivity of the workers. The major complaints about the office buildings are related to space density, thermal, aural, visual and air quality causing Sick Building Syndrome (SBS). The adaptation capability of the physical building refers not only to environmental response to climate change, but also includes an awareness of user behavior. Ultimately, buildings are there to serve the users, so user perception, behavior and interactions are an important part of the adaptation process (Steemers, 2003). As it can be understood from this statement, the user should not be treated as the passive players of the created environments. If the users of IBs are given an individual control of their environments, the productivity and well-being of the user increases. For example, in IBs that are responsive to user interaction, the act of opening a window should turn off heating or cooling locally. The resulting system is a more dynamic mixed-mode operation of buildings – one where IB serves the user. The building can still turn to an 'optimum' state (in energy and comfort terms) after a given time period or in response to occupancy sensors. The robust passive environment-oriented design with intelligent control systems is the solution for reaching the adaptable building design. There can be conflicts between user behavior and 'optimum' performance, level and it offers an integrated approach to resolve occupant well-being and environmental impact. Such flexibility and adaptability gives the control back to the users and enable them to respond to climate change by interacting with the building and its intelligent systems and services.

The indicators recommended for productivity in office buildings by the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) workshop on Indoor Air Quality (Baltimore, 1992) are as follows:

- Absence from work, or workstation;
- Health costs (including sick leave, accidents and injuries),
- Interruptions to work,
- Controlled independent judgments of work quality,

- Self-assessments of productivity,
- Speed and accuracy of work,
- Output from pre-existing work groups,
- Cost for the product or service,
- Exchanging output in response to graded reward,
- Volunteer overtime,
- Cycle time from initiation to completion of process,
- Multiple measures at all organizational levels,
- Visual measures of performance, health and well-being at work,
- Development of measures and patterns of change over time.

Clements-Croome et al., (2000) have carried out environmental surveys in several office buildings showing that: "the crowded work spaces", "job dissatisfaction" and "the physical environment" are the main factors effecting productivity. There is a close relation between physical indoor environment and productivity in the offices.

The sick building syndrome is generally measured with the health symptoms and sick leaves of the workers. It reduces the productivity of the occupants and profitability of the organization. Below are some other causes for SBS specified by Lorsch (2000: 12):

- Building occupancy being higher than intended,
- Low efficiency of ventilation,
- Renovation using the wrong materials,
- Low level of facilities management,
- Condensation or water leakage,
- Low morale,
- Lack of recognition

Surveys in several office buildings have shown that thermal problems, stuffiness, Sick Building Syndrome factors, and crowded work spaces are the most common complaints in office environments. The studies have also shown that productivity can be improved by 4 to 10% by improving the environmental conditions (Clements-Croome, 2000).

The terms of SBS has been coined by Dr. P. Kroling and the possible causes of SBS such as excessive air velocity, microbial allergens, malfunctioning thermal regulation, low frequency sound, and odors are summarized in Figure 2.14.

SBS Complaints	Possible Causes
Draft Susceptibility to flues and colds Rheumatic complaints	Excessive flow velocity Excessive turbulence Poor fresh air supply Intake air temperature too low
Mucous membrane irritation of the upper respiratory tract and eyes, sensation of dryness	Microbial allergy (from air-conditioning system) Dust; mites (carpeting etc.)
Fever Respiratory difficulties Aching joints Fatigue	Microbial cell toxins (endotoxins, cytotoxins) from humidifying water, filters and air intake elements
Fatigue Difficulty concentrating Stupor Headaches	Poor temperature control: – Temperatures > 23 °C – Increase in relative humidity – No window ventilation – Low-frequency noise (< 100 Hz) Allergens, endotoxins, cytotoxins Insufficiency of: – Sun protection/shading (none/internal) – Window areas (too large) – Storage mass (too low) – HVAC capacity/maintenance
Poor air quality	Odour from air-conditioning system: – Technical (material, filters) – Microbiological – Insufficient effective air change

Figure 2.14 : Sick Building Syndrome Complaints, adapted from Eisele et al. (2003).

The physical needs of the office workers are examined under five design criteria as: “spatial quality”, “thermal quality”, “air quality”, “aural quality”, and “visual quality” in the following sections.

- **Spatial quality**

Workplace spatial configuration has a direct influence in office work, flexibility of the occupancy and employee interaction. The workplace should support every type of working. The office worker is turning into “transactional knowledge worker” which means a worker who exchanges information. According to DEGW and BRE, the office work is composed of four principal functions: “logistics and information”, “tasks”, “projects and discussions”, and “meetings” (Hascher et al., 2002)

In Figure 2.15, there can be seen what kind of works are done in which kind of office space. The individual logistic/information work are done in cell-like office, whereas the routine tasks like report writing and data entry are done in open work area. The Projects and developments are done in group room whereas meetings can be done in café/lounge space.

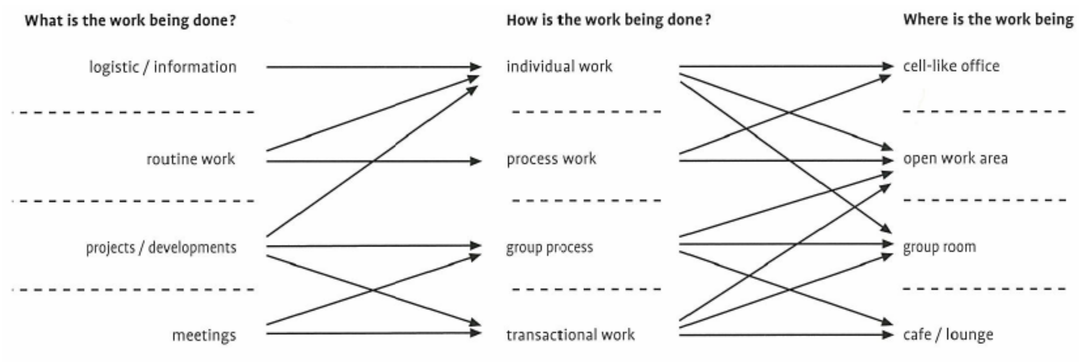


Figure 2.15 : Possible links between “functions”, “modes of working”, and “spatial configurations”, adapted from Hascher et al. (2002).

A spatially flexible office arrangement offers the occupant some degree of choice over where to sit, and it can be affected by the environmental conditions (light, breeze, noise, etc.). It is a well-known fact that increasing an occupants’ degree of control over their environment increases their “comfort” and perceived “productivity”. If this can be integrated with building skin design criteria, the adaptive potential of a building to climatic change will be increased (Steemers, 2003).

It is among the major aims of IB design to reach integration between intelligent systems and passive environmental design criteria for the user comfort. The floor area requirement per workspace still remains as an important planning basis which changes from country to country. In Figure 2.16, the minimum standards for different countries are given. In addition to these figures, there are some regional and cultural influences which are effective in the planning of the workspace.

	Minimum standard (according to state regulations)	Regulation work area	Gross area requirement per workplace
Germany	8-10 m²	12-15 m²	25-27 m²
UK	11 m³ or. c. 4.6 m²	7-10 m²	14-16 m²
USA	–	6-12 m²	19-23 m²

Figure 2.16 : Minimum standards and average area requirement per workplace, adapted from Hascher et al. (2002).

The new office building design should be able to easily accommodate modifications and alterations due to management re-organization, personnel shifts, changes in business models, or the advent of technological innovation, but the office infrastructure, interior systems, and furnishings must be flexible enough to cope with these alterations. For example, there can be used movable walls/partitions allow for different users to change the space raised floors to allow for easy access to cabling and power distribution, and advanced air distribution to provide individual worker comfort. Also, there can be incorporated technical features such as plug-and-play floor boxes for power, data, voice and fiber wiring, in order to provide flexibility at work for daily and future reorganization of workstations.

Organizational effectiveness can be increased by using the space more wisely which means designing flexible space that enables to change as work groups and projects evolve during the time. If the office space is designed intelligently, it can accommodate the right context for concentration, learning, communication, and collaboration which are the key components for assuring productivity.

In Figure 2.17, the key drivers, solutions and issues for changing workplace are summarized. In the changing workplace; team works, communication and information flow increase and end ups with more meetings places, less individual space arrangement, and more use of mobile supports (PDA, laptops, wireless, phone). But, these changes also bring forth increased noise level, more interruptions and distractions, and longer working hours to fix the individual works. Another key driver is the greater use of dispersed work groups, which increase the use of video conferencing, computer-based tools, and mobile technologies to be used in the meeting rooms.

Drivers	Workplace and technology solutions	Issues and concerns
Increased use of teams and cross unit work; More pressure for communication; More information flow	• More meeting space • Greater variety of meeting spaces (open & enclosed, large & small) • Smaller individual workspaces • More open individual workspaces • Unassigned workspaces • Greater interior visibility to support awareness • Mobile supports (phones, laptops, PDAs, wireless) • Personal video, instant messaging, desktop team software • More use of project rooms • Displayed information and work progress • Small rooms for individual focus • Lockers for personal belongings	• Increased noise • Increased distractions and interruptions • Potential for "over communicating" • Cultural barriers to behavioral change • Individuals working longer hours to compensate for lack of time to do individual tasks • Expectations that workers are always available
Greater use of dispersed work groups-often global	• Increased use of video conferencing, computer-based team tools • More reliance on conference calls • Greater need for mobile technological supports for meeting rooms • Use of facilities beyond normal working hours	• Expansion of the workday to accommodate geographically dispersed team meetings • Loss of opportunity to develop trust through face to face interaction • More difficulty managing and coordinating • Very high dependence on technological reliability
Continual reorganization and restructuring	• Flexible infrastructure to support rapid reconfiguration • Mobile furnishings	• Acoustical problems with loss of good enclosure • Potential for reduced ergonomic effectiveness
Reduced costs More efficient space use	• Shared or unassigned workspaces • Centralized filing system • Reduced workstation size and increased overall densities • Greater overall spatial variety to enable different kinds of work to be accommodated at same time	• Increased distractions and interruptions • Increased noise • May meet with employee resistance • More difficult for paper intensive work
Improved quality of work life Attraction of new workers	• More equitable access to daylight, views, and other amenities • More equitable spatial allocation and workspace features • Amenities for stress reduction	• Resistance from those who support hierarchical space allocation

Figure 2.17 : Key Drivers, Solutions and Issues for Changing Workplace, adapted from Heerwagen et al. (2010).

But with these changes, face to face communications reduce and it is more difficult to coordinate from far away. The working hours expand to compensate geographically dispersed team meetings, and highly dependent on technology.

There is a continuous re-organization in changing workplace which requires flexible infrastructure and mobile furnishing which may end up with acoustical problems and reduced ergonomic effectiveness. The office costs are reduced and the space is used more efficiently as a result of shared/unassigned workspaces, reduced workstation size with increased density, whereas these changes also bring forth increased noise problems, disturbances and difficulty in handling paper intensive works.

Lastly, changing workplace has improved the quality of work life with more equitable spatial allocation and workspace features, whereas there is some resistance from those supporting hierarchical space allocations (Heerwagen et al., 2010).

As it can be followed through these explanations, the changing workspace has an impact on physical, social, psychological and economical needs of the users, and brings some new problems to be handled as a result of these radical transformations.

- **Thermal quality**

A good indoor climate is important for its occupant's comfort and for sustainability in terms of energy consumption. People have a natural tendency to adapt to changing environmental conditions and this natural tendency is applied in the adaptive approach to thermal comfort.

Air temperature, mean radiant temperature, humidity, air speed, and occupancy factors/controls are critical performance qualities for thermal comfort (Mill et al., 1988). It is very difficult to define a range of comfortable conditions but the width of the comfort zone will depend on the balance between adaptive thermal comfort and actual temperatures. Also the adaptive relationship between comfort temperature and the outdoor temperature can be useful in comfortable building design (Nicol et al., 2001).

The post-occupancy research studies have shown that most of the complaints about unsatisfactory indoor environments were those connected with high or low temperature variations; stale and stuffy air; dry or humid air (Croome, 2003).

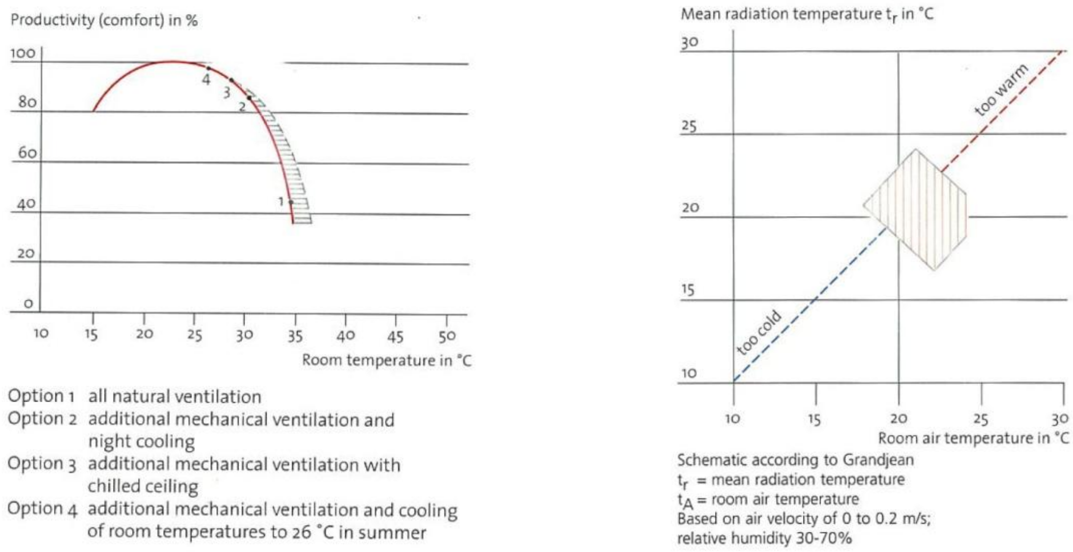


Figure 2.18 : Optimum conditions for workplace productivity and Mean radiation temperature, adapted from Eisele et al. (2003).

The optimum conditions for the workplace productivity and the comfort zones are illustrated in Figure 2.18. It can be seen that the performance level that requires high degree of concentration is linked into a very narrow temperature range. Also, the important parameter for thermal comfort is not only room temperature but also mean radiation temperatures, and relative humidity interaction with room temperature.

In order to avoid thermal problems, buildings should be designed to be able to function without mechanical ventilation systems by the use of operable windows if possible. The mechanical ventilation should be integrated as a supportive service to this natural ventilation. Also, windows should make up at least %50 of the facade and this must be supported with shading devices (blinds, light shelves, louver etc.). There can be arranged separate temperature controls for individual rooms, with the option for switching the system off.

In Figure 2.19, the seasonal air circulation of an office has been displayed. In this sample office building, the lower floors of the office buildings are constructed with a system of floor integrated convectors, some of which are mounted below the window sills. There is also fresh air injection into the office areas via double height floors at an air change rate of 1.5-2 to achieve minimal ventilation for hygienic air conditions. The air volumes supplied in this manner help to reduce a cooling load up to maximum 10 W/m^2.

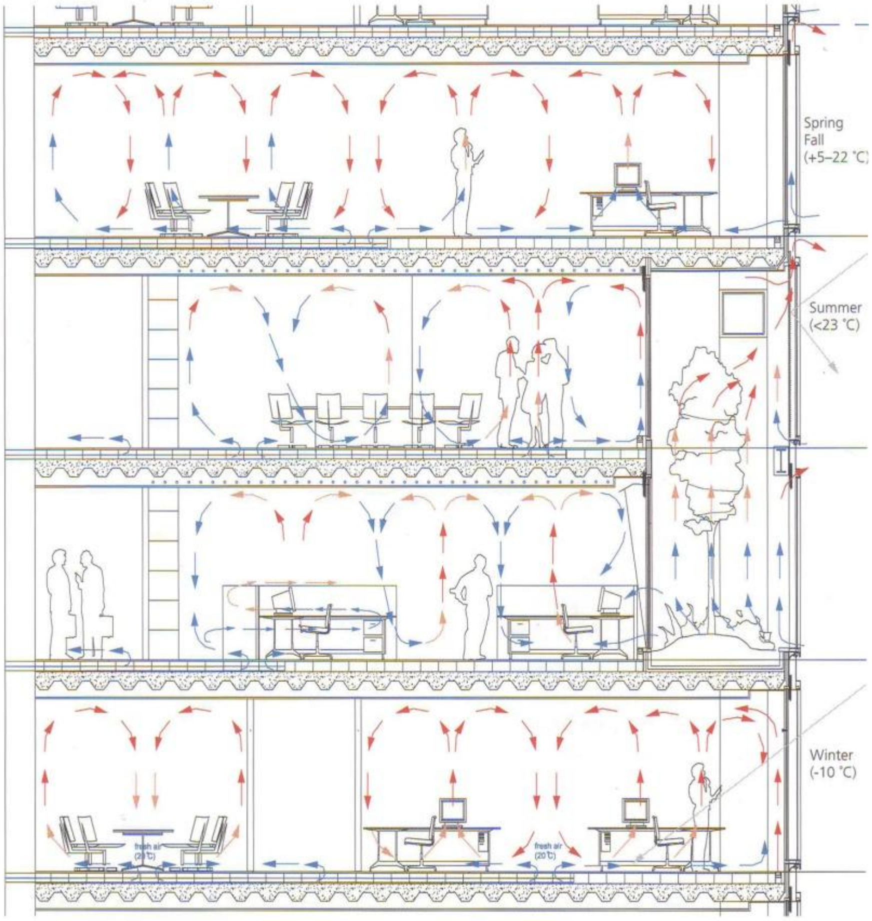


Figure 2.19 : Seasonal air circulation in offices, adapted from Eisele et al. (2003).

During the summer time, the estimated cooling load is approximately around 50 to 60 W/m^2, and the room temperature is maintained around 32°C (Eisele et al., 2003).

- **Air Quality**

The researches reveal that; the users are much healthier in naturally ventilated buildings rather than sealed completely mechanically conditioned buildings. While designing IBs, unsuitable building materials selection and insufficient air circulation level lead to high emission concentration and health risks. Also, while trying to reduce the energy use in the buildings, the main problem lead is inferior indoor quality and non-optimal thermal comfort.

Today the buildings have become increasingly mechanically controlled and deep plan, while consuming significantly greater amounts of energy. Some implications of close mechanical control are now becoming clear such as absenteeism, sick building syndrome and reduced productivity (Bordass et al., 1995).

This type of hybrid systems implementing active and passive ventilation design principles increase the user comfort conditions and reduce energy consumption supporting sustainability. The awareness of the cost and environmental impacts of energy use, natural ventilation has become an increasingly effective method for reducing energy use and cost while providing acceptable indoor environmental quality and maintaining a healthy, comfortable, and productive indoor climate.

The indoor Heating, Ventilation and Air Conditioning (HVAC) systems design shall prevent airborne bacteria, mold, and other fungi systems that are effective at controlling indoor humidity. Fresh air, fresh air distribution, restriction of mass pollution, restriction of energy pollution, and occupancy factors/controls are critical items for air quality. The air quality of the room is determined both by the quality of the intake air, and by air-contaminating factors such as room usage.

In Figure 2.20, the boundary values for CO_2 concentration levels are displayed which can be used as a design basis for the ventilation system.

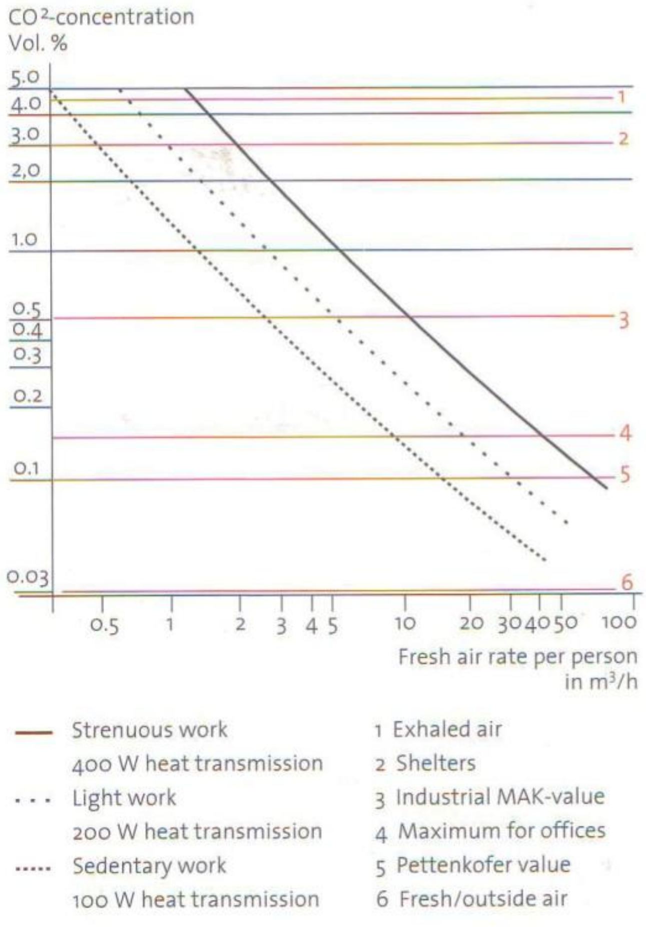


Figure 2.20 : Fresh air rate per person for different permissible CO_2 levels, adapted from Eisele et al. (2003).

According to Djukanovic et al., (2002) human criteria for air quality should be established at three different levels of response:

- Behavioral (task performance, self-estimated performance, observed spontaneous behavior).
- Subjective perception (acceptability, satisfaction, whether air quality has positive or negative effects, description of odor type and character).
- Physiological (self-estimated intensity of health symptoms, objective measurements, e.g., blinking rate, breathing pattern, measurements of metabolic rate and level of activation).

- **Aural quality**

According to different type of researches, the workers in open plan office suffer from noise as a primary source of discomfort and reduced productivity. Sound pressure levels and frequency, background noise, noise isolation, sound distribution, absorption, reflection, and occupancy factors/controls are critical items for aural quality. According to Brill (1985), there are four ambient conditions in the office affecting ease of communication among the workers:

1. Hearing and being bothered by telephone ringing and by others talking on the telephone (this reduces ease of communication)
2. Noise, in general, but with more noise related to higher ease of communication
3. Frequent intrusions into workspace by others (reducing ease of communication)
4. Easier path finding the ability to find one's way around the office (increases ease of communication)
5. [T]he big number of interoffice moving disturbs communication" (Brill, 1985: 55).

During the IB facility design and development process, building projects must have comprehensive, integrated principles that seek to keep the aural quality. Some of the recommendations given by Whole Building Design Guide (WBDG) organization are as follows:

- Reduce sound reverberation time inside the workplace by specifying sound absorbing materials and by configuring spaces to dampen rather than magnify sound reverberation.
- Provide sound masking if necessary.

- Limit transmission of noise from outside the workplace by designing high sound transmission class (STC) walls between work areas and high noise areas inside and outside the building.
- Minimize background noise from the building's HVAC system and other equipment.
- Provide opportunities for privacy and concentration when needed in open plan offices.
- Enclose or separate group activity spaces from work areas where concentration is important (Heerwagen, 2008).
- **Visual quality**

The visual comfort conditions can be reached if the human brains perception can operate without interference. Inappropriate interior design together with incorrect illumination distribution in a room, and glare can prevent visual comfort. Also, facade design plays an important role in providing visual contact with the urban environment and landscape.

The impact of daylight needs to be taken into consideration when planning any type of office buildings. There can be created a high performance luminous environment through the careful integration of natural and artificial light sources. The workspace lighting researches try to distinguish between the effects of artificial, interior lighting and of natural or day lighting from windows on the building occupants. As a result of day lighting research, it has been linked that the comfort and productivity of the user increases with window size and proximity, as well as with the view outside, control over blinds and glare shielding (Hedge, 2000).

In summary, ambient light levels and task levels for artificial and daylight, contrast and brightness ratios, color definition are critical items for establishing good visual quality.

For natural lighting use, partial deflection of the sunlight falling onto the upper part of the window can be deflected into interior for lighting, while direct sunlight falling on the lower part of the window can be screened off by a shading device. The simplest solution is a Venetian blind with horizontal louvers, which can be adjusted to deflect light in the upper window area and to shade in the lower part (Figure 2.21).

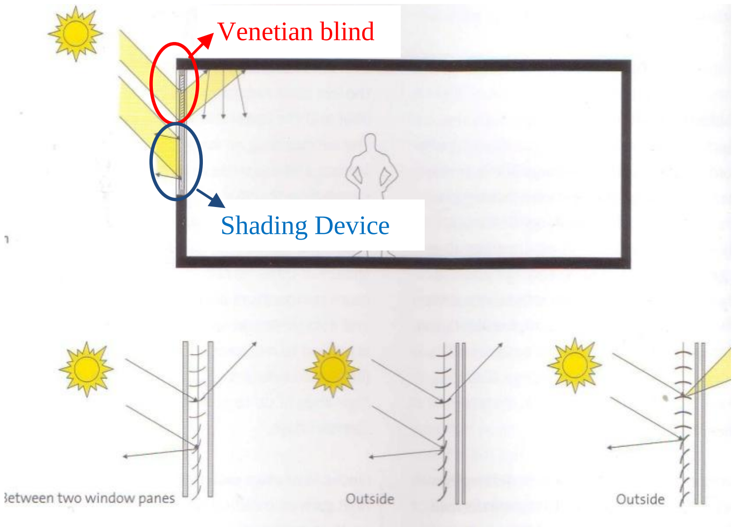


Figure 2.21 : Venetian blind with light reflection louvers and possible louver settings, adapted from Eisele et al. (2003).

Natural daylight helping to improve the productivity of the workers can be used effectively by implementing appropriate shading and glare protection systems in the work space.

A highly efficient light level distribution in the office space lighting that improves visual quality while reducing electrical use can be achieved through efficient lighting layout, lamps, luminaries, and other components, together with localized lighting controls as shown in Figure 2.22.

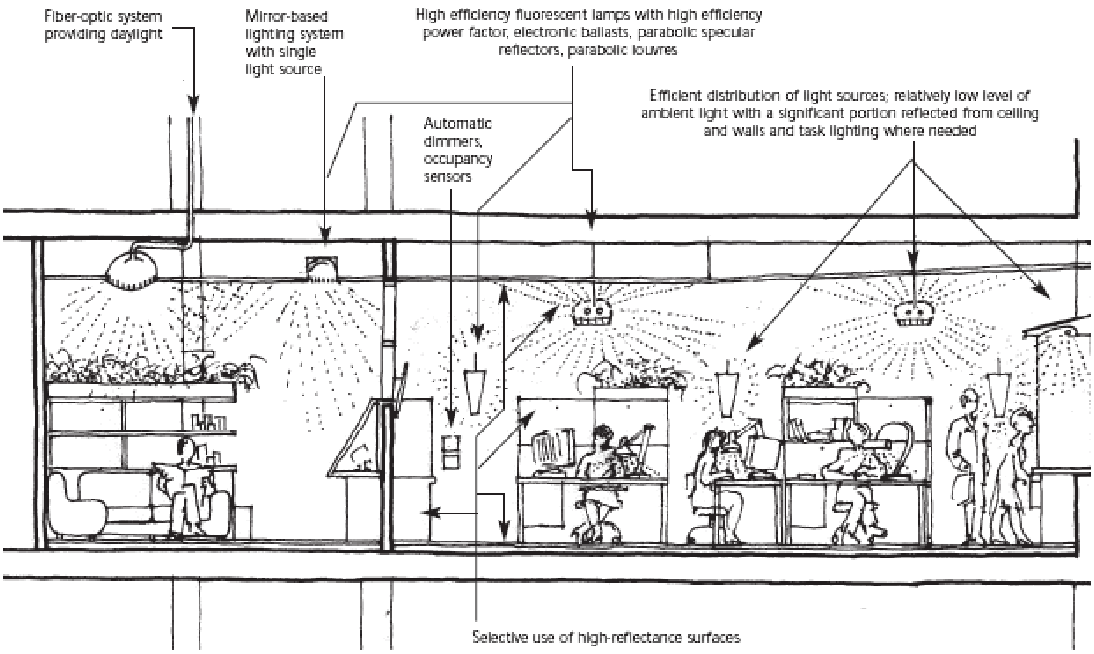


Figure 2.22 : High Performance Lighting Level Proposal sketch in an office, adapted from Url-7.

In order to provide a high performance luminous environment in office space, the below design criteria should be considered:

- Use day lighting for ambient lighting wherever feasible,
- Supplement natural light with integrated, high-performance ballasts, lamps, fixtures, and controls,
- Use task/ambient systems that provide reduced levels of diffuse, general illumination, and supplement with task lighting. Most people do not need lighting in excess of 300 lux (a unit of illumination),
- Substitute magnetic fluorescent lamps with high-frequency electronic ballasts to reduce flickering,
- Reduce direct glare from both natural and man-made sources in the field of view - particularly in spaces with highly reflective surfaces,
- Use light color on walls and locate windows properly (Heerwagen, 2008).

2.3.2.2 Psychological and social needs of the occupants

The user-oriented IB design requires the provision of "psychological" and "social" parameters in addition to "physiological" ones. This can be explained in relation to Maslow's triangle (Figure 2.23). It was designed for explaining the hierarchy of human needs locating the *"physiological needs"* at its base. Then this ascends to the *"safety, social, ego and self-actualization needs"*. This hierarchy of human needs can be applied to IBs as well.

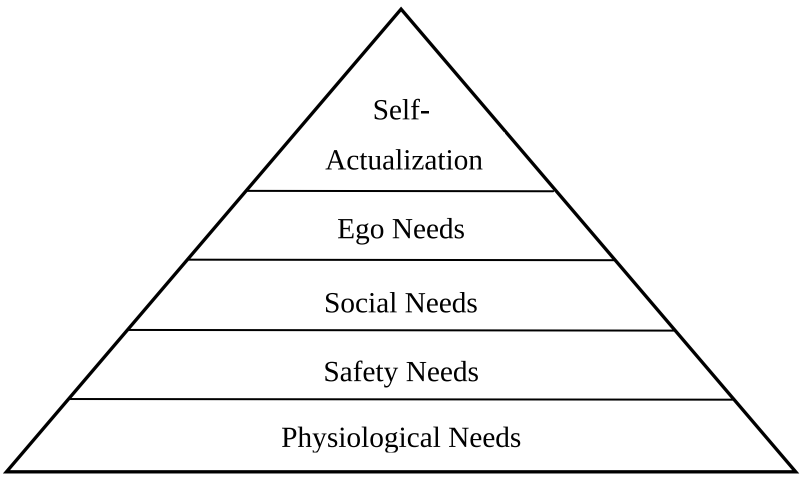


Figure 2.23 : Maslow's Triangle, adapted from Neubauer (1988).

People use buildings to meet their physiological needs in terms of heating, air conditioning, ventilation, light and water. The next step is used to meet the safety needs of the people in terms of security and fire protection. Then, building intelligence including information systems, office automation, and video-conferencing together with telecommunication systems are used to meet the social needs. As a result of these developments, IB becomes a tool for creating the personal environmental and technical conditions for maximizing their individual production and satisfaction (Neubauer, 1988).

As it has been emphasized by the social scientists, it is a psychological need for the occupants to feel that, they have got the necessary tools to control their environments in IBs rather than being controlled by them. Individuals feel better and work more efficiently, if they are given the chance to control their environments rather than fixed central control systems.

IBs designed in collaboration with bioclimatic principles give a certain level of control to its user to arrange his/her microclimate and indoor comfort conditions. The researchers agree that, the individual comfort and satisfaction can be universally provided by giving individual control of the local environment (Bordas et al., 1995).

Buildings with high psychosocial value are designed around basic human needs, previous preferences, and connections to the patterns of nature and the mind. Biologist Stephen Boyden (1971) states that, environments need to fully satisfy both “survival needs” and “well-being needs”. Survival needs deal with aspects of the environment that directly affects human health, such as clean air and water, lack of pathogens or toxins, and opportunity for rest and sleep. Well-being needs, on the other hand, are associated with fulfillment, quality of life, and psychological health. Whereas failure to satisfy survival needs may lead to serious illness or death, failure to meet the well-being needs can lead to psychosocial maladjustment and stress-related illnesses. Environmental psychologists have also considered other needs such as comfort maintenance and sense of equity, which are important in today's building environments.

The researchers identify the below items in building design to be provided as an opportunity for well-being needs of the occupants:

- Engage in spontaneous social encounters;

- Relaxation and psychological restoration;
- Privacy and interaction;
- Learning and information sharing;
- Connection to the natural environment;
- Regular exercise;
- Sound levels not much above or below that of nature;
- Meaningful change and sensory variability;
- Visual environment with aesthetic integrity;
- Sense of social equity and respect;
- Ability to maintain and control personal comfort;
- Making sense of the environment (Heerwagen et al., 2010).

In today's world, the structure, content, and process of work patterns have changed. Work is now more cognitively complex; team-based and collaborative; dependent on social skills; dependent on technological competence; time pressured; mobile and less dependent on geography.

Also, the organizations are likely to be very different due to competitive pressures and technological breakthroughs becoming more dynamic, competitive, and less hierarchical in structure and decisions (Heerwagen et al., 2010).

As working patterns change, the nature of the relationships between employees and employers also transform. In the new work context, the informal, "psychological contract" between workers and employers focuses on competency development, continuous training, and work/life balance. On the contrary, the old psychological contract was all about job security and steady advancement within the firm (Heerwagen et al., 2010). Among the four type of office working modes displayed in Figure 2.24, "process work" describes work types carried out alone in the group, structured clerical works in which tasks can be carried out in sequence, but individual steps of the work are repetitive. In "group process" work, there is an interaction of all those involved around a common goal. The "individual work" means work requiring concentrated attention carried out by an individual.

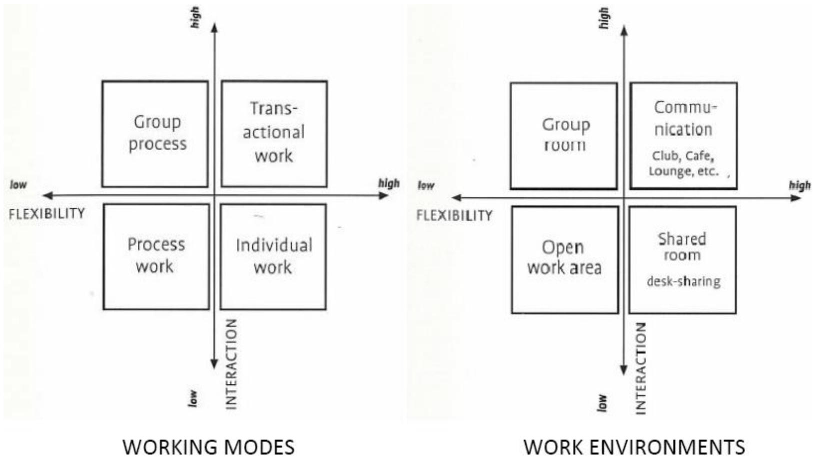


Figure 2.24 : Working modes and environments displayed according to their interaction and flexibility levels, adapted from Hascher et al. (2002).

Lastly, "transactional knowledge" is defined as informal conversation with the goal of exchanging knowledge and experience. The worker who handles knowledge transaction doesn't need to go to office to work on tasks and projects, but uses this space as a meeting point. Transactional work is an autonomous mode of working and gaining great importance among organizations.

While we are working, we interact with our environments in complex and dynamic ways which cannot be purely explained with physical factors. An example to psychological factors can be followed through a study carried by Hardy (1982). The thermal comfort perception of the workers moving from closed offices to open plan offices decreased by 50%, even though the offices had the similar thermal conditions. This difference was the result of loss in personal control caused by moving to open plan offices (Morrow, 1995). Designers of IBs should provide appropriate means of flexibility to building users for customization of their environments in compliance to their needs. If the user is given a certain level of control in his working environment, it will have a positive impact on productivity and work efficiency of the user.

In Table 2.1, the relation between basic human needs and work environment are given. If we look at the architectural reflection of these spaces, design parameters like daylight, landscaping, natural ventilation, operable windows, open and closed offices are among the psychological and social needs of the worker. Most of these passive design parameters are "environment-oriented" which will be explained in details in Chapter 3.

- **Privacy/Autonomy**

The forms of interaction have changed from face-to-face to online virtual communications as a result of newly emerging technologies. The new knowledge work type requires high levels of interaction and autonomy. In the new office design, there is a link between the structure of the organization, working modes (i.e. autonomous individual work or interactive group work), and spatial form. The exchange of information type determines the space arrangement and boundaries that will be established in the new office building design.

Communication and human interaction are the preconditions for the efficient exchange of information and need to be supported by spatial organization. Organizations realized the importance of “informal communication” and requesting their buildings to be designed for “information worker”.

Autonomy is the degree of control, responsibility, and discretion each office worker has over the content, method, location, and tools of the work process. The more autonomy office workers enjoy, the more they are likely want to control their own working environments, singly and collectively (Duffy and Powell, 1997). The worker autonomy is higher in shared cellular rooms rather than open plan office areas.

Privacy is the need to exercise control over one’s accessibility to others. The range of the workspaces available by an organization to staff is very important means of giving them autonomy. Knowledge workers that are given high degree of freedom to choose when, where and how to work will make them more effective and increase productivity. However in order to achieve this, workspace should provide not only for their specific work or activities but for those of their colleagues and others involved in the tasks (Harrison et al., 2003).

As a result of the increasing public interaction and technological evolutions in workspace, one of the most difficult things to keep is “privacy”. Harrison et al, (2003: 39) defined the future workplace as follows: “Workplaces of the future must be evaluated in a way that takes account of people’s need to balance their working and private life, and that takes account of people’s perhaps contradictory feelings about wanting the freedom to work flexibility without allowing work to intrude too far into their home life”.

Table 2.1: Relation between basic human needs and work environment, adapted from Heerwagen (2008).

Social engagement	• Comfortable meeting places • Indoors and outdoors • Circulation systems and layouts that support informal interaction • Attributes that draw people to space and encourage conversation
Cultural and Collective Meaning	• Celebratory spaces • Artifacts and symbols of cultural and group identity • Sense of uniqueness
Relaxation and psychological restoration	• Quiet spaces with low sensory stimulation • Connections to nature • Distant views • Outdoor seating or walking paths in visually appealing landscapes
Visual and aural; movement between interaction and solitude	• Enclosure or screening • Distance from others • Ability to regulate the desired degree of social interaction by moving between spaces or by manipulating personal space • Variety of informal social spaces to develop relationship
Learning and information sharing	• Good acoustics for training/learning environments • Good visibility to support situation awareness • Layouts, meeting spaces, and circulation that support conversation and information exchange without unduly disturbing others
Connection to nature and Natural processes	• Daylight, • Views of nature outdoors, • Careful use of indoor sunlight • Natural ventilation • Interior plantings • Nature décor, and nature patterns in spatial layouts, furnishings
Sensory variability	• Daylight access • Indoor sunspots • Variation in color, pattern, and texture • Natural ventilation
Sound levels similar to nature	• Operable windows to allow connection to positive outdoor sounds • Acoustic conditioning to reduce equipment and industrial noise
Interesting visual environment, with aesthetic integrity	• Adoption of naturalistic, bio-inspired design • patterned complexity • reduced monochromatic environments • More organic layouts and forms
Way finding and making sense	• Landmarks, variability of space to serve as location cues • Windows to orient by outdoor views • Use of color and pattern on walls or carpeting to provide location and movement cues
Exercise	• Indoor gym • Outdoor bike and hiking paths • Open stairways to promote interaction and walking • Visually interesting landscape to entire exploration
Sense of equity	• Design of spaces and allocation of amenities that shows concern for the health and well-being of all occupants, visitors and other users of the space

- **Interaction**

Office work is currently influenced by terms “interaction” and “flexibility”. During a workday, it will change from highly concentrated individual work to highly interactive project work in changing team. So, the workspace should support every mode of working. Spatial interaction between the workers can strengthen communication in office buildings.

Part of collaboration and communication involves awareness of others. A great deal of research in social psychology, sociology, and human communication research has reviewed topics such as how first impressions are formed, what kinds of inferences are made from manner, appearance, talk, and setting (Goffman, 1959), social status and hierarchy. Collaboration and relationship development in work space also take time and effort. In order to understand co-workers, there has to be spent some time for listening, integrating, and synthesizing the shared information.

In 2001, the National Research Council’s report on the changing nature of work, called attention to the importance of “relational” and “interactive” aspects of work as follows:

- **Team work and collaboration:** In collaborative work, conflict resolution and negotiation skills are essential for solving problems. Conflicts often occur about group goals, work methods, assignments, workloads, and recognition. Team members with good conflict and negotiation skills are better equipped to deal openly with problems, to listen and understand different perspectives, and to resolve issues in mutually beneficial ways.

- **Relationship development and networking:** Sharing important information, fulfilling promises, willingness to be influenced, and listening are building blocks for the development of mutual trust. When workers trust one another, they are more committed to attaining common goals, more likely to help one another through difficulties, and more willing to share and develop new ideas.

- **Learning and growth:** Many organizations strive to be learning centers to create conditions in which employees learn not only through formal training but through relationships with co-workers. Learning relationships build on joint problem solving, insight sharing, learning from mistakes, and working closely together to aid transmission of tacit knowledge (Heerwagen et al., 2010).

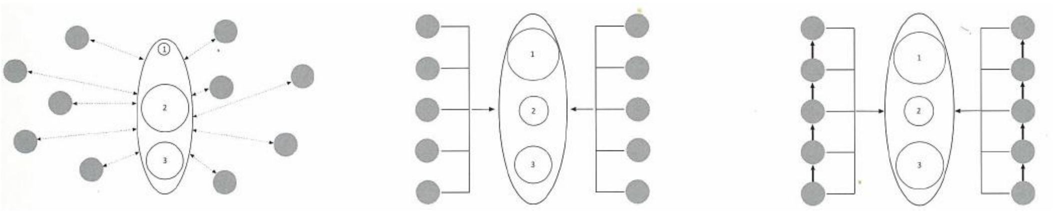
According to Brill (1985), there are four physical aspects of the office affecting the ease of communication:

1. "[D]egree of enclosure, with more enclosure being better (a high degree of physical enclosure relates to high ease of communication and openness to low ease of communication)
2. [T]he amount of space a person has, with more being better
3. [T]he layout of a workstation with greater suitability for the work at hand, correlated with greater ease of communication
4. [R]elocations, with higher frequency of location correlated with more disruption of ease of communication" (Brill, 1985: 54).

Interaction is the personal, face-to-face contact that is necessary to carry out office tasks. As the amount of interaction increases, there is more pressure to accommodate and support such encounters. Forms of interaction vary depending on the importance of the tasks being carried out increase, so settings for interaction can range from the most informal to the most formal meetings and from the most casual to the most structured encounters (Duffy and Powell, 1997).

It has got reflections in workspace arrangement of highly adaptive, responsive and flexible IBs based on the requirements of the user.

1. Meeting Areas | 2. Relaxation Areas | 3.Office Services Areas



Individual work | Group Work | Team Work

Figure 2.25 : Work forms and interaction, adapted from Eisele et al. (2003).

Office works are carried out by individuals, by teams or by groups (Figure 2.25). These work forms the individual work, there is a very low interaction among the members mainly in meeting, relaxation and office service areas. Where as in group works, the total task is distributed among individual experts working autonomously.

In collaborative team work, there is intensive interaction between all team members. As a result the new IT applications, work can be done from everywhere, and reduce the necessity of face-to-face communication. This has a direct impact on workspace planning and infrastructure of the services and systems in IBs.

- **Habitability**

As result of information revolution, the classical definition of workplace and organizations changed. Today, the workplace is dominated by knowledge workers, and their needs and actions are different from the clerical ones. They are trained to make decisions and they want tools to support their tasks. They also expect high quality and comfortable environments. Mill et al., explain the user-technology relation in workplace as follows:

> "The effective workplace is the one which responds to the whole person, including the needs for **self-esteem, motivation, autonomy, self-expression, growth and control**. In the high technology workplace it is particularly important to ensure that the worker is the master, not the servant of technology." (Mill et al., 1988)

The comfort conditions of the worker contain three hierarchically related parameters: "physical", "functional", and "psychological". They are as follows:

- Physical comfort: includes basic human needs such as safety, hygiene, and accessibility to reach habitability level.
- Functional comfort: consists of ergonomic support for user's performance of work-related tasks and activities such as ergonomic furniture for computer users, appropriate lighting for screen based works etc.
- Psychological comfort: results from feelings of belonging, ownership and control over workspace (Vischer, 2007).

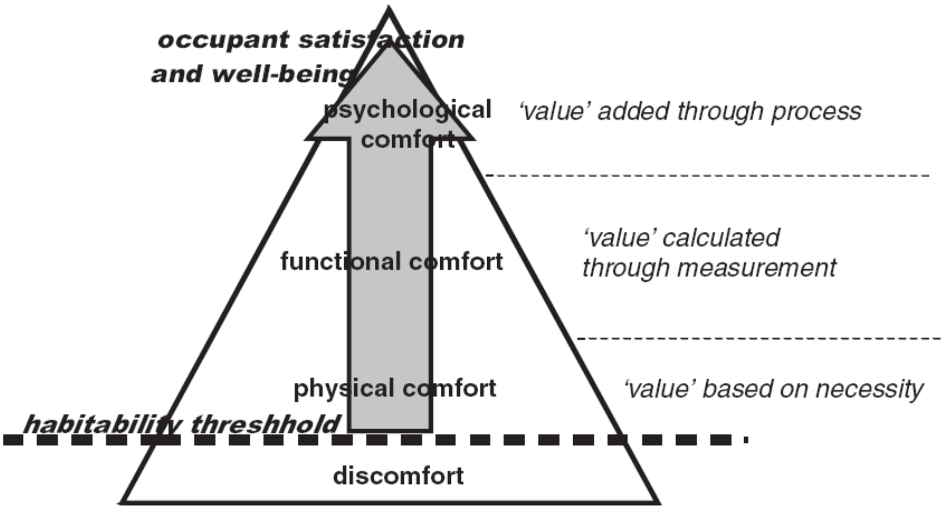


Figure 2.26 : The "Habitability" pyramid, adapted from Vischer (2005).

In Figure 2.26, the diagram illustrates habitability pyramid according to above mentioned three parameters. In this pyramid, while the physical comfort is at the threshold of acceptable workspace (habitable), psychological comfort is affected by the degree of physical comfort conditions. The functional comfort needs to be measured in order to determine which physical conditions support or fail to support the work. This has an impact on productivity of the worker as functionally uncomfortable workspace draws energy out of the worker rather than orienting to perform the work. While the users try to cope to with the adverse effects of the workspace, they display stressed behaviors affecting their mental health.

- **Mental health/Stress**

The stress in the workspace affects both job performance and job satisfaction. There are several theories developed for defining workspace stress and mainly used to refer the effects of the physical environment. The term stress refers to “the effects of fatigue on performance, namely in the context of man-machine systems, and to mental hygiene, or the diagnosis and treatment of mental problems at work” (Cooper et al., 2004: 11).

Another researcher, Mason (1972) identified three main situational stressors:

- Novel situation,
- Unpredictable situation,
- The individual having the feeling that she has got no control over the situation.

These three stressors can be transferred into analysis of physical work environment. It is not an unusual situation for the workers to feel little or no control over the workspace. Almost all theoretical models of stress at work refer to a mismatch or misfit between the requirements of the situation and the resources of the individual. All the prevailing theoretical models of work stress emphasize the need for a “good fit between a person’s abilities, skills and degree of control and the workspace demands, complexity, expectations. The poor compliance in either direction creates stress (Vischer, 2007).

There are several research studies done for measuring how the physical environment meets the users’ needs, and several misfits are recorded in this area. The physical workspace elements that are affecting the misfit between the worker and the workspace are studied by ergonomics discipline. This discipline applies assessment tools to office furniture and equipment to protect the workers from poor bodily positioning or muscle use. Ergonomics also studies features in workspace such as lighting and day lighting, noise and noise control, and office furniture and spatial layouts. For example, daylight research revealed that productivity is increased with window size and proximity as well as with view out. Another finding is that, the noise level in open plan offices are creating stress over the worker and reduce productivity.

The largest number of environmental psychology studies of workspace has focused on “floor configuration” and “furniture layouts in the open plan office”. Research indicates that these environmental factors have the greatest influence on worker satisfaction and performance (Brill et al., 1985). As a result of several studies, it has been realized that the office workers are uncomfortable in open plan configurations and prefer private enclosed workspace. The spatial layout affects the psychological comfort such as privacy and territoriality; office size is related to status; office partitioning influence acoustic properties; amount of office storage is linked to territoriality and status.

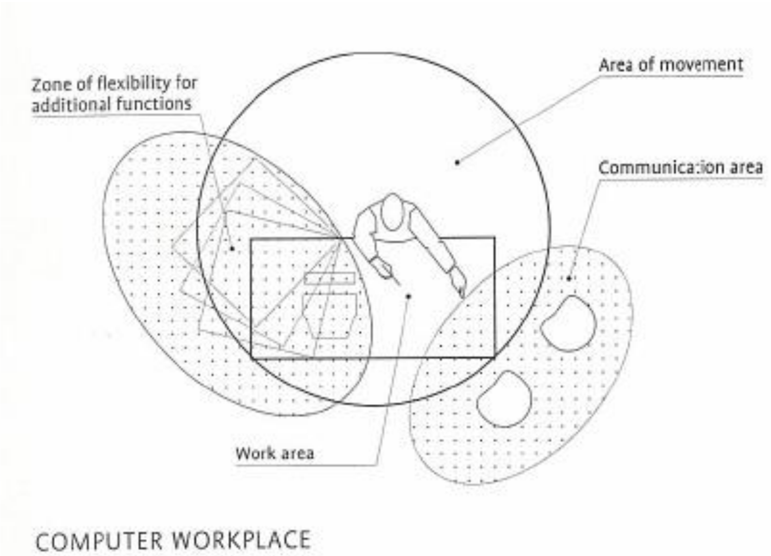


Figure 2.27 : Regular workplace according to Gottschalk, adapted from Hascher et al. (2002).

The workstations are also important components defining the office space and they have been transformed into different concepts together with the new working patterns. According to Mill et al., (1988), they must be designed to reflect a range of human needs such as: “anthropometric”, “sensory”, “social”, and “privacy”, “territory ”,“ status. The workstations should be designed to meet both organizational and personal requirements such as physical, sensory and cognitive needs. For example, the physical comfort, body movement and individual needs should be considered while selecting the workstation furniture and equipment as shown in Figure 2.27.

Stressors in the work environment affect employee performance adversely when they are high intensity; they slow down the individual’s ability to process and understand the number and predictability of ‘signals’, which increase with task complexity. Potential stressors include “spatial organization, architectonic details, ambient conditions and resources, and view or visual access from the workspace. As environmental stressors, [these] can influence physiological processes, produce negative effect, limit motivation and performance, and impede social interaction” (McCoy et al., 2005: 222).

Spatial organization issues include the openness of the layout: that is, the proportion of open workstations to private, enclosed offices, the height of partitions and the distance between open workstations, as well as access to needed resources, such as technology and equipment, meeting rooms and washrooms.

There are also ambient conditions such as sound, visual openness and light, as well as ventilation and thermal comfort in relation to spatial organization. Architectonic details, which include colors and decoration, signage, artwork and design details, convey meaning and can have symbolic significance that affects people emotionally. For example, some work environments promote “personalization and individual decoration”; some have key landmark elements that facilitate “territorial definition for individuals or groups”; some carry symbolic status, such as proximity to windows (positive) or to washrooms (negative) (Vischer, 2007). The fit and misfit between the workspace and the worker is the main reason behind the workspace stress which is effecting productivity

- **Security/Territoriality**

In the office space, sense of territory is associated with feelings of belonging and ownership. According to geographer Jay Appleton, people prefer to be in places where they have good visual access to the surrounding environment, while also feeling protected and safe. Conversely, negative reactions are common when visual access is denied or when the sense of refuge is absent, and one feels “on view” to others (Heerwagen, 2008). If the workers are given ability to maintain and control over their personal comfort conditions, they feel more secure in their workspace.

2.3.2.3 Economical needs of the occupants

The life-cycle cost distribution for a typical service organization is about 3% to 4% for the facility, 4% for operations, 1% for furniture, and 90% to 91% percent for salaries. As such, if the office structure can leverage the 3% to 4% percent expenditure on facilities to improve the productivity of the workplace, it can have a very dramatic effect on personnel contributions representing the 90% to 91% percent of the service organization's costs. To accomplish this impact, the buildings must use an integrated design approach through which a new generation of high-performance office buildings is beginning to emerge. These newly emerging IBs offer the users an increased work satisfaction and productivity, improved health, greater flexibility, and enhanced energy and environmental performance. Typically, these projects apply life-cycle analysis (Figure 2.28) to optimize initial investments in architectural design, IB systems selection, and building construction (Conway, 2010).

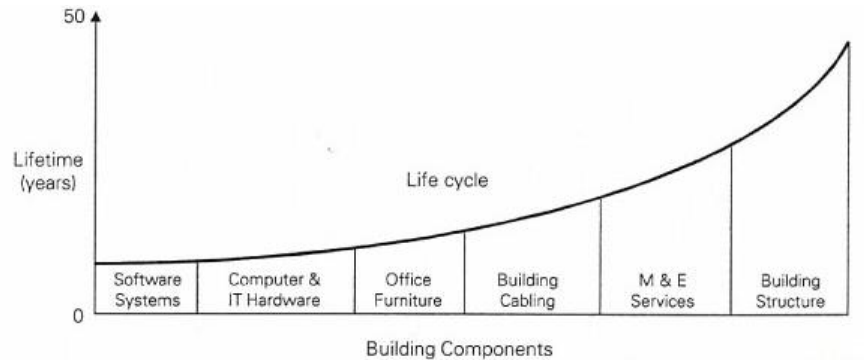


Figure 2.28 : Life cycle of Building components, adapted from Harrison et al. (2004).

Many of the design, construction and facilities management processes are led by capital cost arguments which generally ends up with low cost which brings low quality buildings. According to Croome (2003), there are three key attributes interacting in building design process: “the type of building”, “the facilities provided for environment and utilities, and “the use of the building”. In other words, “form”, “function” and “human needs” are the driving forces behind design which contributes to the well-being of individuals occupying the building and have a significant impact on the business organization. The cost of absent staff due to poor building conditions is a huge cost to the economy of the country (Croome, 2003). So, these economic assessments also emphasize the importance of user comfort and responsiveness to user needs as major design criteria. If the buildings do not serve to the users in an effective and healthy manner, it will have reverse impact on social, psychological and economical aspects.

The workspace has to provide comfort conditions to the users but this has to be achieved in a way to reduce occupancy costs by using the space more efficient manner. The changing nature of the business organizations require greater flexibility in the use of space and time, rapid responses to operational needs; and responsiveness to user needs. As a result of the IT enabling to work in a wide variety of locations within or outside of the office, the office space planning understanding has undergone complete transformation with shared working settings, meeting rooms, and other intelligent environments (Harrison et al., 2004). The production can be de-centralized and the work and life are no more rigidly separated in space.

Since the user is the most important resource and greatest expense of any organization, the long-term cost benefits of a properly designed, user-friendly work environment should be factored into any initial cost considerations. Any kind of investment for increasing the quality of indoor environment is cost effective when the economic effect of indoor climate to health and productivity are considered.

The economic needs of the users can be summarized under four main topics: “space conservation”, “material conservation”, energy conservation”, and “investment conservation”. All these economic parameters have a direct impact to physical, social and psychological parameters and need to be carefully analyzed by cost benefit analysis before starting IB design.

In this thesis study, the user requirements supported by “environment-oriented” and “technology-oriented” design criteria are taken as the main driving force behind Human-centered IBs. The second major component of an integrated Human-centered IB design is “environment-oriented” design criteria. It has a direct impact on physical, psychological and social, economic needs of the user by increasing productivity and comfort conditions of the user in Chapter 3, environment-oriented parameters effective in IB design are discussed in details.

3. ENVIRONMENT-ORIENTED DESIGN CRITERIA OF IBs

For an integrated Human-centered IB approach, the second major component is "environment-oriented" design criteria which needs to work in collaboration with user needs and technology-oriented criteria. There are hybrid design systems in which environmental passive design parameters can be reconciled with active intelligent technologies.

Before discussing the environment-oriented design criteria, the sustainable and ecological design issues which are closely related to passive design parameters are briefly explained in this section.

3.1 Sustainability and Ecological Building Design

The Report of the World Commission of Environment and Development (WCED, 1987) defined sustainable development as: "development which meets the needs of the present without compromising the ability of future generations to meet their own needs". The sustainable development is concerned with not only current environmental problems of pollution, energy consumption, and global warming but also prepares the strategies for leaving healthy environments for future generations.

The sustainability in developing countries requires "systemic world view". In this view, the planet and the world are seen as one organism, and consist of encapsulated countless sub-systems, which together form a part that is greater than the whole. This systemic worldview requires two concepts; "interconnectedness" and "impermanence". Through interconnectedness, the built environment can achieve a physical harmony with the nature, and while doing this the main focus will be communal good rather than individual. By impermanence, just like everything in nature, the building should be allowed to die at the end of their life-cycle (Plessis, 2001). As it can be seen, there lies an active, responsive, adaptive system in the origin of the sustainability and the same principle can be applied to ecologically responsive IBs.

In the ecological design approach, sustainable use of energy and materials over life-cycle of a building system is aimed in order to reduce the impact of building upon natural environment. The IB management systems are also used to support the passive environmental systems whenever necessary. As the energy consumption of built environment is enormous (Figure 3.1), the high-rise building designs should become more environmentally responsive for sustainable development.

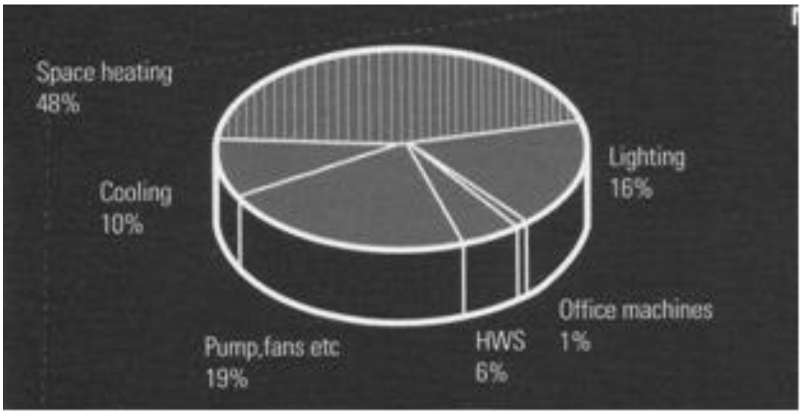


Figure 3.1 : Energy use in a typical Air-Conditioned office building, adapted from Yeang (2002).

Ecological architecture, which is mostly limited with energy efficiency, has shifted its goal to the improvement of human comfort conditions and healthy work environments. The energy efficiency has been replaced by a wider context of "social sustainability". T. Blake defines a sustainable society as the one:

> "…which is capable of meeting basic human needs while maintaining resilient and diverse ecological systems. Basic human needs encompass a person's need for social recognition, personal meaning and self-expression, as well as more widely acknowledged physical requirements of shelter, health care and security (Blake, 1991).

As stated by T. Blake, the buildings should be not only ecologically, but also socially responsive to their occupants. The ecological architecture should satisfy society's psychological, cultural and biophysical needs and energy efficiency should be considered as a sub goal of sustainable architecture.

The limitations of our ecological environment should be considered for sustainability while designing high-rise buildings. As stated by K. Yeang:

> "….Buildings will need to be designed not as high energy polluting open systems but as mimetic urban ecosystems that relate their inputs, outputs and operations within the context and carrying capacities of the ecosystems in the biosphere…" (Yeang, 2002: 180).

In his book *"Reinventing the Skyscraper: A Vertical Theory of Urban Design*", in 2002, K. Yeang defines five fundamental goals that should guide the design of high-rise building to ensure sustainability as follows:

- Conservation of natural resources for present and future generations through the efficient use of land, less wasteful use of non-renewable resources, their replacement by renewable resources wherever possible and the maintenance of biological diversity;
- The use of physical resources by ensuring a harmony between built environment and natural environment;
- Prevention and reduction of the processes that pollute the environment;
- The social goal of encouraging the development that reduces the social inequality between poor and rich;

To change attitudes, values and behavior by increased participation in political decision-making and environmental improvements (Yeang, 2002: 188-190) Ecological design is a broad concept and bioclimatic design is just one of its subgroups. Bioclimatic design includes the use of passive low energy systems such as building orientation, natural ventilation, natural lighting, and landscaping. Ecological design is interconnected to biosphere and its ecosystem.

BIOCLIMATIC DESIGN → **PASSIVE LOW ENERGY APPROACH**

ECOLOGICAL DESIGN → **INTERCONNECTEDNESS IN BIOSPHERE & ITS ECOSYTEMS**

In relation to energy conservation of the high-rise buildings, Ken Yeang examines:

1. Passive Systems (Building orientation, configuration and its relation with the environment)
2. Efficiency Systems (Energy Management Systems)
3. Active Systems (Mechanical and Electrical Systems) (Powell, 1999: 71).

For achieving an intelligent and ecologically responsive building, these three systems should be planned together as a layered structure from the beginning of the design process. According to Norman Foster, there stands "building orientation" at the base of the pyramid, and in the middle part "passive systems", and at the top of the pyramid expensive “active systems” for green buildings (Crosbie, 2000). Foster achieves a sensitively shaped architecture that blends the social, technological, economic and environmental issues by keeping the environmental responsiveness as a pivot point.

According to Kohler, there are three dimensions of sustainable building: “ecological sustainability”, “economic sustainability” and “social and cultural sustainability” (Kohler, 1999). Ecological sustainability includes resource and ecosystem protection; economic sustainability can be divided into investment and use costs; social and cultural aspects of sustainability include comfort and health protection, and preservation of social and cultural values (Figure 3.2).

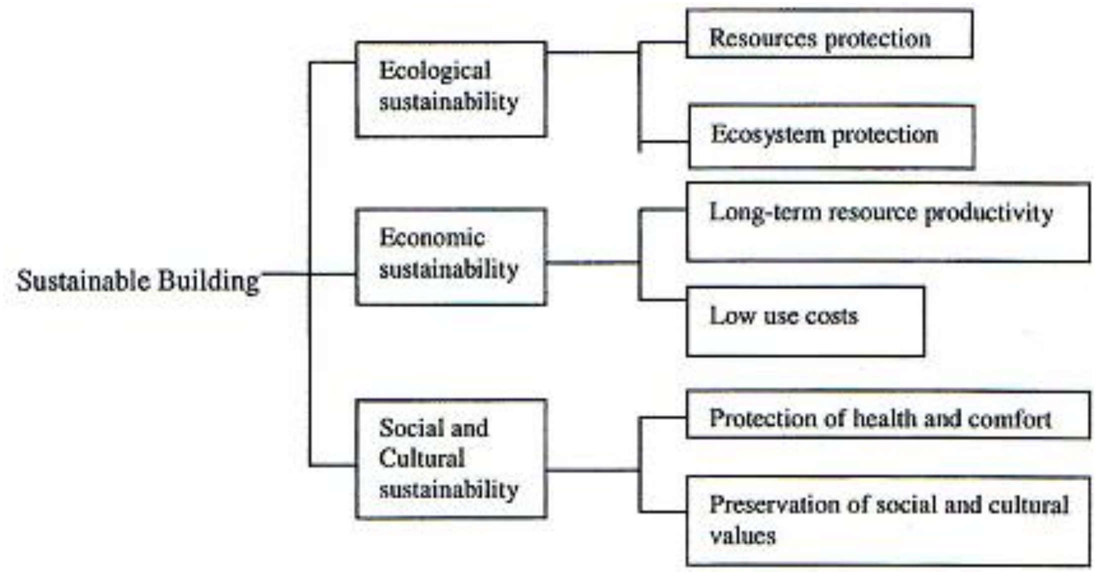


Figure 3.2 : Three dimensions of a sustainable building, adapted from Kohler (1999).

The IBs of the future should promote “ecological”, “social-cultural”, and “economic” sustainability. In the following sections, the ecological, social-cultural, and economic sustainability are briefly explained before passing into environment-oriented design criteria.

- **Ecological Sustainability**

The ecological high-rise building designs aim to conserve energy, minimize the impact of building on their periphery, and use recyclable construction materials. Their relation to the environment determines the success and failure of their designs. The ecological building design is affected by “new building technologies in facade design”, “new mechanical systems” and “new materials” (Höweler, 2003: 176).

As a result of technological developments, architects formed new collaborations with engineers for integrated ecological and technological solutions. Helmut Jahn and Werner Sobek have coined the term *"archi-neering"* to describe this collaboration. As stated by Eric Höweler:

> "They imagine an architecture that takes constant readings of the local climatic conditions and adjusts itself accordingly, creating self-darkening facades, or facades that are capable of generating energy, or double skin facades that generate heat in the cavity with the aid of solar radiation. The incorporation of these technologies they believe will result in totally new solutions and an 'aesthetic that is itself dynamic and changeable' (Höweler, 2003: 177).

Yeang's propositions for high-rise buildings as ecologically responsive entities include some contradictions within itself. The high-rise buildings are by no means low energy, and they are high consumers of energy because of their enormous sizes. But it will continue to be built as long as the human population increases (Powell, 1999). There has to be developed strategies for ecologically responsive buildings.

Each place is different with its climate, resources, geography and each building requires different solutions. This means that appropriate technologies, best method of construction, local energy sources and materials need to be selected. The half of the fossil-fuel energy is consumed by the buildings and the whole cities consume three-quarters (Edward et al., 2001).

- **Social Sustainability**

Energy issue is one aspect of ecological design and low energy design is not enough to produce completely sustainable buildings. The recent projects of Foster and Future Systems are not low energy designs, but ecologically responsive buildings. Their buildings try to meet physical and psychological needs of the user and they express "social sustainability" in terms of human health, productivity and well-being. In the natural world, human can make necessary adjustments for changing the external conditions - extra clothes, more shelter etc., - while adjusting, in order to feel better. In modern, environmentally sealed buildings, the occupants cannot make these adjustments as most of them are controlled through central units. In the workplace, the stress levels change during the day, but the building is often fixed. But sustainable building designs are more adaptive, allowing the user to adjust the space according to his/her physical and psychological needs (Edwards, 2001).

- **Economic Sustainability**

The initial cost of ecological and environmentally conscious intelligent high-rise buildings will be higher than conventional high-rise buildings, but because of its energy saving strategies, the high-rise buildings will cover its first costs in short period and become cost effective. The developments in material science will also shorten the construction period and the cost of the durable materials will decrease. The intelligent and ecologically responsive building has advantages such as reducing the amount of land use in ground level, decreasing the transportation costs, and energy use, and recycling the materials.
After brief description about the sustainability concept, in the following part one of the major components of IB design is discussed by formulating the basic design parameters for "environment-oriented" criteria.

3.2 Environment-oriented Design Criteria of IBs

An IB is the one that is responsive, adaptable and flexible to correspond to its users' needs, designed intelligently with regard to whole life-costs and adaptable to changing conditions. Technological developments prepared the ground for the emergence of IBs, but as stated by Derek Clements-Croome, technology alone doesn't make buildings intelligent; it is only a tool to help creating better working environments (Fletcher, 2004). Human-centered IBs shall be intelligent not only in terms of the selected "Technology-oriented criteria (systems, services and materials), but intelligent in terms of integrating User-oriented (physical, psychological, social and economic) and Environment-oriented criteria. In this section, selected Environment-oriented design criteria of IBs are defined by concentrating on three main design parameters (Table 3.1) which can be summarized as follows:

1. Building Orientation and Climate
2. Building shell
3. Building skin

In the following section, these three passive design criteria are explained with the relevant sub-parameters, and formulated as "Environment-oriented Design Criteria Matrix" (Table 3.2) which can be used as a generic design tool for IB design.

Table 3.1: Table for Environment-oriented Design Criteria of IBs.

ENVIRONMENT-ORIENTED DESIGN CRITERIA		
Building Orientation & Climate		
Climate	Cool Zones	
	Temperate Zones	
	Arid Zones	
	Tropical Zones	
Building form	Compact	
	Fragmented	
Core Location	Side	
	Central	
	Dispersed	
Building Shell		
Floor plate	Floor plate Area	
	Floor plate Depth	
	Floor plate Shape	
Structural planning	Structural Grid	
	Planning Grid	
	Sectional Height	
Plan Type	Cellular Plan	
	Open Plan	
	Landscape Plan	
	Combi-Office Plan	
Building Skin		
Natural Ventilation	Cross Ventilation	
	Operable Windows	
	Double Skin	
	Atriums	
	Sky-courts (Vertical Landscaping)	
Natural Lighting	Light wells	
	Passive Shading Devices	Louvre
		Blinds
	High Efficiency glazing	

3.2.1 Building orientation and climate parameters

The building orientation and form should reflect the cultural and climatic aspects of the region. In architectural space, this can be reflected in the floor plate configuration, the building's depth, the position and layout of entrances and exits, and movement pattern between the spaces. For example, in Germany privacy is the most dominant aspect of office culture, and the rooms open to a corridor as a plan scheme. This can be achieved by understanding the working patterns of the people and privacy/community arrangement in a particular culture.

3.2.1.1 Climate

The Köppen Climate Classification System is the most widely used for classifying the world's climates. Most classification systems used today are based on the one introduced in 1900 by the Russian-German climatologist Wladimir Köppen. He divided the Earth's surface into climatic regions that generally coincided with world patterns of vegetation and soils.

The Köppen system recognizes five major climate types based on the annual and monthly averages of temperature and precipitation. Each type is designated by a capital letter. This classification includes quantitative definitions for climate categories based on temperature and precipitation indices.

A - Moist Tropical Climates: are known for their high temperatures year round and for their large amount of year round rain.

B – Dry Climates: are characterized by little rain and a huge daily temperature range. Two subgroups, S - semiarid or steppe, and W - arid or desert, are used with the B climates.

C - Humid Middle Latitude Climates: in which land/water differences play a large part. These climates have warm, dry summers and cool, wet winters.

D - Continental Climates: can be found in the interior regions of large landmasses. Total precipitation is not very high and seasonal temperatures vary widely.

E - Cold Climates: are part of areas where permanent ice and tundra are always present. Only about four months of the year have above freezing temperatures (Heerwagen, 2008).

In general, the global classification of climatic zones is collected under four titles:

- Cool Zones
- Temperate Zones
- Arid Zones
- Tropical Zones

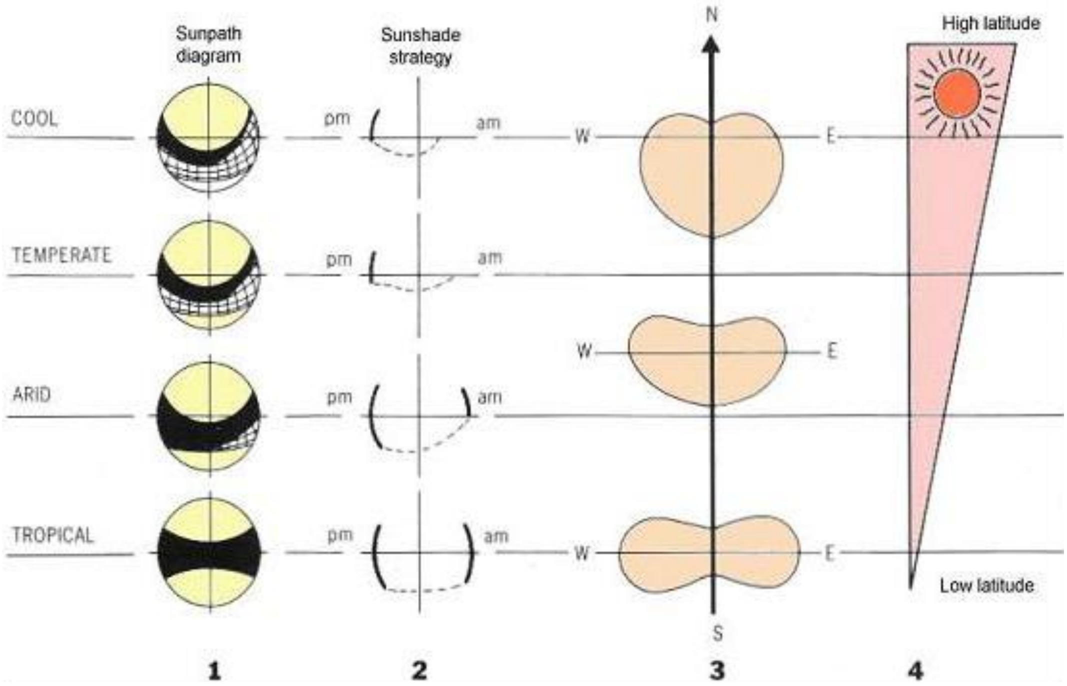


Figure 3.3 : Solar paths, sunshade, insulation and sun requirements, adapted from Heerwagen (2008).

In Figure 3.3, the shaded areas displayed in the first column represent the periods of overheating as a result of undesirable solar gain, and the diagrams in the second column show the optimum location of vertical sun shading, in order to protect the buildings from low sun angles in the morning and evening. Also horizontal sun shading displayed in the 3rd column should be used for preventing the high midday sun.

Tropical regions require both vertical and horizontal shading throughout the year. In cool and temperate zones, horizontal and vertical shading is only needed during the summer on the south facade. As it can be followed in the 4^{th} column, while moving from the lower latitude to upper latitude, the need for solar heating increases while the need for solar shading decreases.

3.2.1.2 Building form

In relation to building form, there can be two design strategies to achieve a minimum energy impact:

- **Compact:** Minimize surface area and use compact building form to reduce the heat losses. By this way, both the building materials and energy requirements will be reduced.
- **Fragmented:** The use of shallow plan form can maximize the amount of natural lighting and ventilation (McElroy, 1996). This second alternative is the most prevalent design approach in tropical and arid zones.

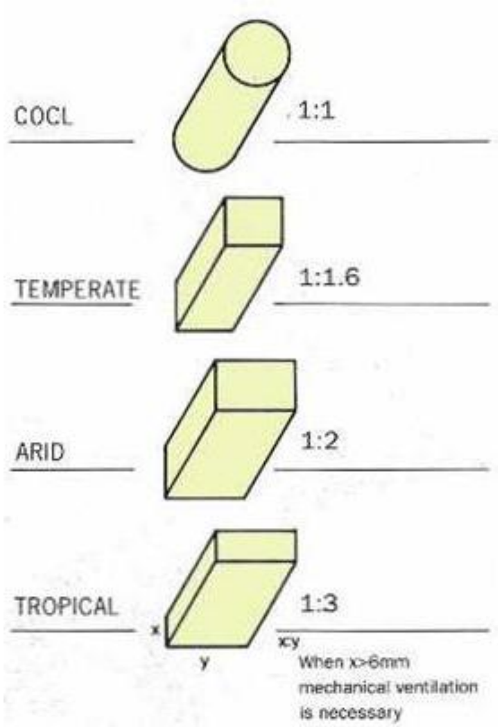


Figure 3.4 : Optimum Building form for each climatic zone, adapted from Yeang (1999).

The preferred length and width of the buildings in different climatic zones compared in Figure 3.4 can be summarized as follows:

In the Tropical and Arid Climates: Elongated Form should be preferred to minimize east and west side solar exposure.

In the Temperate zone: More compact and reminiscent to square forms are convenient.

In the Cool zone: cylindrical form or square form is more convenient.

3.2.1.3 Core location

The building cores will determine about which parts will be openings and which parts will be solid external walls. The core locations can be designed in a manner to provide shade or retain heat within the building form. In general, the most convenient core locations for different climate zones are as follows:

The Tropical zone: The cores are located on the east and west sides of the building form in order to shade the building from the low angles of the sun during the daytime.

The Arid zone: The cores should also be located on the east and west sides for serving shading purposes during the summer.

The Temperate zone: The core should be located on the north side in order to leave the south facade available for solar heat gain during the winter.

The Cool zone: The core should be located at the center of the building mass so that the maximum perimeter of the building can benefit from solar heat.

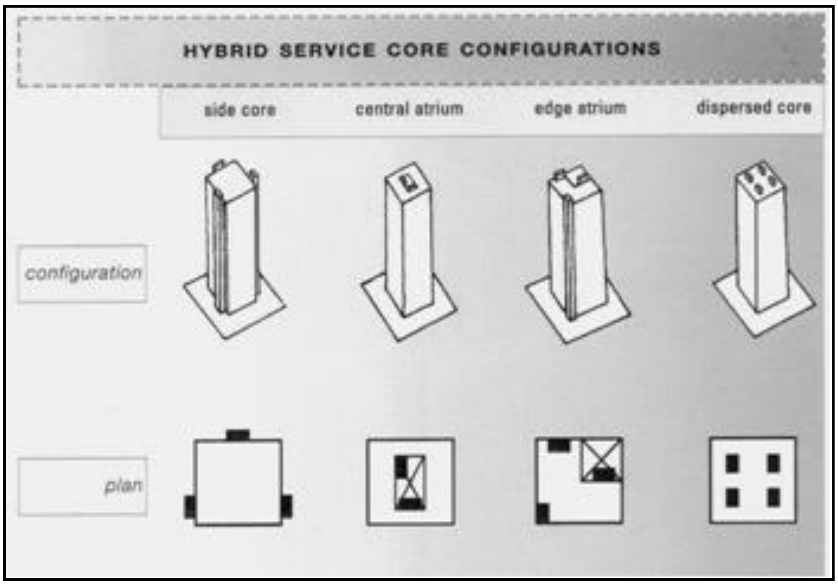


Figure 3.5 : Hybrid service core configurations and plans, adapted from Yeang (1999).

K. Yeang orients the main openings to north and south while designing in Malaysia, which has a high stable temperatures and humidity. The hybrid service core configurations and their formulated plans are shown in Figure 3.5. The sun shading devices and the service core are split on east and west facades for thermal buffering. By locating the lift lobbies, stairs and toilets on the outside, natural ventilation will be provided for these spaces (Evans, 1994). In Figure 3.6, the zoning for transitional spaces and solar gain in relation to cool, temperate, arid and tropical climate areas are compared as follows:

In the tropical and arid zones: The solar heat gain will be from east and west sides.
In the temperate and cool zones: The solar heat gain will be from south side.

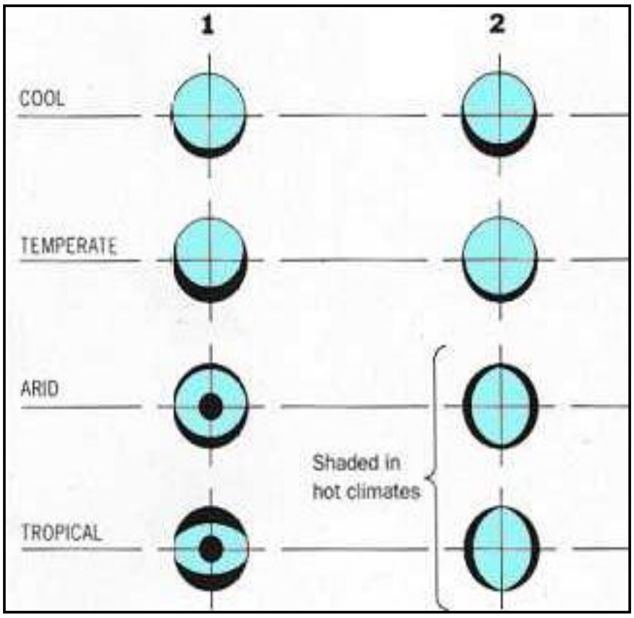


Figure 3.6 : Zoning for Transitional spaces and solar gain, adapted from Url-8.

The most effective design for core locations together with the building orientations are shown in Figure 3.7.

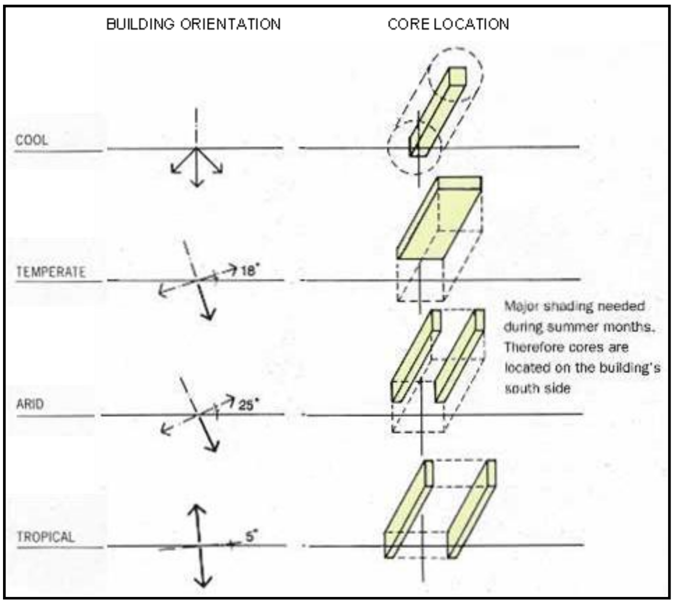


Figure 3.7 : The main building orientations and core locations, adapted from Yeang (1999).

3.2.2 Building shell parameters

The description of office building shell is based on three elements: "the location of the core in relation to the shell"; "the position of major circulation routes"; and "the depth of office space".

Francis Duffy developed his doctoral research into a model of finding affinities between features of office shells and different organizations (Duffy, Cave & Worthington, 1976). This study revealed for the first time the complex link between the static container shell and the dynamic layout contained, which expresses different organizational ideas. The static shell of office building is designed to withstand changing requirements of organizations during the entire lifetime of the building, and the flexible scenery and sets vary periodically according to requirements of organizations (Shpuza, 2006). As it can be seen from Duffy's study, there exists a tension between static nature of the building shell and dynamic nature of the office layout, and the successful office buildings are the ones which can reconcile these two aspects. The most important parameters for Building shell design are: "floor plate area, shape and depth", "sectional height", "structural grid", "sectional height" and "planning type". A brief explanation for these parameters is given in the following sections.

3.2.2.1 Floor plate

- **Floor plate area**

The floor plate area can be associated with quantitative aspects of number of workstations, construction and maintenance costs, and value. The floor area determines which functions can be accommodated in buildings.

According to IBs in Asia study, the optimal floor plate size is between 2000-2500 m^2 for most flexible arrangements.

- **Floor plate depth**

The modular methods take into account dimensional aspects of shape by weighing the configuration analysis with metrics of size and distance which are essential for influencing fitted layouts, for instance, the depth from core to perimeter, as shown by Duffy determines what kind of layout can occupy a part of floor plate (Shpuza, 2006: 90).

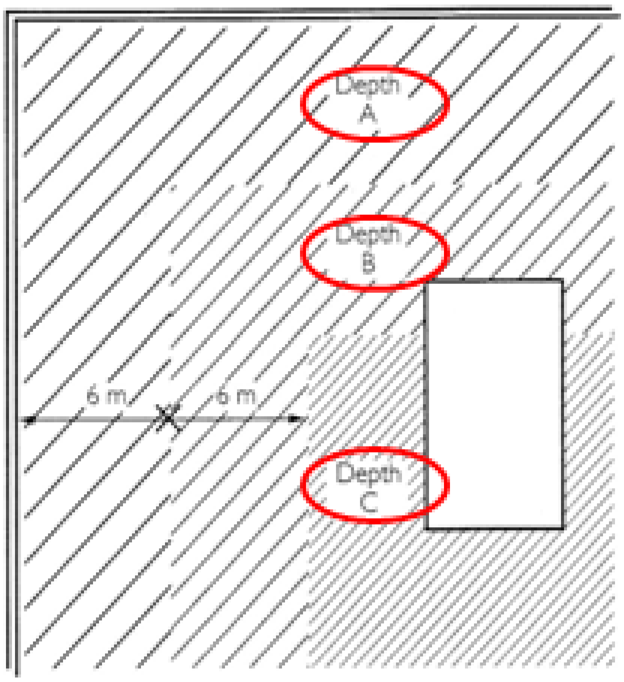


Figure 3.8 : Floor plate depths of A, B, and C types proposed by DEGW, adapted from Harrison et al. (1998).

DEGW identified three types of depth for floor plate as shown in Figure 3.8 which are:

- **Depth A**: NIA (Net Internal Area) within 6m of external or atrium walls. This type is convenient for cellular office arrangement.
- **Depth B:** NIA within 6-12m of external or atrium walls. Suitable for open plan workstations, internal closed offices and support functions.
- **Depth C:** NIA deeper than 12m of external or atrium walls. Suitable for support functions or special uses such as computer rooms. (Harrison et al, 1998)

- **Floor plate shape**

The floor plate shapes, as the key aspect of office buildings, affecting internal organization of office layouts. Office layouts are affected from the organizational criteria but they are also inseparable from building shell.

The shape of an office floor plate can be defined as "the area of the usable space bound by the building perimeter, where atria and cores have been removed" (Shpuza, 2006: 13). The floor plate shape is mainly related to qualitative aspects of the building. In between two buildings with the same floor area, the one with elongated floor plate provides an added value to activities that rely on proximity to perimeter, whereas, the one with a compact floor plate is more convenient for functions which require energy conservation, enclosure and proximity between locations. In contrast to measurement of floor plate area, there are no exact and implicit ways of describing shape, specifically with regard to distances contained in the shape (Shpuza, 2006).

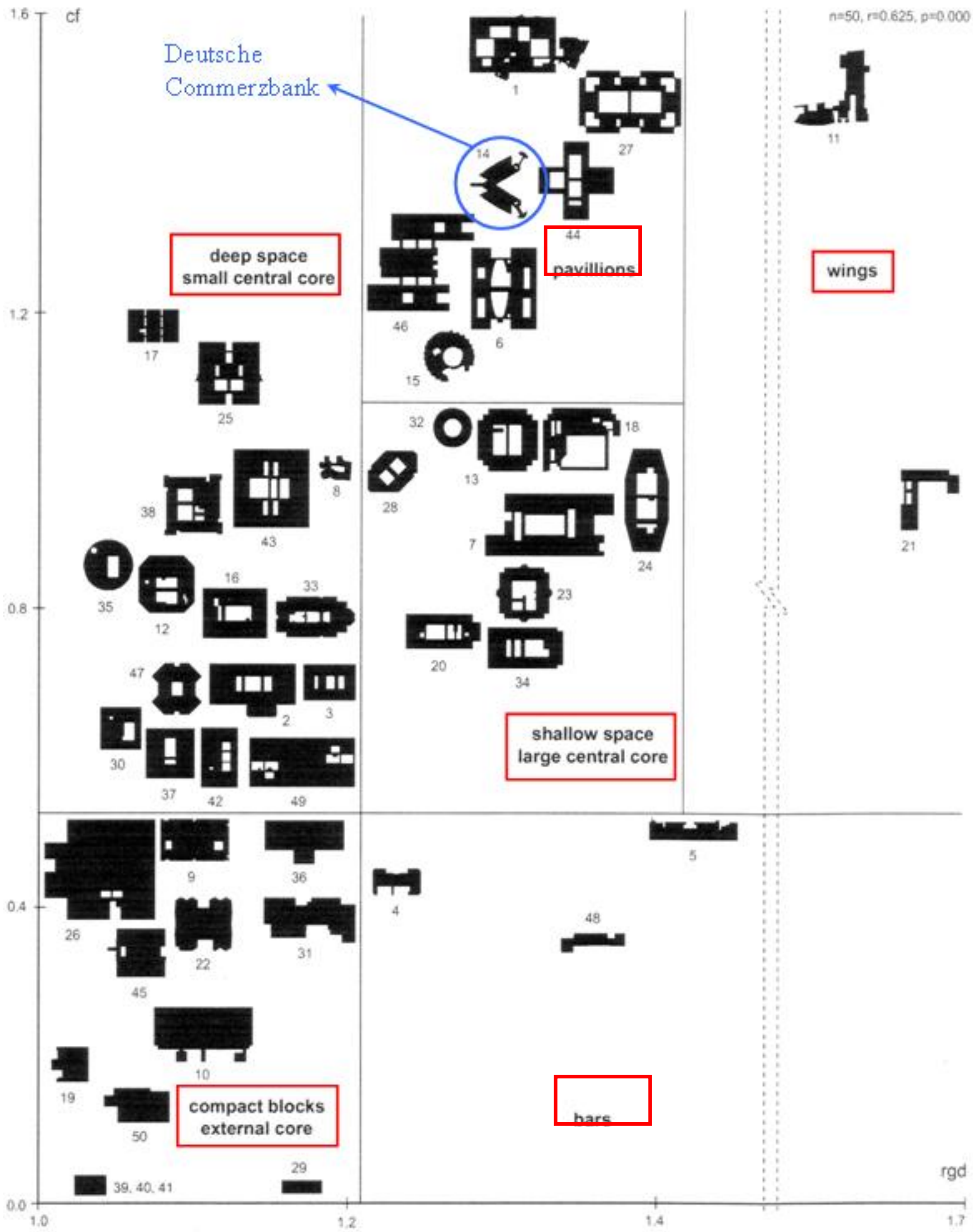


Figure 3.9 : Fifty Buildings floor plate categorization in relation to six floor plate types, adapted from Shpuza (2006).

According to floor plate study done by Shpuza (2006), there can be formulated six floor plate shapes formulated through fifty floor plate analysis (Figure 3.9):

1. **compact blocks external core*:*** floor plates with compact shapes and those with external cores and a few and small internal cores;
2. **bars**: floor plates with elongated rectangular shapes and external cores.
3. **deep space small central core:** floor plates with internal cores where dimensions of cores are relatively small in comparison to the depth between core and perimeter;
4. **shallow space large central core:** floor plates with ring-like configurations of shapes with large holes, which correspond to large cores in high-rise buildings, central atria and internal courtyards;
5. **pavilions*:*** floor plates with distinct pavilions and floor plates with many large internal cores or atria;
6. **wings:** elongated floor plates broken into distinct wings (Shpuza, 2006).

3.2.2.2 Structural Planning

- **Structural Grid**

The structural grid of the building should be a multiple of the internal planning grid so that the ceiling, partitions and other building elements can be tied. Generally in the office space no columns are planned and the structural grids are covering large spans, which will increase the dimensions of the structural members as well.

- **Planning Grid**

The planning grid should guide the structural as most of the building systems such as partitions, raised floors, lighting and diffuser layouts will be arranged according to this grid. In the *IBs in Latin America* study, DEGW/Technibank/Northcroft (1999) has confirmed that the planning grid of 1.5 m (Figure 3.11) is the most flexible one.

- **Sectional Height**

The sectional height of the building is one of the key determinants for providing flexible and adaptable IBs. It affects the design of the building systems such as HVAC, lighting, data cables, etc. In deep floor plates, it is also important for the visual comfort of the occupants. IB Asia research team reached to this optimization for sectional heights:

Glass to glass depth of 13 m**: 3.6 m-4.5 m** slab to slab height

Glass to core depth of 6-12 m: **3.8 m-4.5 m** slab to slab height

According to the IB in Europe (IBE) Study, slab to slab height of 4-4.5 m is recommended for providing flexible space for the building services (Harrison et. al., 1998).

In deeper buildings sectional height is specifically important for the visual comfort of the occupants. It is closely related to the structural system of the building.

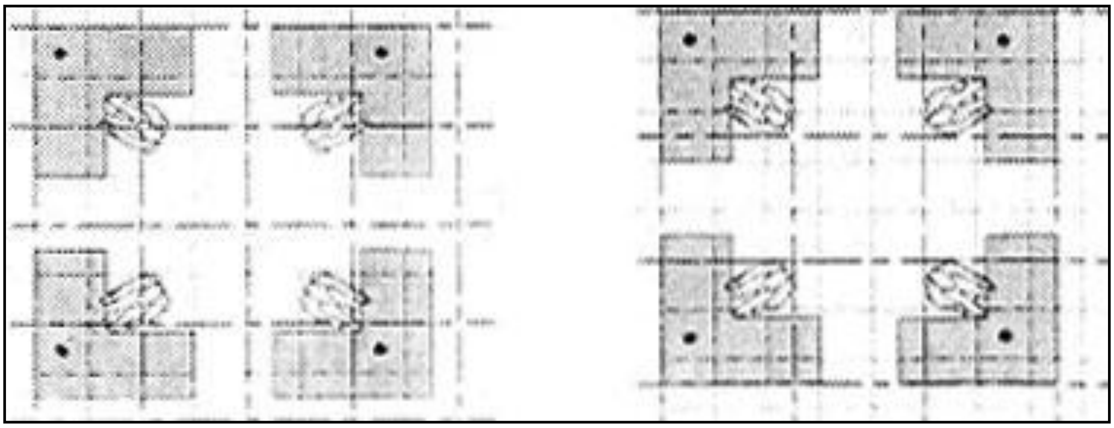


Figure 3.10 : The workspace planning grids for 1.2m and 1.5m, adapted from DEGW et al. (1999).

3.2.2.3 Plan Type

The floor plate shapes are important for generating office layouts, which consist of the design principles of two different natures: organizations and building shells. There exists a problem when the shell properties do not coincide with organizational requirements, as the layouts of the workplace will not serve properly for tasks to be achieved.

In the thesis study, F. Duffy's office plan types (Figure 3.11) are used in which he categorizes layouts as follows:

- Cellular Office
- Open Plan Office
- Landscape Office
- Combi-Office.

The model produced by Duffy in Figure 3.11, relates to the sociological dimensions of organizations to physical properties of office layouts and their relationship to one another is measured in a quantitative way.

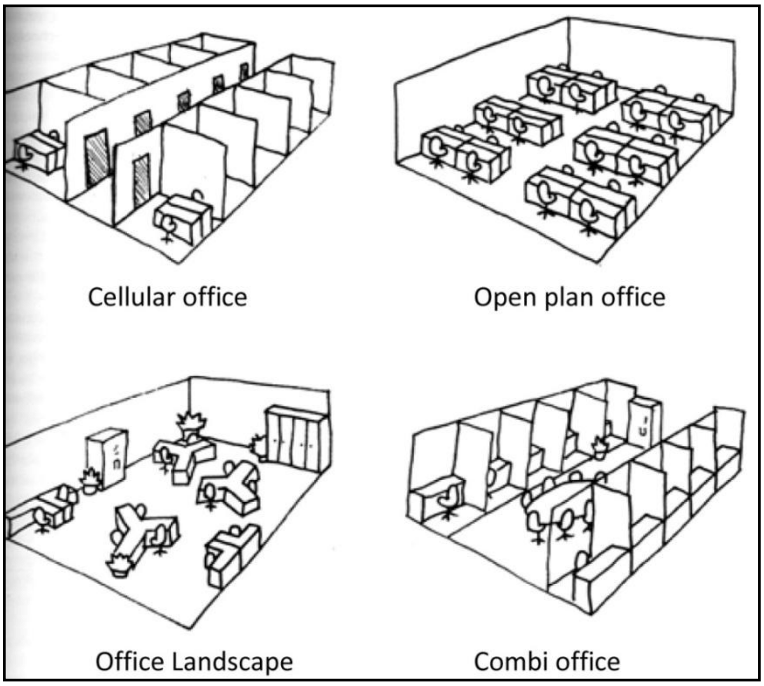


Figure 3.11 : Principles of different office concepts, adapted from Van Meel et al. (2000).

His study suggests, both a *descriptive* and *analytical model* for office shells, and, *normative guidelines* for understanding what kinds of layouts for office organizations are suitable to occupy certain shells or parts of them. This model also includes the description of shells and the categorization of layouts (Shpuza, 2006).

3.2.3 Building skin parameters

Building skin is an important design parameter of an IB which needs to be highly adaptive and responsive to changing exterior and interior conditions, and provide energy savings**.** It acts as a filter between the indoor and outdoor environment conditions rather than a passive barrier. This IB skin has to regulate water, humidity, air, sound, light, view, heat, fire, pollution, safety and security.

In most of the IBs, there exists a Building Management System (BMS), which monitors the external conditions and overrides when the natural heating and ventilation is not convenient such as stormy weathers or high external pollution. The most effective solution is the mixed-mode (including both active and passive systems) use for providing a responsive, adaptive and flexible IBs integrating environment-oriented and technology-oriented design criteria. The responsiveness and adaptability of the intelligent skin can be provided by combining Technology-oriented design criteria such as automatic facade control systems and Environment-oriented design criteria such as “natural ventilation”, and “natural lighting” which are explained in the following sections.

3.2.3.1 Natural Ventilation

One of the most energy consuming systems of IB is heating and cooling loads. The active systems can be supported by passive design criteria of natural ventilation by implementing “cross ventilation”, “operable windows” “double skin”, “atriums” and “sky-courts (vertical landscaping) which are briefly explained as follows:

- **Cross Ventilation**

A good air movement provides heat emission from the human body, and gives a feeling of comfort, even in air-conditioned spaces. Sky-courts, balconies, atriums of high-rise buildings will direct wind flow into internal spaces. Side ventilations capture the wind and use it in a most efficient way as it can be seen in Ken Yeang’s bio-climatic skyscrapers. This wind can be channeled into ceiling plenums to ventilate inner spaces as well (Yeang, 1999).

Cross ventilation is far more important in the tropics than in temperate zones. The theoretical strategy for blocking or inducing wind flow into a building is based on local *prevailing wind conditions*. The cross ventilation requirements of the buildings will depend on the climate zone of the building. For example:

- Tropical zones, require as much ventilation as possible.
- Arid zone, also requires cross ventilation, but high-velocity winds should be filtered out.
- Temperate zone, both cross ventilation and shielding is necessary (for summer and winter, respectively) in buildings.
- Cool zone, should be protected from cold, high-velocity winds, although cross ventilation is still required.

- **Operable Windows**

Operable windows that provide flexibility of the user to adjust his/her comfort conditions by passive ventilation; cooling, etc. increase the productivity of the user in the workspace. The building facade has to provide the necessary thermal protection in winter as well as in summer, glare-protection, lighting and contact to the outside. But, if the user is given the opportunity to regulate his/her work environment, it contributes enormously to the comfort and productivity, and energy savings by using passive systems by automatically de-activating the mechanical systems.

- **Double Skin**

The double skin is a system that consists of a second glazed envelope, which can maximize daylight and support energy performance. During the summer time, the double facade reduces the solar gains and heat loads of the buildings can be lessened by ventilated cavity. There will be a natural "stack effect" and absorbed solar radiation through glass, structure and blinds can be re-radiated. During the wintertime, the double facade will act as a buffer zone between the building and the outside by minimizing heat losses (Wigginton et al., 2002). The space between the double glasses forms a transition zone between exterior and interior having heat, light, and air transfer capabilities. This double glazing can:

- act like a well-insulated wall;
- use solar energy for temperature control;
- provide air movements for ventilation purposes;
- react to the changes of the environment and interior space by changing transmission characteristics of the glass acting as an intelligent skin.

The four basic double skin typologies identified by K. Harrison (2003) are as follows as shown in Figure 3.12:

- **Buffer facade:** consists of two layers of glazing mounted approximately 250-750 mm apart, with the air space between the two layers sealed.

- **Extract-Air facade:** consists of a main double-glazed skin of insulating glass with a second single-glazed skin placed inside. The air space between the two layers of glazing becomes part of the HVAC system. The heated used air between the glazing layers is extracted through the cavity with the use of fans. This system is used when natural ventilation is not possible because of high noise, wind or fumes. The shading devices are mounted within the cavity.

- **Twin-Face facade:** consists of a conventional curtain wall or massive wall system with an outer skin of single glazing. The internal skin provides insulating properties to minimize heat loss and the outer skin protects the shading devices from weather conditions. The windows in the interior façade can be opened allowing for natural ventilation differing from extract-air facade. The night time cooling will help the lessening of the loads of HVAC system.
- **Hybrid facade:** consists of the combination of one or more of the basic characteristics of the aforementioned typologies to create a new hybrid system.

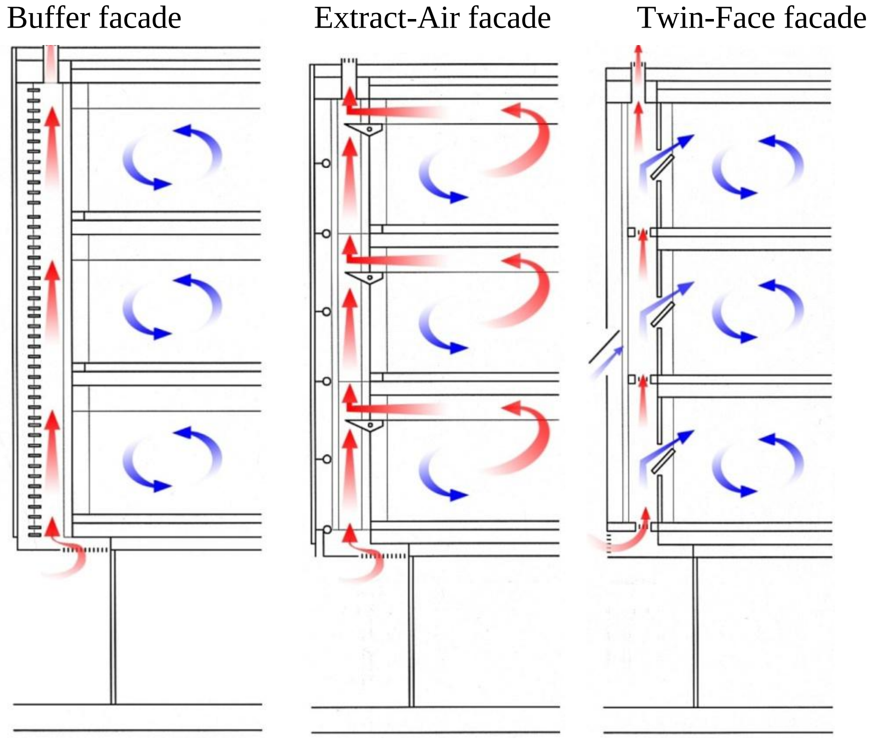


Figure 3.12 : Double skin types, adapted from Harrison (2003).

- **Atriums**

Enclosed central courtyar**ds** and atriums can be used as intermediary spaces to bring fresh air and to provide natural heating. These spaces can be used for maximum daylight penetration and cross-ventilation as well. These air movements can be provided by temperature and pressure differences between inside and outside.

The preferred atrium locations in different climate zones are shown in Figure 3.13:

- In tropical zones: The atrium should be located both at the center and at the corners of the building for ventilation purposes.
- In arid zones: The atrium should be located at the center of the building for cooling and shading purposes.
- In temperate and cool zones: The atrium should be located at the center of the building form for heating and natural lighting purposes.

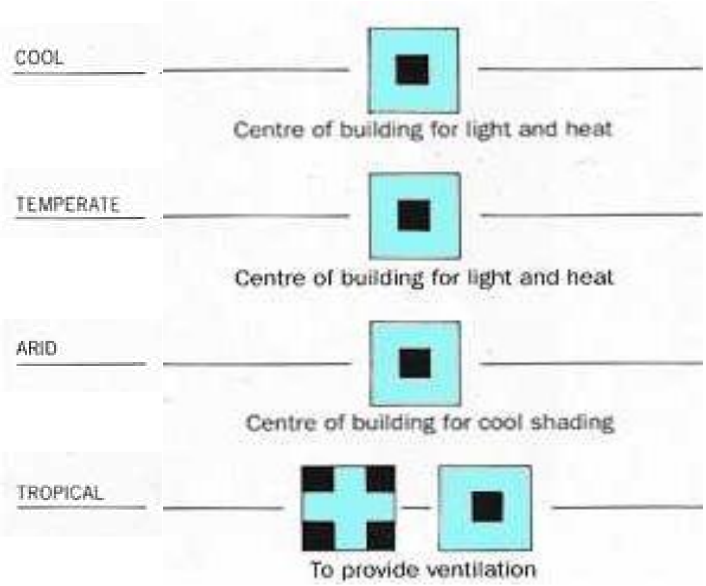


Figure 3.13 : Atrium Locations in different climate zones, adapted from Url-8.

- **Sky-courts (Vertical Landscaping)**

Deep recesses may provide shade on the building's hot sides. These spaces can be in the form of balcony (Figure 3.14), or large terraces for planting and landscaping. In these sky-courts and terraces, vertical landscaping should be used for their cooling function together with their ecological and aesthetic benefits. For the high-rise buildings, planting can be achieved in vertical landscaping and inner sky-courts.

The vertical landscaping can help to produce ecologically, socially and aesthetically defined high-rise buildings by helping the fusion of indoor and outdoor spaces. The horizontal ecological corridors of the city can be continued as vertical ecological corridors flowing upwards to all levels of the high-rise building (Yeang, 2002).

In the high-rise buildings, large green spaces equivalent to parks may be in the form of larger trays or a series of stepped gardens. In temperate climatic zones, the sun path is generally southwards and the greenery is best located in the south facade. Conversely, in the tropic climate, the greenery would be on the east and west facades and on the roof (Yeang, 2002).

In the design of the high rise buildings, sky-courts can be effectively used for the natural ventilation of the building by reducing cooling loads. Planting systems could be implemented into high-rise buildings to reduce the need for mechanical ventilation and by this way reduce energy consumption. Interior gardens could also produce breathable oxygen to occupants of the buildings.

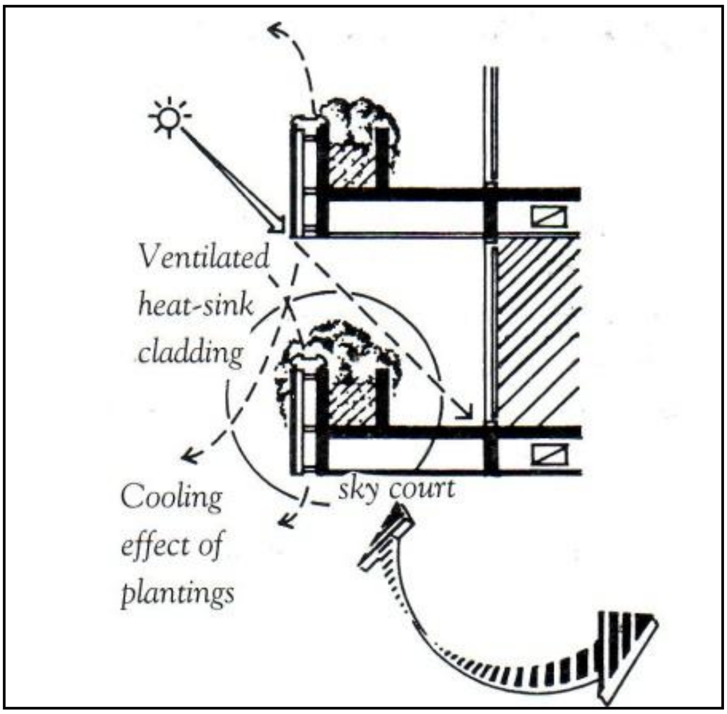


Figure 3.14 : Balconies with ventilated-heat sink cladding and planting, adapted from Powell (1989).

3.2.3.2 Natural Lighting

Natural daylight provides a feeling of well-being if the occupants have direct control over its quality and quantity (McElroy, 1996). Whenever the users are given certain level of control for their working environment, the productivity and effectiveness of the workers increases.

It is a fact that large glass surfaces without shading increase the summer heat-gain and radiation of the building. By using special type of glasses such as *thermo-photo* and *electro-chrome*, the radiation intensity can be changed by converting transmission characteristics.

In this study, there are taken three major design parameters for natural lighting which are as follows:

- **Passive shading devices**

During the summer time, the solar gains should be minimized by the help of shading devices and these devices can be adjusted by control systems as well.

Solar shading needs to be provided for glazed facades facing the sun. These shading devices prevent over heating of the building both in tropics and temperate zones. These shading devices can be blinds, louvers, and light shelfs.

The light shelf is a conventional design item, which has been re-discovered again shading the spaces from excessive solar gain. It also reflects the diffused daylight into interior space.

- **Light wells**

The light-wells pull warm air out of the building during the summer time and warm the building in the winter using passive solar heating. Also, they allow sunlight to pass through the building, making the work environment more pleasing, and keeping the lighting costs down.

- **High-efficiency Glazing**

High efficiency glazing should be designed in an intelligent and dynamic way which can automate change with outside environmental conditions. High efficiency glass consists of a series of efficiency multi-layers which become the key role in managing heat gain, heat loss, sun protection, glare protection and moisture penetration (Arnold, 2009).

The energy and indoor climate efficiency for a glazing building is very dependent on the climate and the design of the façade. The variety of technological solutions used to produce high efficiency glazing facades are based on fundamental building physics concepts for insulation, shading, day lighting, ventilation, space conditioning and energy production.

The following descriptions are therefore related to high efficiency glazing fundamental concepts:

- Integration with Insulation System;
- Integration with Sun Protection System;
- Integrated with Day lighting System;
- Integration with natural ventilation system;
- Integration with harvesting solar energy system;
- Integration with wind energy system;
- Integration with heating and cooling system (Xhang, 2009).

3.3 Evaluating Environment-oriented Design Criteria on Seven IBs

In this section, the Environment-oriented IB Design Criteria such as: "Building orientation and climate", 'Building Shell", and "Building Skin parameters" are analyzed by reviewing the selected seven office buildings from different parts of the world.

The purpose of reviewing these buildings is to establish a common basis for design parameters of IBs. These buildings are selected as they are considered to take into account the environment-oriented design criteria which are categorized under three parameters: "building orientation and climate", "building skin" and "building shell".

For a responsive, adaptive and flexible Human-centered IB design, to cope with the changing user requirements is the primary target to be achieved. Environmental design criteria have a direct impact on physical, psychological, social and economic requirements of the user. For example, if we focus on "natural ventilation" and "natural lighting" design parameters under the "building skin", they have got direct impact on the spatial, thermal, air quality, aural and visual quality of the physical space of the user.

The researcher correlates the environment-oriented design criteria with user-oriented and technology-oriented design criteria through the checklists prepared for Human-centered IB design in Chapter 5. There is also a correlation matrix displaying the impact of environment-oriented design parameters on the user requirements (physical, psychological and social, economic) in Table 5.2.

After reviewing the selected seven buildings, the passive design parameters based on environment-oriented criteria is tabulated in as a checklist which can be used as a common design basis for other IBs. The selected buildings are belonging to a period between 1997- 2010.

The selected seven building that are reviewed and formulated in a checklist for "Environment-oriented Design Criteria" are:

1. **Commerzbank Headquarters**, Foster and Partners, Frankfurt, 1997
2. **RWE Headquarters Building**, Ingenhoven Overdiek and Partner, Essen, 1996
3. **30st Mary Axe / Swiss-Re Headquarters Building**, Foster and Partners, 2004
4. **Condé Nast Building**, Fox & Fowle, New York, 1999
5. **Menera Bousted**, Ken Yeang, Kuala Lumpur, 1983-1987
6. **Menara Mesiniaga**, Ken Yeang, Kuala Lumpur, 1992
7. **Elephant & Castle Eco-Tower**, Ken Yeang, London, 2010.

In order to check these design parameters, Building Rating Method (Appendix A: 265) can be implemented to these buildings, and results can be compared for checking the generalizations for IB design model. But it is not within the scope of this thesis study to do a post-occupancy evaluation for building users and work organizations.

In this building review and analysis section, it is not aimed to benchmark the selected buildings with each other in terms of performance or better functioning. The selected buildings are only used for formulating the list of common environment-oriented design basis criteria for Human-centered IBs.

Among these buildings, Deutsche Commerzbank Headquarters has been selected for testing the design parameters proposed for Human-centered IB design in the second phase of correlation matrices formulated as checklists in Chapter 5. The reason behind the selection of this building is mainly the extensive Post-Occupancy Evaluation studies and available information.

3.3.1 Commerzbank Headquarters, Foster and Partners, Frankfurt, 1997

In 1991, an international architectural competition was held for Commerzbank Headquarters Building, in Frankfurt. It has been previously occupied approximately in 30 buildings and changes in the banking business made it desirable to bring the employees together under one roof to improve communication and promote creative teamwork (Davies et al., 1997).

Many architectural critics have praised this building for its environmental responsiveness. “What Foster and Partners have achieved is nothing less than the reinvention of the skyscraper”. Foster and Partners is said to have talked about the importance of social and environmental responsibility, but have never delivered that message more clearly than with this design (Buchanan, 1998).

Figure 3.15 : Commerzbank Headquarters view and sky-gardens, adapted from Davey (1997a).

The vertical sky gardens (Figure 3.15) become the bioclimatic, visual and social focus and it is among the first of a new generation of environment-oriented high-rise buildings. Commerzbank Headquarters is important not only for its environmental concerns, but also important for its approach to office environment and workspace design.

3.3.1.1 Building orientation and climate parameters

- **Climate:** Temperate
- **Building form:** “petal and stem” system

The building form consists of three petals containing the offices and there exists a central atrium stretching from the ground floor to the top of the building. The triangular form smoothed with curved sides is used to improve the efficiency of the space.

- **Core Location:** Side

Triangular floor plan arrangement consisting of a central atrium and three service core at each corner (Figure 3.16).

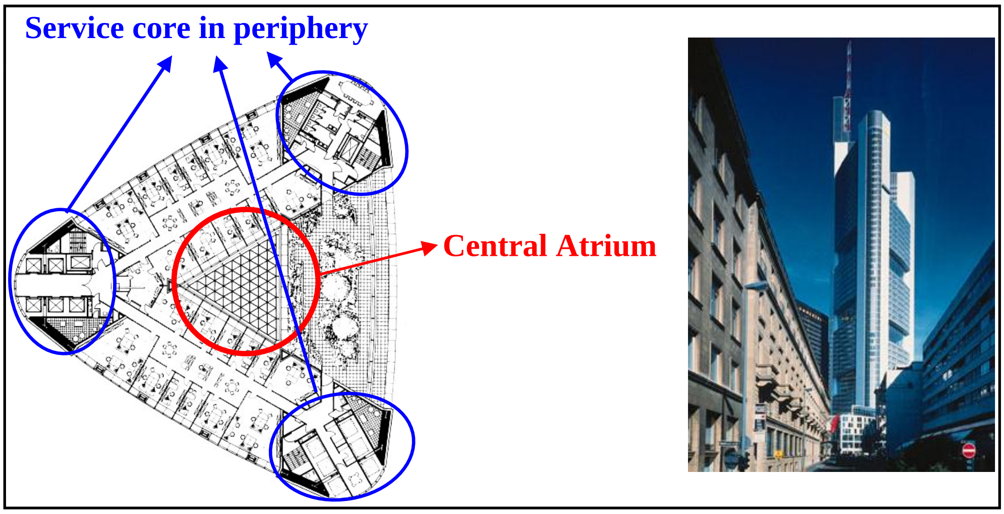


Figure 3.16 : Commerzbank Headquarters floor plan and exterior view, adapted from Höweler (2003).

3.3.1.2 Building skin parameters

- **Natural Ventilation**

There exists a BMS, which monitors the external conditions and overrides when the natural heating and ventilation is not convenient such as stormy weathers or high external pollution. The major components of Natural Ventilation examined in Commerzbank Headquarters are as follows:

Cross Ventilation: The central corridors of each floor will be served by a mechanical air supply and exhaust system at all times. Only in the middle of the seasons is the building also automatically sealed and air-conditioned.

All night-time cooling (Figure 3.18) in the summer is through natural ventilation, reducing energy demands. In the heat of summer, offices are cooled by water-based chilled ceilings and in winter conventional convectors under the windows.

Operable windows: Every office in the tower takes daylight and has operable windows (Figure 3.17), resulting in energy consumption levels equivalent to half those of conventional office towers. The different states of operable windows cannot be seen from outside because of the double facade.

The natural ventilation strategy allowing the user to arrange his/her comfort conditions provide both healthy and energy conscious environmental control (Davey, 1997a).

Figure 3.17 : Operable windows allowing natural ventilation with double skin, adapted from Davey (1997a).

Double Skin: A double-layered facade that intercepts the rain and breaks the force of the wind allows even the exterior facing offices to be naturally ventilated. For most of the year the building relies on natural light and ventilation alone during daylight hours. The double skin consists of two layers of glass with a 200 mm ventilation cavity in between them (Figure 3.18).

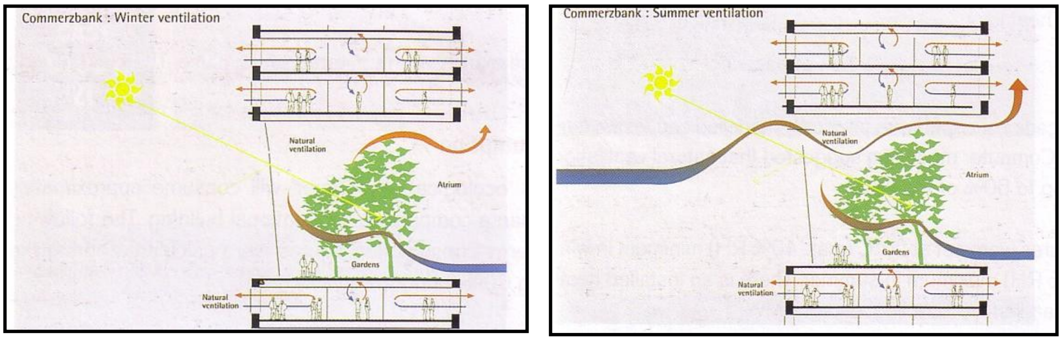


Figure 3.18 : Winter and Summer time ventilations, adapted fromWigginton et al. (2002).

The outer layer is a fixed sheet of glass and the inner one is a low-e double glazed unit, which can be opened inwards at the top. Within the cavity, anodized aluminum Venetian blinds with 50 mm blades are used in summer, which can be inclined to reduce excessive solar heat gain; in winter can be adjusted to reflect sunlight upwards to ceiling by BMS.

The special aluminum transoms at the bottom and top of the fixed panels allow air to enter and leave the cavity. By this way, the hot air of the office space can be evacuated through open windows (Davey, 1997a).

Atrium: The atria in the central part bring daylight and fresh air and acts as a natural convection chimney for the interior facing offices.

Sky-courts (Vertical Landscape): The 14 m high screens shielding the sky gardens can open at the top to control the microclimate and balance the fresh air intake. The vertical gardens act as solar collectors and thermal buffers (Figure 3.18). They are kept at minimum temperatures of 5°C, warming by the exhaust air from the offices and under floor heating.

Four-storey sky gardens, set at different levels on each of the three sides of the tower, are the visual and social focus for offices. Every four stories the garden level rotates to the next facade and this spiraling continues till the roof level. The gardens are designed as places to relax and socialize, bringing richness and humanity to the workplace, and from the outside they give the building a sense of transparency and lightness.

The creation of social interaction spaces through sky gardens is one of the most important contributions of the building in addition to ecological sustainability.

- **Natural Lighting**

According to German regulations, the occupants should be no more than 7 m away from a window, which has been achieved in Commerzbank with 16.5 m floor plates that can be naturally lit and ventilated from both sides. The major components of Natural Lighting parameter examined in Commerzbank Headquarters are as follows:

Passive Shading Devices: The amount of natural light intake will be determined by the intelligent computing system that is specifically designed for Frankfurt. Each window includes a motorized blind for solar shading that permits the occupant control as well.

Energy efficient lighting with dimming control in response to daylight is used throughout the building. Responsive lights support BMS**,** which automatically turns off the electric lamps when there is no movement.

Light wells: The central atrium acts as a light well for natural lighting for the offices facing to interior. Also massive quantity of light is taken from sky-courts and transferred into central part.

High-efficiency Glazing: The windows facing the atrium consists of insulating glass, and the windows facing the outer face are double glazed (low-e coating) with a third protective pane providing a cavity for ventilation.

3.3.1.3 Building shell parameters

- **# of Floors:** 56 floor
- **Net Floor Area:** 85,503 m^2 (GFA=121,000 m^2)
- **Structural Planning**

Structural Grid: The structural grid incorporates both steel and concrete structure, and there are six vertical supports, two at each corner of the triangular plan. The structural system allows the office floor plates to bridge over the sky gardens and create an interior space that is free from columns. This will provide a great flexibility for different organizational arrangements in the future (Wigginton et al., 2002).

The triangular-shaped plan provided the rigid structural support that is only provided by an equilateral triangle. At each corner of this triangle, the cores are located providing the vertical load support for the entire structure. Eight floor deep, Verendeel are used for the structure to span the gardens between the core vertical load members. The building's structural layout is closely integrated with the spatial qualities of the office space and garden. It has a rounded equilateral triangular plan (Figure 3.19). All of these structural elements are wrapped around a central void allow the building's structure to carry loads like a tube, a very efficient method for forming a structure (Url-9).

Planning Grid: Floor plan of the tower is equilateral triangle and each side is approximately 64 m with rounded corners. Each floor has three wings two of which serve as offices and one wing as a garden. There is a flexible planning grid consisting of combi-offices based on the geometry of the wings.

Sectional Height: Slab to slab height is 3.80 m

The three sections on each arm of the plan are reserved for office space and one section devoted to the sky garden at every floor. This leaves a central triangular atrium in the middle that run the height of the building, only separated by steel and glass diaphragms every twelve floors.

The atriums serve as the airshafts that connect airflow between sky gardens. The central atrium of the building was a major part of the sectional development.

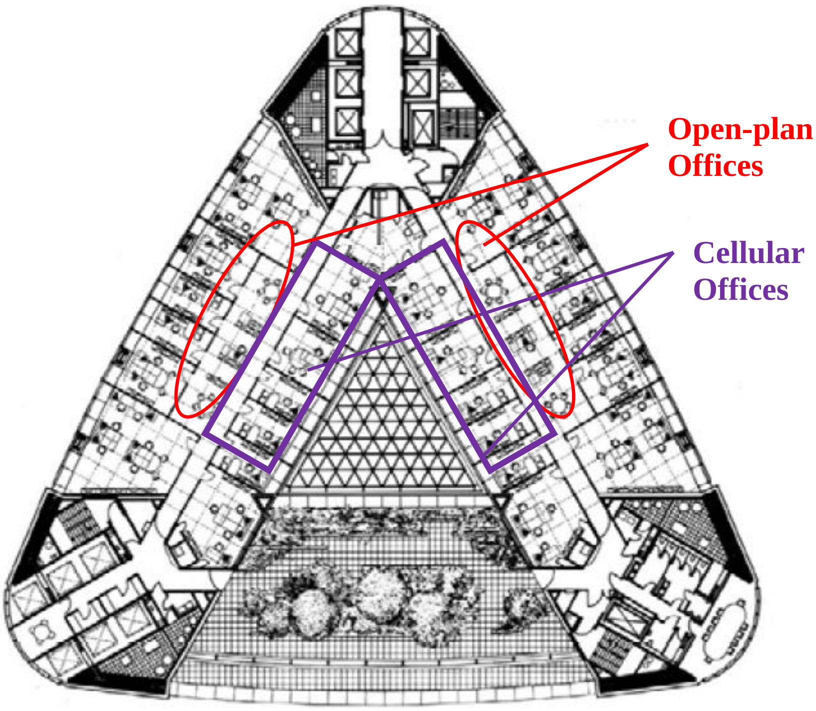


Figure 3.19 : Typical Floor Plan and office layouts of Deutsche Commerzbank, adapted from Höweler (2003).

This space was free of structural members except the ones used to frame the skylights which divide the building up into sections vertically. It was essential to have minimum structural intrusion into this space because it provided light both vertically, from the glass roof at the atrium's top, and horizontally, from the winter garden facades to the office across the atrium.

Each twelve floor is further divided into sections of four floors (Figure 3.20). Each section holds a four level high open sky garden that changes orientation from one arm of the triangle to the next at every section, spirraling the height of the building until it reaches the top of the building on the 60th floor.

- **Floor plate**

Floor plate Shape: Pavillion

The two sides of the triangle that embrace the sky-court and the atrium provide an L-shaped configuration stretched into a 60 degree angle. The layout type is matching with "combi-office" concept while the circulation between two bands of private rooms widens to allow for teamwork round tables and filing.

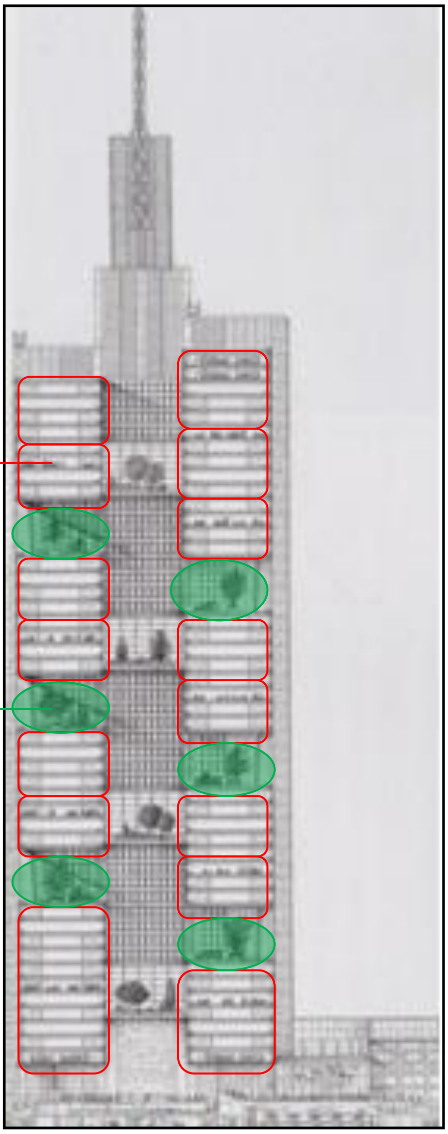


Figure 3.20 : Section from Sky gardens and atrium, adapted from Höweler (2003).

Floor plate Depth: Depth C (> 12 m)

The depth of the floor plate is 16.5 m which can be naturally lit and ventilated. It can be categorized as Depth C as per types produced by DEGW

- **Plan Type:** Combi-office

The flexible office spaces aligning on the two sides of the each sky-garden with a corridor arrangement is a typical office design for German culture giving high priority to individual cellular offices (Figure 3.19). But there is also open plan team areas combined with the cellular arrangement, which is a new concept to Germany (Wigginton et al., 2002).

3.3.2 RWE Headquarters, Ingenhoven Overdiek and Partner, Essen, 1996

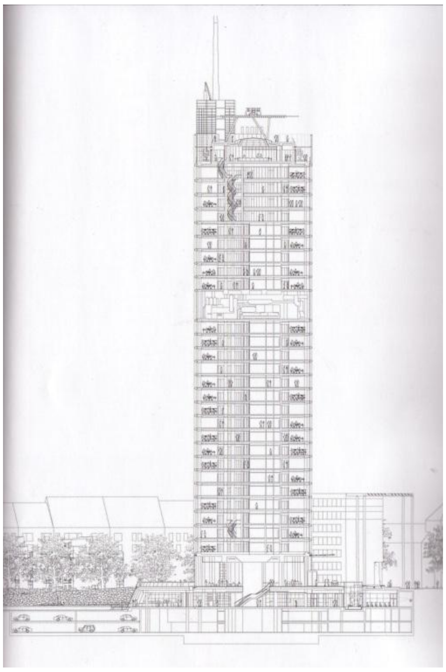


Figure 3.21 : RWE Headquarters view and section, adapted from Höweler (2003).

The RWE Tower or also known as the “Power Tower” is headquarters to Germany’s largest producers of electricity. This unique tower is not only a landmark to the city of Essen but is the one of the first instigator of incorporating sophisticated environmental principles in the design of high-rises (Figure 3.21). The Glass RWE Headquarters building utilizes sophisticated building systems, by consuming less energy while providing necessary comfort conditions for the user. RWE Headquarters is extremely important for its integrated intelligent systems in terms of new smart facade technologies, energy efficiency and sustainable materials. It is more akin to Eco-intelligent building terminology in which active and passive systems are integrated to reach a human-centered IB. The building’s environment is consistently regulated through computers in the central administration room by sensors built into each room and on the exterior of the building. This sensor sends the computer information about the outside condition and of each individual space. Based on this information, it can control the adjustment of sunshades and ventilators and activate the mechanical ventilation system if required (Evans, 1997). Some of the buildings energy is generated by PV panels which are situated on above the entrance canopy. These power-generating cells provide shading for the entrance as well as convert the sunlight directly into electricity.

3.3.2.1 Building orientation and climate parameters

- **Climate:** Temperate
- **Building form:** Compact

RWE Headquarters has a compact form consisting of a 32 m diameter circular shape, chosen for its maximum surface to volume ratio. With the cylindrical shape, air speeds are twice the wind pressure, which eases vertical circulation of airflow and the diagonal ventilation in all stories (Url-10).

- **Core Location:** Side

The cylindrical plan allows all the offices to be located at the perimeter providing to each office natural light and air (Figure 3.22). The cylindrical part is allocated to office spaces and it has an adjacent elevator tower. The service areas and meeting offices are located at the central part of the building.

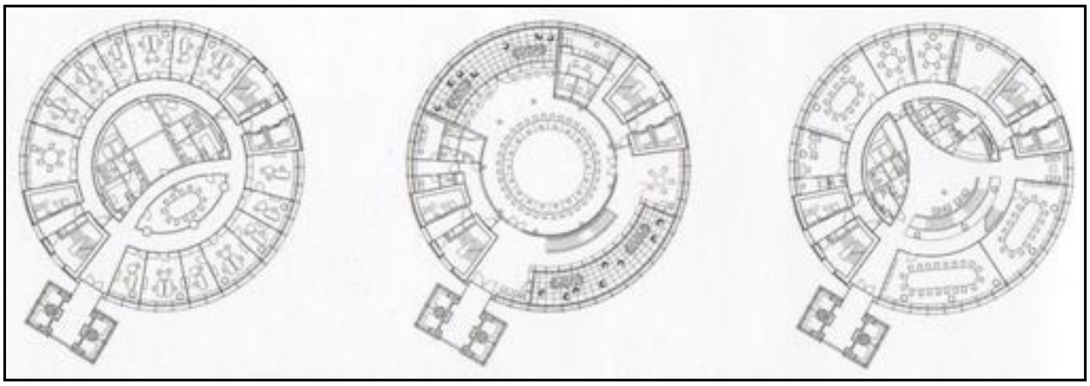


Figure 3.22 : RWE Headquarters different floor plans, adapted from Höweler (2003).

3.3.2.2 Building skin parameters

- **Natural Ventilation**

The design of the office places around the outer perimeter allows every office to directly use natural ventilation system through double-skin façade. Environmental conditions are managed by Building Management Systems technology, with a single control panel in every room enabling light, temperature, facade and sun protection to be adjusted to individual. Also mechanized sunshades are integrated into facade cavity and automatically raise or lower according to climatic data (Höweler, 2003).

Some of the building’s energy is generated by PV panels, which are situated on adjustable fixings incorporated into elements on the roof-level.

The major components of Natural Ventilation examined in RWE Headquarters are as follows:

Cross Ventilation: The extra air cavity acts as a thermal buffer, decreasing the rate of heat loss between outside and inside. Fresh air is supplied through the opening at the bottom and warm air is exhausted through the opening at the top of the façade. During extreme cold conditions, the windows are closed. Warm air is returned to the central plant via risers for heat recovery in the winter.

Operable windows: All office windows can be opened for ventilation. Except under extreme weather conditions, the building is naturally ventilated. Each office consists of a minimum of two bays of glazing with at least one operable window.

The users of the building can lessen the opened gap of the sliding door to manipulate the cross-ventilation in the room and to adjust it to their comfort level. It has been observed that a reduction of air change is possible when the gap is reduced for both the perimeter facade with two sectors and for box-type windows. The reduction is stronger in the former case, because of the pressure balance created by the facade cavity (Url-10).

Double Skin: The 163 m height tower is encased in a double glass skin. This double skin provides a breathing space for the building that allows the tenants to benefit from natural lighting and ventilation. Outside there is a single layer of strengthened safety glass, while the inner glazing is heat-insulated Clima plus white glass, allowing daylight to be maximized. A 50 cm void between the layers of glass acts as a thermal buffer. (Pank et al., 2002). The glass sliding doors in the interior part of the double skin, allow the user to control the amount of the fresh air taken to interior.

Atrium: There is no atrium in this building and the services and meeting areas are located in the central part.

Sky-courts (Vertical Landscape): RWE Headquarters is revised from the second prize-winning scheme of Commerzbank, in Frankfurt, which has been also designed by Ingenhoven Overdiek. In the original design, the width of the air cavity was much wider including the plants. But, this scheme has been revised by decreasing the cavity and omitting the plants. There is a sky-court on the 29th floor together with a board room.

Figure 3.23 : Intelligent double layer glass facade, adapted from Höweler (2003).

- **Natural Lighting**

On a typical floor plan in the RWE Tower, all the offices are placed around the outer perimeter of the floor, giving each space ample amounts of natural light and a beautiful panoramic view of the city. The placement of these spaces allows every office to be illuminated with natural light.

Double-glazing of floor to ceiling glass (Figure 3.23) allows maximum daylight in office spaces, and mechanized sunshades integrated into facade cavity controls its intake (Davey, 1997b). The major components of Natural Lighting parameter examined in RWE Headquarters are as follows:

Passive Shading Devices: There are several specially developed, innovative features designed to minimize energy consumption of this building. For example, the "fish-mouth" elements placed between glazing layers help to integrate devices for sun and glare protection with an air-exchange system (Figure 3.24). Their electronically controlled aluminum mullion provides protection from the sun, while optional motorized internal textile blinds shield against glare

Daylight, direct solar and glare can be controlled with blinds and an interior anti-glare screen. The façade provides good heat insulation in the winter and with the combination of slatted blinds, effective solar protection in the summer (Davey, 1997b).

Light wells: There are no light wells designed in this project.

High-efficiency Glazing: Most of outer curtain wall use "Climaplus" extra clear insulating glass, which consists of 10 mm toughened safety glass, 19 mm cavity and 17 mm laminated safety glass and finished with a heat-reflective coating.

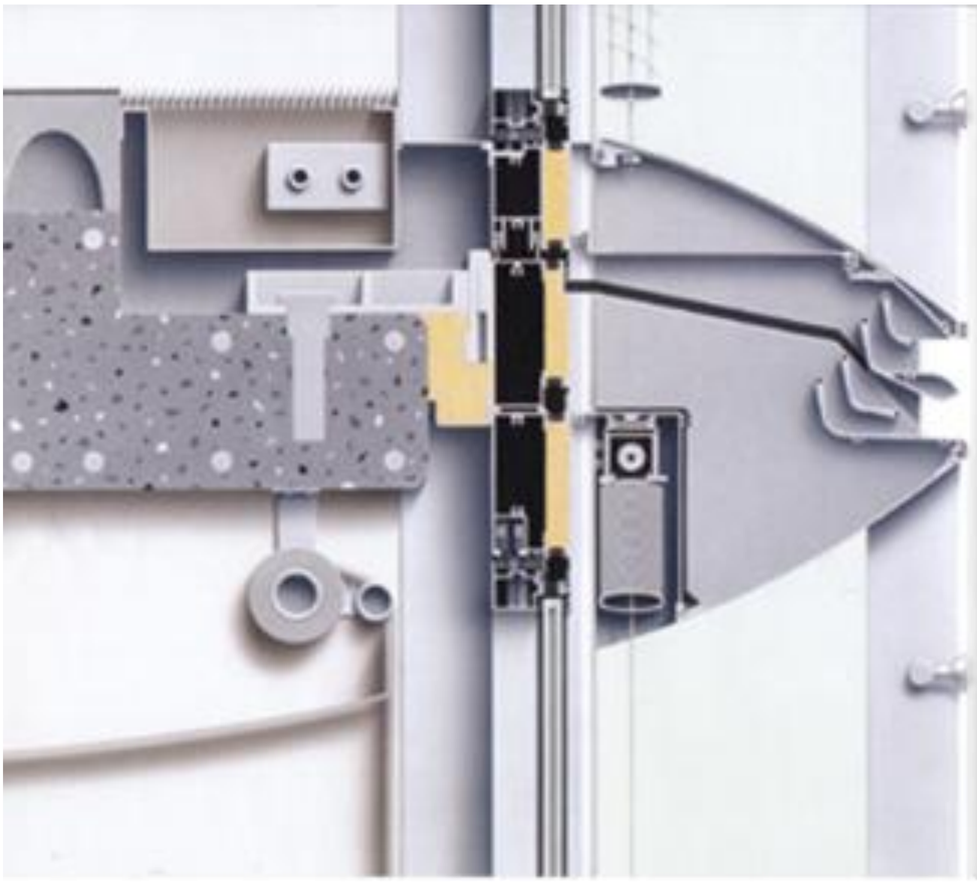


Figure 3.24 : The "fish mouth" mullion detail, adapted from Höweler (2003).

3.3.2.3 Building shell parameters

- **# of Floors:** 29 storey
- **Net Floor Area:** 32,150 m^2 (GFA: 35,000 m^2), Diameter: 32 m
- **Structural Planning**

Structural Grid: Radial concrete grid.

Planning Grid: Radial form.

The office planning grids are also split in radial form along the perimeter of the building.

Sectional Height: Slab to slab height is 3.6 m

The most remarkable characteristic of the RWE Tower is the use of glass double-skin on the entire facade. Since its inner skin consists of pair glass, the tower has virtually a triple glass shell.

It is with the double-skin facade that the natural ventilation of the high-rise was actualized, and the transparent and energy-saving building was made possible. Between the inner and outer facades, there exists a distance of 50 cm and a set of louver blinds that can be remotely controlled (Figure 3.25).

- **Floor plate**

Floor plate Shape: Compact blocks with external core

Floor plate Depth: Depth A (Shallow office spaces)

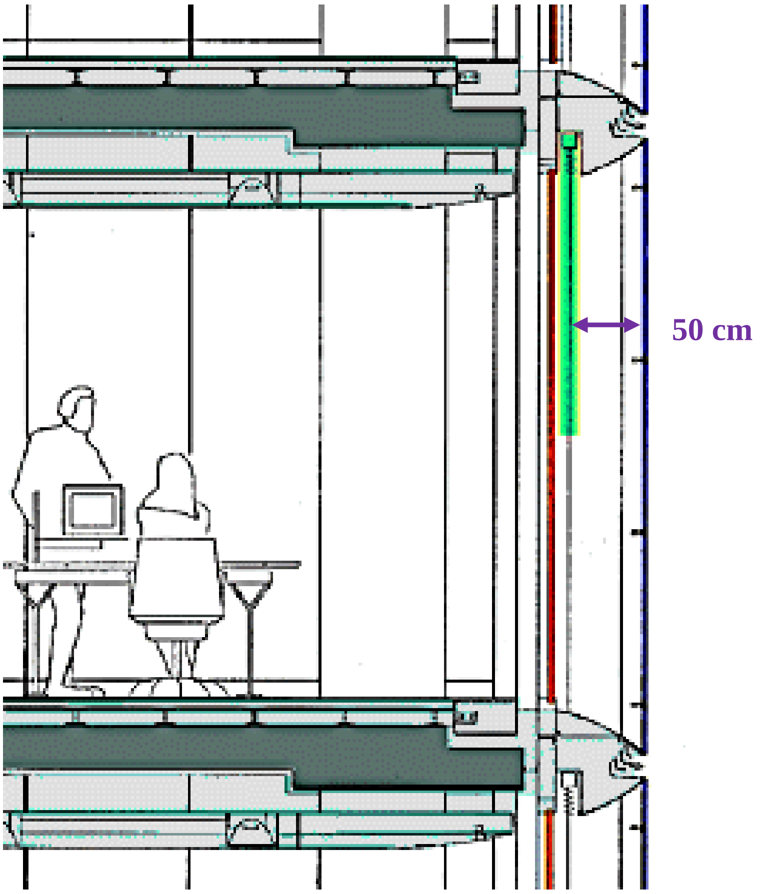


Figure 3.25 : Section height detail, adapted from Höweler (2003).

- **Plan Type:** Combi-office

The Office rooms are located on the 2-18 and 20-24 levels. They are organized along the perimeter of the floor plan, around the main circulation core located in the center. Elevators are placed independently at the side of the main building, keeping the floor area open and free of any obstructions (Figure 3.22).

3.3.3 30 St Mary Axe / Swiss-Re Headquarters Building, Foster and Partners, 2004

30 St Mary Axe/Swiss-Re Headquarters Building is the first environmentally responsive high-rise building of London. The 40-storey Headquarters building is innovative in terms of technical, climatic, social and environmental design issues. This cigar-shaped office building (Figure 3.26) can be defined as an ecological one operating with minimum energy consumption and providing maximum comfort conditions.

Figure 3.26 : 30 St Mary Axe / Swiss-Re Headquarters Building, adapted from Höweler (2003).

3.3.3.1 Building orientation and climate parameters

- **Climate:** Temperate
- **Building form:** Compact

The building shell consists of a compact form rather than fragmented and open form because of climatic conditions. The circular plan of the tower widens as it rises from the ground, and then tapering towards its domed apex. The principal challenge of the building is the convex core and the orthogonal floor plate relation.

The appropriate form of the building has been determined after wind tests and the light penetration possibility at ground level. Building a round building on square site resulted in unintentional public spaces that can be landscaped. The aerodynamic form of the building will encourage people to walk around the base structure as displayed in Figure 3.27 (Williams, 2002).

- **Core Location:** Central

The services and circulation areas are located in the central core, and the perimeter space accommodates orthogonal office area utilizing daylight, fresh air, and external vistas.

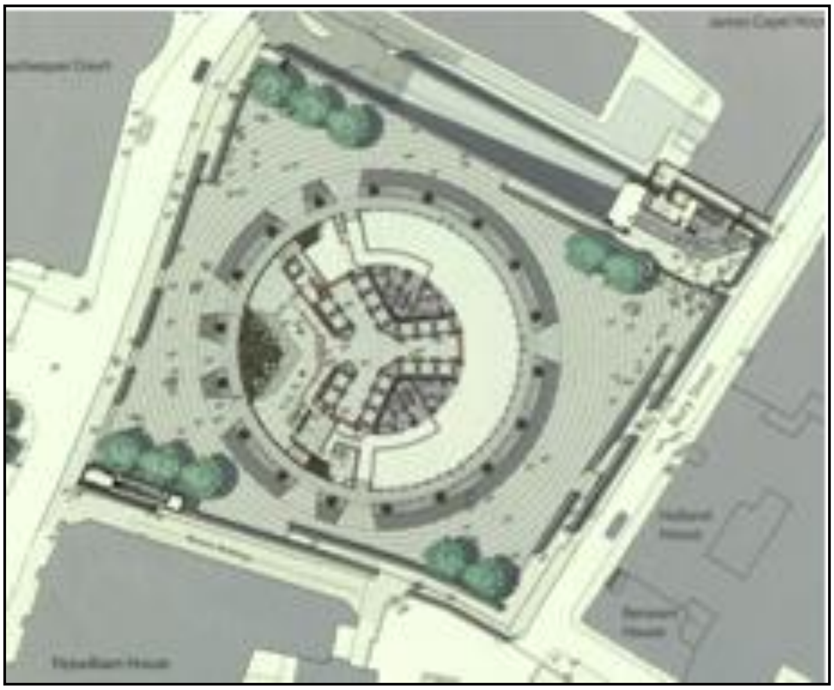


Figure 3.27 : Ground Floor Plan, adapted from Williams (2002).

3.3.3.2 Building skin parameters

- **Natural Ventilation**

The aerodynamic form of the building and created light wells provides natural ventilation and lighting. The building utilizes natural ventilation for much of the year, reducing carbon dioxide emission and energy consumption. The spiraling light wells create pressure differences improving passive ventilation of the building (Höweler, 2003). The mechanical ventilation can be controlled floor by floor through decentralized plant system.

Cross Ventilation: There exists an air plenum around the perimeter of each floor opening to external air through a louver blade at the horizontal glazing joints.

Operable Windows: Windows in the light-wells open automatically to augment the air conditioning system with natural ventilation, an occurrence anticipated to save energy for up to 40% of the year.

Double skin: The operable curtain walls allow fresh air and natural light. The building envelope consists of two layers of a glass and cavity. The fresh air will be taken from this double skin, and then ventilated by natural convection through light wells spiraling up through building perimeter.

Gaps in each floor create six shafts that serve as a natural ventilation system for the entire building (even though required firebreaks on every sixth floor interrupt the "chimney"). The shafts create a double glazing effect; air is trapped between two layers of glazing and insulates the office space inside.

Atriums: The atriums are arranged in a spiral form so that air drawn into the tower via the light wells circulates around the building due to the differences in external air pressure. The atriums are closed at every sixth floor in order to divide the building into vertical fire compartments.

Sky-courts (Vertical Landscape): Atrium between the radiating fingers of each floor link together vertically to form a series of informal break-out spaces that spiral up the building. The vertical landscaping of the building provided by light wells, designed as social activity areas. These spaces are places for relaxing and meeting areas and function as the building's 'lungs', distributing fresh air taken through glass panels in the facade. This system reduces the tower's reliance on air conditioning and together with other sustainable measures, means that the building is expected to use up to half the energy consumed by air-conditioned office towers (Url-11).

- **Natural Lighting**

The spiraling form of the building provides light wells in different floor levels of the building and reduces the need of artificial lighting. This building's energy consumption is %50 lesser than the conventional high-rise building. The staggered floor plans allow daylight to penetrate into buildings. Each of the six 'fingers' of accommodation on each floor is offset by five degrees. This increases daylight penetration and cuts back on the need for artificial lighting.

Passive Shading Devices: Louvre and blind are not used.

Light wells: Light wells penetrate deep into the tower's interior, reduce dependency on electric lighting and result in savings on electricity costs. The diagonally placed structural envelope (Figure 3.28) allows column free interior space and a fully glazed facade opening up to daylight and vista. This fully glazed skin has operable and fixed double-glazed panels that reduce solar radiation (Hascher et al., 2002).

The light wells pull warm air out of the building during the summer time and warm the building in the winter using passive solar heating. These shafts also allow sunlight to pass through the building, making the work environment more pleasing, and keeping the lighting costs down (Figure 2.32).

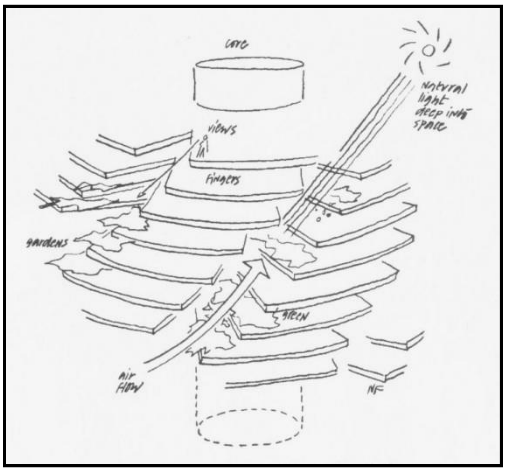


Figure 3.28 : The light well separated by glass partition and staggered floor plans, adapted from Williams (2002).

High-efficiency glazing: The light wells' glazing comprises openable double-glazed panels and a high-performance coating which effectively reduces solar gain. The apparently decorative grey-tinted glass which covers the spiraling light wells (Figure 3.29) not only leads the eye upwards, but exists to counter solar gain (Gregory, 2004).

3.3.3.3 Building shell parameters

- **# of Floors:** 40 storey
- **Net Floor Area:** 41,810 m^2 (GFA: 55,000 m^2)
- **Structural Planning**

Structural Grid: The main structure is designed as steel A-frames that provide a double curvature outer skin that stretches evenly over the entire facade like a net. The core of the building is mainly carrying the weight and with the reduction in the number of lifts and services as the building rises, become smaller and office areas can be increased. The individual elements of the structural frame are minimized by the favorable weight distribution. The tower is aerodynamically designed to reduce wind load on the structure, whilst the lower part tapers so that wind wraps around the tower and reduces the incidence of air flow to lower part on the surrounding plaza. Also, the building's shape reduces the amount of wind deflected to the ground in comparison to a rectangular tower of similar size (Hascher et al., 2002).

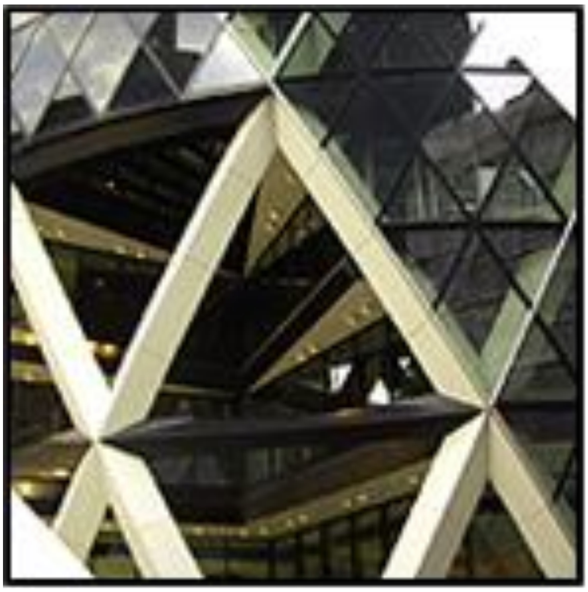


Figure 3.29 : A view through triangular light wells, adapted from Williams (2002).

Planning Grid: The planning system is based on a 1.5 m plan grid, and this system allows 16.5 m wide rectangular plates (Figure 3.31) leaving varying amounts of residual space within the terraced balcony. The floor plate comprises like "fingers" radiating from the central core and provides parallel edged floor spaces based on a grid. The resulting triangular dead areas will be cut and used as wells to improve ventilation and daylight intake. These spiraling triangular voids will be rotated with the staggered floor plans and demarcated with tinted glass (Williams, 2002).

Sectional Height: The floor plan is rotated for each successive floor, creating a series of spiraling 5 storey atria that stretch the full height of the building. In the typical office floors, the air intake and distribution through ceiling section can be seen in Figure 3.30. The height of the typical office floor from finished floor to ceiling is 2.75 m. Also, at the very top of the building; London's highest occupied floor - is a club room that offers a spectacular 360-degree panorama.

- **Floor plate**

Floor plate shape: Shallow space large central core.

Each floor is divided into six-equal sized segments. The structural system allows column-free floor space, light and views. The energy-conscious enclosure of the building resolves walls and roof into a continuous triangulated skin.

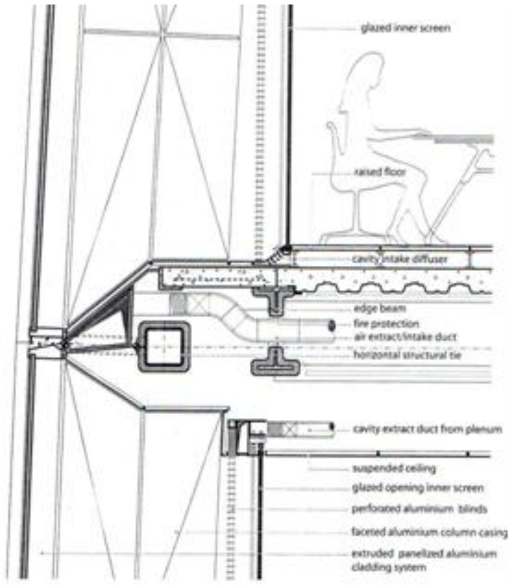


Figure 3.30 : Section through typical floor and wall junction, adapted from Hascher et al. (2002).

Floor plate Depth: B Type

The core to perimeter dimension varies from 6.4 to 13.1 m

- **Plan Type:** Combi-Office

The access to the office spaces are through a ring around the core and the layout develops counter clockwise to the atrium, from private cellular office spaces to open offices looking to balcony (Figure 3.31).The floor plans are shaped like flowers, with a circular perimeter indented by 6 triangular light courts. The indentations remain a constant size at each level, while the space between them diminishes.

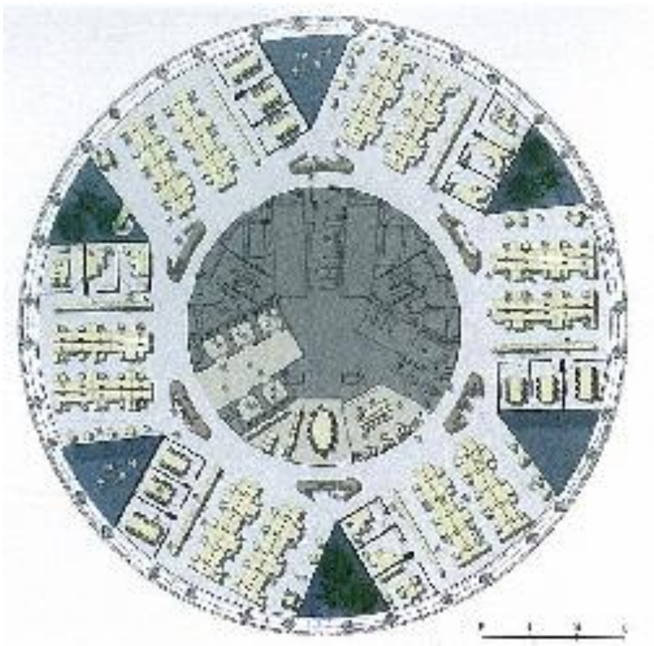


Figure 3.31 : Typical Layout of Office Space, adapted from Hascher et al. (2002).

3.3.4 Condé Nast Building, Fox & Fowle, New York, 1999

This is the first ecologically designed North American skyscraper (Figure 3.32) and at the time of its construction, high-rise buildings rarely addressed environmental issues. The innovations made during its construction became standard for office buildings (Höweler, 2003).

The Condé Nast Building is significant for being the first environmentally responsible design in North America. All building systems and construction technology have been evaluated for their impact on occupant health, environmental sensitivity, and energy reduction. When the total building area is considered, it is a great achievement to adopt standards for energy conservation, indoor air quality, recycling systems, and the use of sustainable manufacturing processes.

The building sets new standards in terms of "energy conservation", "indoor environmental quality", "recycling systems", and "the use of sustainable materials". Lighting, power usage, furniture systems, carpet, and finishes have enriched the environmental sustainability as well.

Figure 3.32 : The first environmentally sensitive North American skyscraper, adapted from Höweler (2003).

3.3.4.1 Building orientation and climate parameters

- **Climate:** Cool
- **Building form:** Compact

The rectangular plan form of both the base and the set-back tower is broken by a rounded corner at Broadway and 42nd Street.

- **Core Location:** Central core

The plan of the building is organized around a central core, and the offices on the periphery (Figure 3.33). The high-rise office buildings with a large, central core demand complex mechanical and electrical systems.

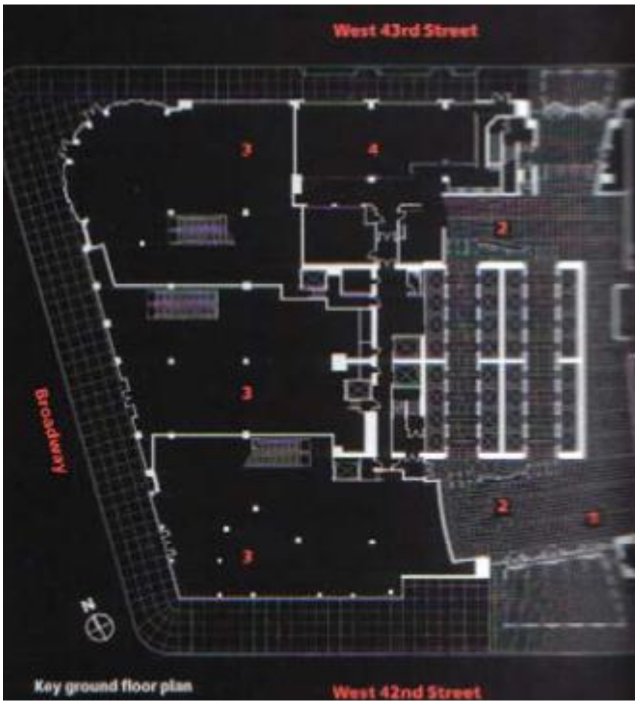


Figure 3.33 : Ground Floor Plan of Conde Nast Building, adapted from Höweler (2003).

3.3.4.2 Building skin parameters

- **Natural Ventilation**

The sophisticated mechanical systems provide high indoor air quality by taking filtered fresh air to the environment. The building has also two fuel cells that will cover the electric needs of night hours. The fuel cells generate power quietly and cleanly and convert hydrogen-containing gas by using a chemical reaction without combustion (Bosch, 2000). The heating and cooling is provided by environmentally efficient gas-fired absorption chillers/heaters.

The air delivery system will provide 50% more fresh air than New York City Building codes, and a network of recycling channels will serve the entire building. The building has 50% more insulation in the walls than typical New York skyscraper, and double the insulation in the roof (Bosch, 2000).

Cross Ventilation: There is no cross ventilation principle implemented in this building.

Operable windows: There are no operable windows in this building.

Double Skin: Solar panels incorporated into the facade generate idle-time power for the building.

Atrium: There is no atrium in this building and the services and meeting areas are located in the central part

Sky-courts (Vertical Landscape):

The sky-courts do not exist in the planning principles of Condé Nast Building, in New York.

- **Natural Lighting**

The large glazed curtain wall areas maximize daylight penetration and it includes a low-e coating to filter the undesirable ultraviolet light. The interior lighting of the building is centrally controlled by occupancy sensors.

Passive Shading Devices: There are no passive shading devices in this building.

Light wells: There is no light well in this building.

High-efficiency glazing: The top of the building resembles a powerhouse with its curving, horizontally-banded corners, and has four protruding frameworks, one on every facade, for electric signs of 16 by 16 m (Bosch, 2000).

The photovoltaic panels are integrated in the spandrel areas on the upper floors of the east and south facades, producing a symbolic amount of electricity.

3.3.4.3 Building shell parameters

- **# of Floors:** 48 storey
- **Net Floor Area:** 149,000 m^2 (GFA: 168,000 m^2)
- **Structural Planning**

Structural Grid: The frame incorporates concrete core walls for the first 20 floors, with a steel core extending to the top, where a hat truss connects it with a perimeter column tube (Figure 3.34). Both the concrete core portion and the hat truss were worked out to lessen structural steel usage.

Figure 3.34 : Condé Nast Building view from 41st Street, adapted from Url-12.

Planning Grid: Rectangular type of planning grid is used.

Sectional Height: The 264 m height office building of the Condé Nast is in fact 52 storey (Figure 3.35). The 49th floor is occupied by mechanical operations, and floors from 50th to 52nd are used by television and radio stations for their transmitters. Slab to slab height for the offices are 4.0 m.

- **Floor plate**

Floor plate shape: Shallow space large central core

Floor plate Depth: C Type (> 12 m)

The building is located on the corner of 42nd street and Broadway, has been designed with two distinct faces, the west and north facades respond to Times Square with their glittering metal and glass cladding, while the east and south facades respond to the corporate context with a historical stone facade (Kaplan, 1997).

- **Plan Type:** Combi-plan office

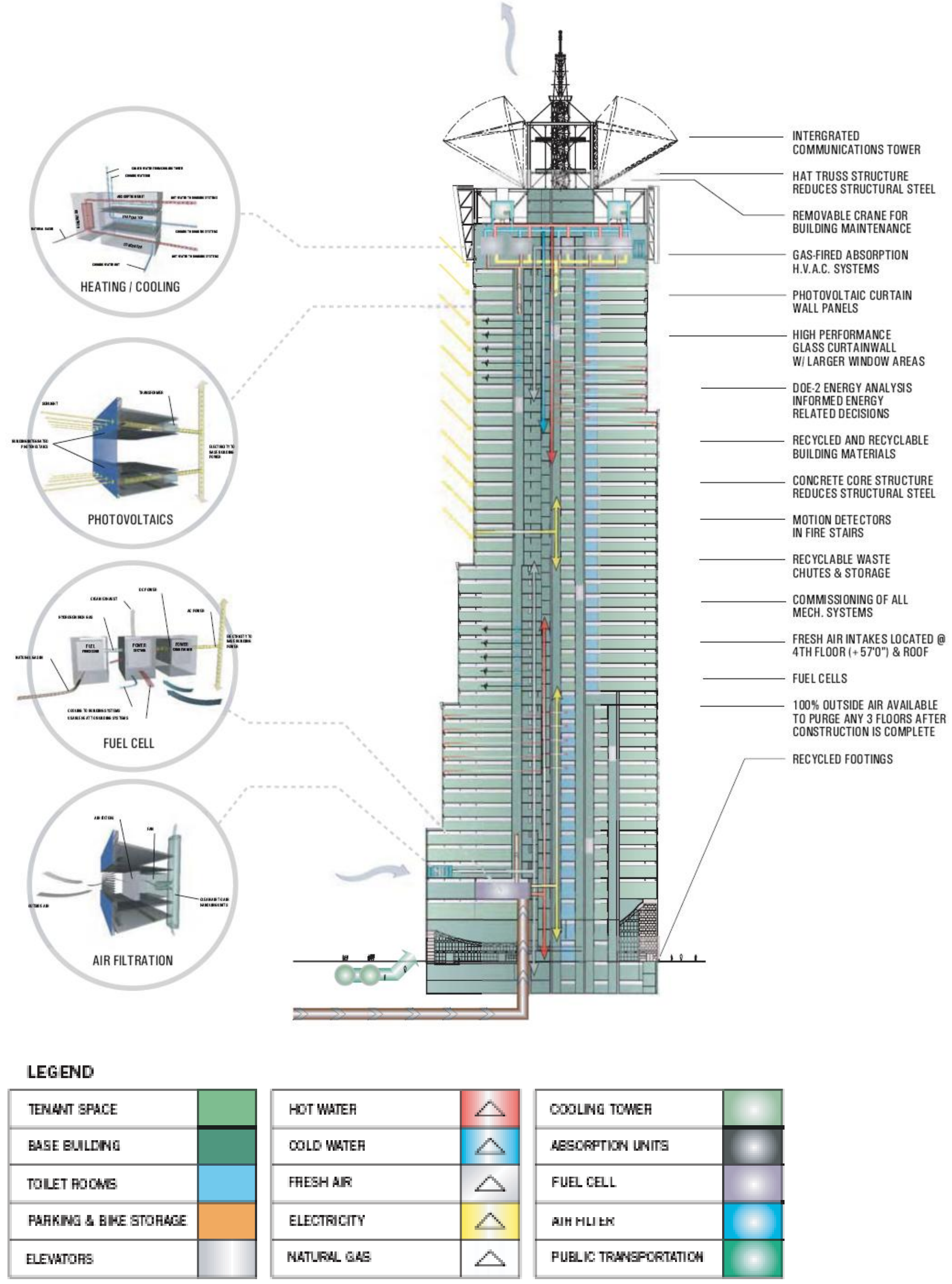


Figure 3.35 : Section displaying services and systems used in Condé Nast Building, adapted from Url-13.

3.3.5 Menera Bousted, Ken Yeang, Kuala Lumpur, 1983-1987

Figure 3.36 : The planting upon the voids of Menera Boustead, adapted from Powell (1999).

The 32 storey office tower developed an idea of a tropical building language being soft-edged, ambiguous and multi-layered (Figure 3.36). An important factor in the design was the path of the sun which is an integral element in the determination of the shape of the building.

3.3.5.1 Building orientation and climate parameters

- **Climate:** Tropical
- **Building form:** Compact

It has a circular shape with terraces and sky-courts on the corners of each floor by means of which plants and landscaping is made possible in the upper floors of the building as well as future accommodations.

- **Core Location:** Side core

The building cores are located on the east and west sides, and open plan office space is created facing to south and north sides (Figure 3.37).

Figure 3.37 : The ground floor and typical floor Plan, adapted from Powell (1999).

3.3.5.2 Building skin parameters

- **Natural Ventilation**

The cladding system consists of a double-ventilated heat sink shield to reduce the heat load of the building. The building cladding consists of a light-weight composite aluminum material that enables the heat to be dispersed before it can be transmitted to structure (Powell, 1999).

Cross ventilation: Ken Yeang uses the analogy between engine cylinder cooling fins as cooling fins of the building (Powell, 1999). He has created the cross ventilation concept of the building as per attached sketches shown in Figure 3.38.

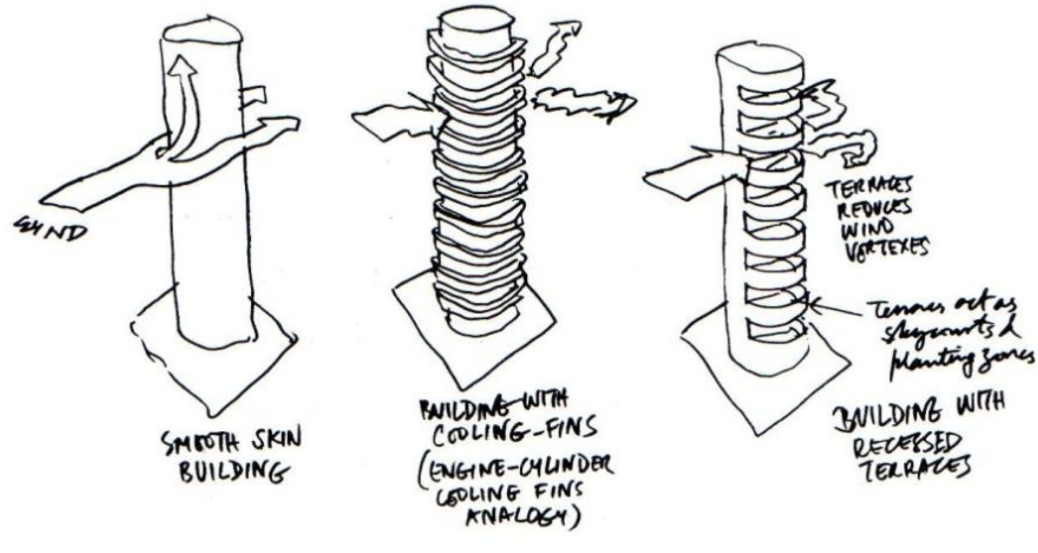


Figure 3.38 : Conceptual sketches for climatic issues of Menera Bousted, adapted from Powell (1999).

Operable windows: On all office floors terraces are provided with sliding doors for workers to control the level of natural ventilation.

Double skin: The majority of the building's double-glazed, operable curtain walls lie flush to the façade only on the north and south side. Being near the equator, a slight overhang is enough to block shallow penetrating rays into the building.

Atriums: Sky-courts are emphasized instead of a peripheral atrium, and planted corner balconies or "sky-terraces" are located at the edges of the building together with vertical landscaping on the facade.

Sky-courts (Vertical landscape): The sky-courts provide sun shading that allows for full height glazing to enhance the quality of light in office space and provide places for supplementary air conditioning units.

The landscaping and buildings are not treated as separate elements, but they are integrated into each other (Figure 3.39). The shading, air infiltration, photosynthetic absorption of the pollutants is provided through greenery (Yeang, 1994).

Figure 3.39 : Hairy Building concept of Menera Boustead, adapted from Powell (1999).

- **Natural Lighting:**

All glazing is recessed unless facing exactly north or south.

Passive Shading Devices: The shading devices are installed on the building face for passive cooling whenever the main components of the building and its orientation cannot shade the building.

Windows on the east and west sides are sun-shaded, and the lift lobbies have natural ventilation and natural day lighting.

Light wells: Instead of light wells, there are recessions as terraces in front of the offices for shading purposes.

High-efficiency glazing: The light-green glass and glazing detailing acts as a ventilation-filter without wholly insulation the interior

3.3.5.3 Building shell parameters

- **# of Floors: 32** storey
- **Net Floor Area:** 12,345 m^2
- **Structural Planning**

Structural Grid: Column free interior spaces designed for office area and soft-edged, multi-layered tropical building understanding has been developed.

Planning Grid: The building has a circular floor plan, which offers no dark corners.

Sectional Height: The recessed terraces acting as cooling fins lightens the massive form of the building.

- **Floor plate**

Floor plate shape: Compact blocks with External core

Floor plate Depth: C Type (> 12 m)

Floor plate depth is 28 m from facade to facade

- **Plan Type:** Open Plan

Any enclosed rooms are located near the central core to allow natural lighting and high quality views for the workstations located on the outside edge.

3.3.6 Menara Mesiniaga, Ken Yeang, Kuala Lumpur, 1992

When the IBM headquarter Menara Mesiniaga (Figure 3.40), situated in Subang Jaya near Kuala Lumpur, was erected in the summer of 1992, its architect Ken Yeang had the terms energy-saving, climate-consciousness and occupancy comfort realized in built form.

3.3.6.1 Building orientation and climate parameters

- **Climate:** Tropical
- **Building form:** Compact

The circular building has a sloping landscape base, a spiraling body with landscaped sky courts, and external louvers shading the offices. The upper floor has been designed to include recreational activities such as swimming pool and sunroof (Figure 3.41).

- **Core Location:** Side core

The transitional spaces such as the lift cores and toilets are found on the hotter west and east sides.

Figure 3.40 : The cylindrical building form corrupted by irregular recessions, adapted from Powell (1999).

3.3.6.2 Building skin parameters

- **Natural Ventilation**

The key idea behind the placement of the fire exit stairs and lift core on the east and west sides to serve as passive low energy solar thermal buffers. Much of the building, from stairways and lift lobbies to the toilet areas, was conceived as a permeable membrane supporting natural ventilation.

Also, an intelligent feature of BAS is used for energy saving in corporation with the natural ventilation.

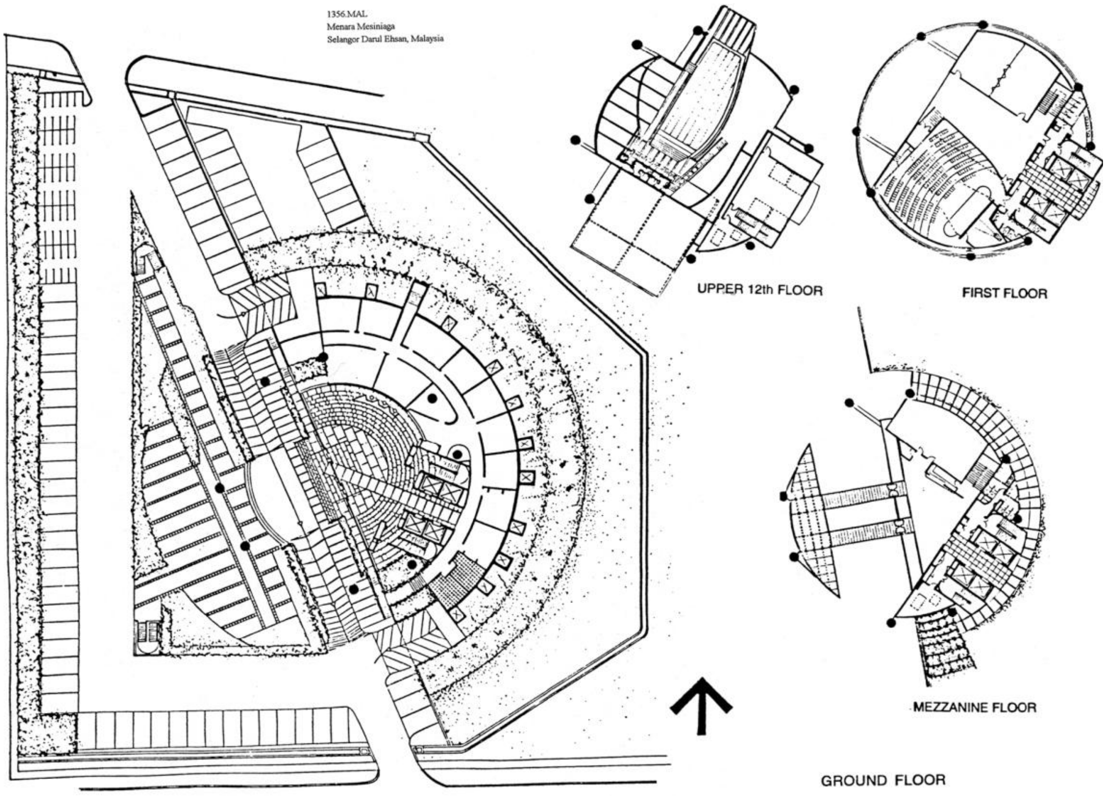


Figure 3.41 : Plan of the first storey, adapted from Powell (1999).

Cross ventilation: By partially opening the top of the building through louvered sunroof, more wind movement and fresh air can be taken into the spaces below. The sunroof also acts as a wind scoop to direct natural ventilation to the inner parts of the building as well as an exit for rising hot air.

Operable windows: From three panes of each window, one mullion is operable, and also roof terraces have sliding doors.

Double skin: The majority of the building's double-glazed, operable curtain walls lie flush to the façade only on the north and south side. Being near the equator, a slight overhang is enough to block shallow penetrating rays into the building.

Atriums: Sky-courts are emphasized instead of a peripheral atrium, and planted corner balconies or "sky-terraces" are located at the edges of the building together with vertical landscaping on the facade. Because of the hot and humid climate of the Malaysia, the inner floor plates are recessed from the facade allowing air flow between the different parts of the building (Figure 3.43). The spiralling stepped terraces allow fresh air through glass doors.

Sky-courts (Vertical landscape): The idea of landscape spiraling up the outside of the tower and linking the sloped base creates a physical continuity. The sky courts also provide visual relief for the office workers (Figure 3.43). The tower has a sun-shaded roof, recessed and shaded windows on the east and west sides, spiralling vertical landscaping, naturally sun-lit spaces and low energy mechanical systems (Powell, 1999).

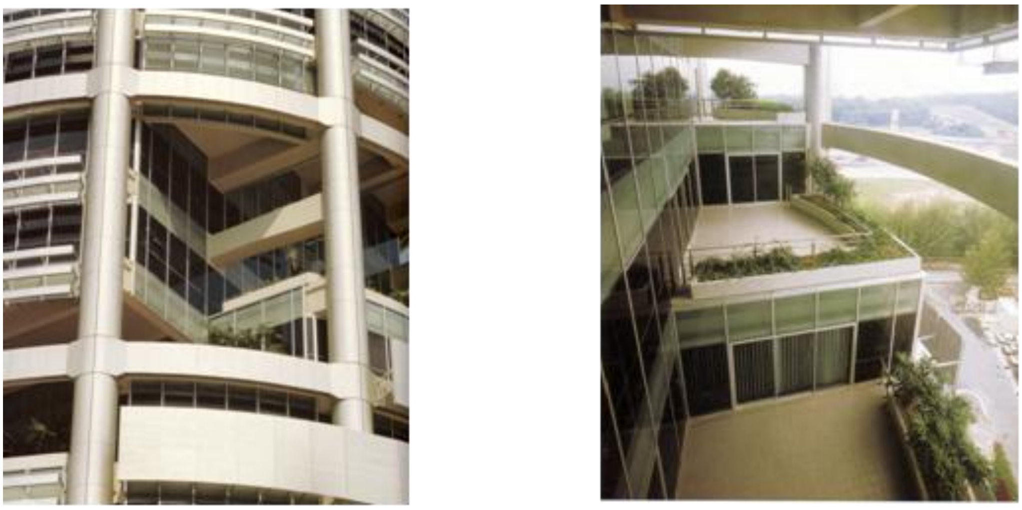


Figure 3.42 : Sun shading devices combined with recessed sky courts, adapted from Powell (1999).

- **Natural Lighting**

The building's general form, structural strategy, cores and glazed surfaces, is oriented for maximum environmental efficiency shading against direct overheating but allowing for natural daylight (Figure 3.43).

Passive Shading Devices: The shading devices are installed on the building face for passive cooling whenever the main components of the building and its orientation cannot shade the building. The building facade is designed to be "an environmentally responsive filter". The configuration of the louvers is arranged according to orientation of the building to the sun in order to minimize solar gain (Powell, 1999). Windows on the east and west sides are sun-shaded, and the lift lobbies have natural ventilation and natural day lighting. For most of the west half of the building, external solar shades are installed. The southwest and northwest facades are protected by aluminum fins offset approximately 40 cm away from the building face. These devices are utilized where high-angled rays hit the curtain walls. But for more far reaching direct light, deeper, single panel aluminum louvers offset from the building twice as far as the fins is installed (Chan et al., 2004).

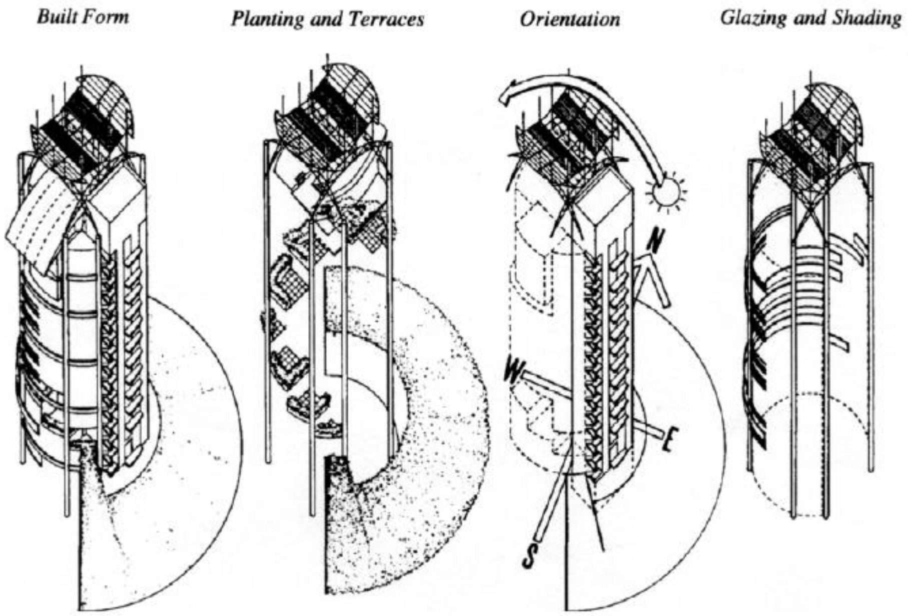


Figure 3.43 : The Menara Mesiniaga Building orientation determined by climatic factors, adapted from Safamanesh (1995).

Light wells: Sky-courts in the form of recessed terraces have been used rather than light wells.

High-efficiency glazing: On the north and south facades, there are deep recessions for shading of the facade. Also, except east facade, the other windows use tinted glass.

3.3.6.3 Building shell parameters

- **# of Floors:** 15 storey
- **Net Floor Area:** 11,364 m^2
- **Structural Planning**

Structural Grid: The structural system is reinforced concrete with a steel structure used for the mezzanine and balconies.

Planning Grid: Column free interior spaces designed for office area and soft-edged, multi-layered tropical building understanding has been developed with this building.

The Spatial hierarchy can be seen in each floor starting from the base of the building to crown at the top. Allocation of the central part of the building to the upper management and allocation of the periphery to general staff is not a general office planning. In general, the offices on the periphery with a good vista, natural lighting and ventilation are provided to upper management. The spatial hierarchy is quite opposite to the staff titles hierarchy.

Sectional Height: The slab to slab height is 3.9 m

The tri-partite structure consists of a raised "green" base, ten circular floors of office space with terraced garden balconies and external louvers for shade, and is crowned by a spectacular sun-roof, arching across the top-floor pool (Figure 3.45).

The structure of the building is completely exposed and the crown of the building at the top is the only decorative element which will have more shading with PV panels in the future.

- **Floor plate**

Floor plate shape: Compact blocks external core

Floor plate Depth: C Type (> 12 m)

Floor plate depth is 23 m from facade to core.

- **Plan Type:** Combi-office

The major requirement of Menara Mesiniaga was that the floor configurations that can accommodate layout needs, future changes and future expansion. The final design of the layout differs to some extent from a typical office building. It has cellular enclosures in the centre rather than the perimeter (Figure 3.44). These cellular offices - divided by glass-partitioned walls - are occupied by IBM managers while the workstations in the peripheral areas of the open-plan offices are used by the executives and administrative staff. Several perimeter offices are also partitioned to accommodate support spaces for meetings, equipment storage and staff training.

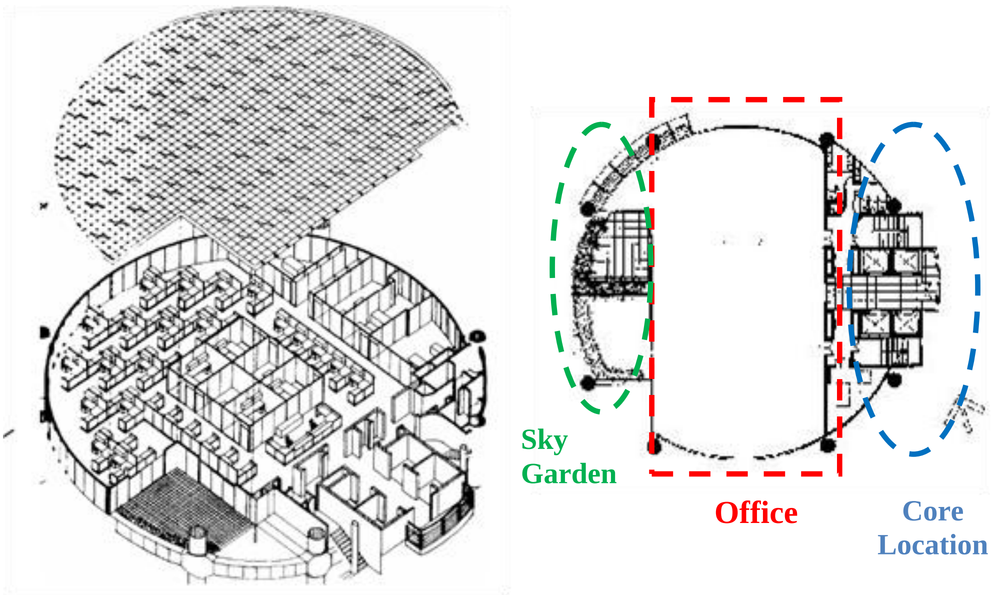


Figure 3.44 : Typical floor Plan with cellular offices mainly in the center and open plan offices on the periphery, adapted from Höweler (2003).

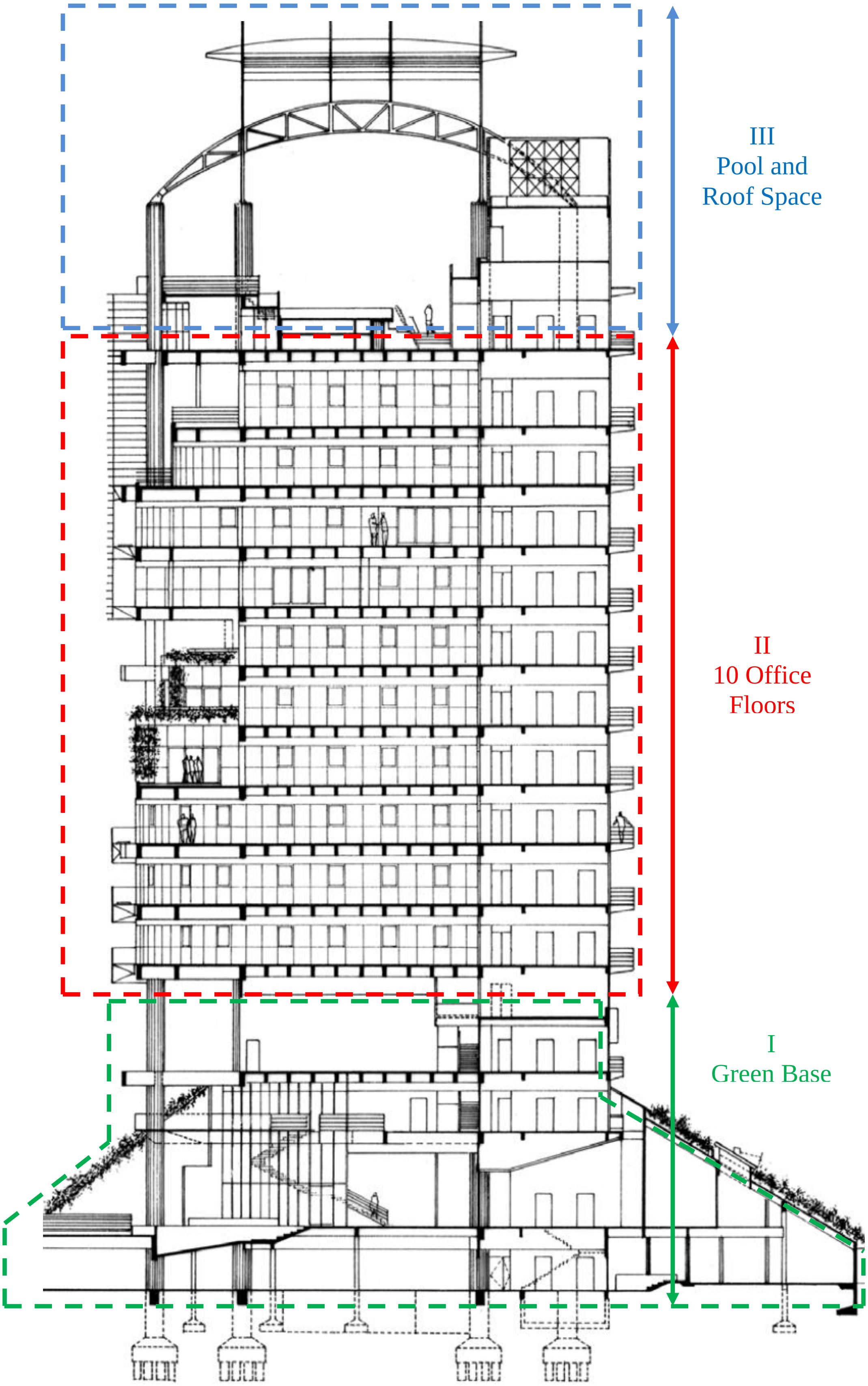


Figure 3.45 : Tripartite Division of the Menara Mesiniaga building section, adapted from Powell (1999).

3.3.7 Elephant & Castle Eco-Tower 1, Ken Yeang, London, 2010

T. R. Hamzah and Ken Yeang have been designing a tower as part of the major regeneration of the Elephant and Castle area in South London. His proposal for the 35-storey residential tower (Figure 3.46) introduces environmental concepts for high-rise buildings developed in Asia to European context (Höweler, 2003). A new railway interchange divides the project site into two. The left hand side of the railway track was developed by Foster & Partners and the right hand side by TR Hamzah & Yeang, HTA Architects and Benoy Limited. The high-rise residential building includes public spaces such as shops, bars, restaurants, and sport facilities.

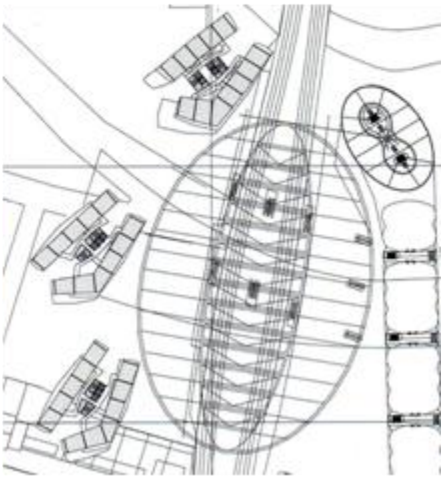


Figure 3.46 : Open lattice structure and site plan of the Eco-Tower 1, adapted from Höweler (2003).

3.3.7.1 Building orientation and climate parameters

- **Climate:** Temperate
- **Building form:** Fragmented
- **Core Location:** Central

The high-rise building is split into two volumes, with the circulation and service areas in the central core of the building.

3.3.7.2 Building skin parameters

- **Natural Ventilation**

Most of Ken Yeang's buildings were designed for tropical conditions. Yeang emphasizes the fact that internal spaces of a skyscraper do not have to be totally enclosed. Instead, cross ventilation and daylight need to be taken into the building, providing cooling and a comfortable environment that relates to its tropical location. These ideas can be adapted to temperate conditions, and Yeang currently has a bio-climatic tower block for London.

Cross ventilation: The tower employs a number of low energy concepts. The porous cage structure of the tower allows natural ventilation for cooling the apartment units as seen in Figure 3.47. The building has been orientated to maximise solar gain into the interior spaces in winter and mid-seasons, and to maximise solar shading in the summer months. For this reason, the tower makes the most of a southerly orientation to catch the winter sun (Pank et al., 2002).

Operable windows: The operable windows of the double glazed facade allow occupants to arrange their indoor comport conditions according to building's mechanical systems, which changes from passive to mixed mode. There exists a balance and collaboration between natural and mechanical systems. The Eco-Tower's orientation, moreover, would also allow it to maximize passive solar energy gain. (Pank et al., 2002).

Double skin: In temperate locations, such as London, adjustable openings in the building's skin are added to filter and control the entry and emission of heat, glare and drafts as necessary (Pank et al., 2002). Such features are also incorporated in the design proposed for the Elephant and Castle redevelopment.

Atriums: The wings of the building allow cool breezes in the summer to enter the central atrium while protecting it from the winter wind.

Sky-courts (Vertical Landscape): In this project, two thirds of the building exterior will be greened and construction materials will be recycled on site. This green space, which was to occupy 20 percent of the building, is more than just an amenity for tenants.

The sky-courts are designed to shade various parts of the building and to allow efficient wind circulation. Yeang aims to include the conditions of the ground on the building, and creating a new eco-habitat to enhance bio-diversity. Continuous ramps of vegetation around a building and sky-courts built into internal spaces can bring positive benefits to local ecology rather than attempting to minimize impacts (Pank et al., 2002).

- **Natural Lighting**

Passive Shading Devices: The sky-courts shade various parts of the building. Also, the porous cage structure of the tower allows passive shading around the building.

Light wells: The internal void and walkways capture the sun, creating a series of light wells to brighten the service areas in the apartments. The wings of the building allow cool breezes in the summer to enter the central atrium while shielding it from the winter wind.

High-efficiency glazing: The tower makes the most of a southerly orientation to catch the winter sun by using high-efficiency glazing system.

3.3.7.3 Building shell parameters

- **# of Floors:** 35 storey
- **Net Floor Area:** 21,500 m^2 (GFA: 25,600 m^2)
- **Structural Planning**

Structural Grid: Because of the irregular form of the building, there is no specific grid identified.

Planning Grid: The Eco-tower is configured as two blocks with weather protected central landscape.

Sectional Height: There is a vertical zoning inside the Eco-tower and the occupants can take a lift directly from platform level of the transport interchange to the car park in roof top level or at street level.

The design aims to create ground floor conditions with features like entrance lobby, light wells and balconies for every unit. Also, it creates shared secondary and tertiary landscaped open spaces and sky pods within groups of housing. There will be a high-level bridge over the proposed railway station and direct connections onto the sky-courts into the retail zones (Url-14).

- **Floor plate**

Floor plate shape: Wings

The Eco-tower consists of two elongated floor plates connected with a central core.

Floor plate Depth: B Type (6 m-12 m)

- **Plan Type**

The buildings have been pierced to allow view across the city in all directions. At the same time, these openings provide passers-by a refreshing view of the parkland above. There are residential use above retail and commercial areas located in the ground floor. Mixture of residents from different ages, occupations and family structures are accommodated by the provision of a variety of accommodation types: studio apartments, 2-room apartments and Penthouses in Eco-tower.

Figure 3.47 : The porous cage structure allowing cross ventilation natural daylight, adapted from Höweler (2003).

3.4 Environment-oriented Design Criteria Checklist Implementation to the Selected Seven Buildings

The selected seven buildings which are reviewed in terms of the specified three main categories of "environment-oriented" design criteria are tabulated in a checklist in Table 3.2. These design parameters checklist can be extended and revised based on the requirements of the user/client. Also "technology-oriented" design criteria are integrated into passive design criteria to support the changing needs of the user by using intelligent systems, services and materials.

As a result of this case study, it is understood that proposed environment-oriented passive design criteria are common design basis for majority of the selected IBs. This environment-oriented design criteria checklist is a basic preparatory matrix for the next stage in which passive design criteria and user-oriented criteria (physical, psychological and social, economic needs) are correlated as part of an integrated Human-centered IB design approach. The specified three main categories of "environment-oriented" design criteria and their impact on "user-oriented" design criteria can be defined as follows: "building skin" and "building shell" design criteria have great impact on the physical, psychological and social, and economic needs of the user.

If we take the implementation of "natural ventilation", and "natural lighting" design parameter of the "building skin" design, they have direct positive impact on the productivity and well-being of the user. For example, the office user who is close proximity to operable windows having direct daylight with integrated passive shading devices work more productive and more comfortable than the one working without this parameter.

Above highlighted passive design parameters are the minimum design basis for the Environment-oriented design criteria of a Human-centered IB, and can be extended by adding relevant design parameters according to different user requirements. After discussing on the environment-oriented design criteria that have direct impact on the success of a responsive, adaptive and flexible Human-centered IB design approach, the third major component: "technology-oriented" design criteria are discussed in the next chapter to cope with the changing user requirements.

Table 3.2: Environment-oriented Design Criteria Matrix for IBs.

ENVIRONMENT-ORIENTED DESIGN CRITERIA									
Building Orientation and Climate			**1**	**2**	**3**	**4**	**5**	**6**	**7**
Climate	Cool		-	-	-	X	-	-	
	Temperate		X	X	X	-	-	-	X
	Arid		-	-	-	-	-	-	-
	Tropical		-	-	-	-	X	X	-
Building Form	Fragmented		-	-	-	-	-	-	X
	Compact		X	X	X	X	X	X	-
Core Location	Side		X	X	-	-	X	X	-
	Central		-	-	X	X	-	-	X
	Dispersed		-	-	-	-	-	-	-
Building Skin			**1**	**2**	**3**	**4**	**5**	**6**	**7**
Natural Ventilation	Cross ventilation		X	X	X	-	X	X	X
	Operable Windows		X	X	-	-	X	X	X
	Double-skin		X	X	X	-	-	-	X
	Atriums		X	-	X	-	X	X	X
	Landscaping		X	X	X	-	X	X	X
Natural Lighting	Light Wells		X	-	X	-	-	-	X
	Passive Shading Devices	Blinds	X	X	-	-	X	X	X
		Louvre	-	-	-	-	-	-	X
	High-efficiency glazing		X	X	X	X	X	X	X
Building Shell			**1**	**2**	**3**	**4**	**5**	**6**	**7**
# Floors			**56**	**29**	**40**	**48**	**32**	**15**	35
GIA Area (m^2)			**85,503**	**32,150**	**41,810**	**149,000**	**12,345**	**11,364**	**25,600**
Structural Grid									
Planning Grid									
Sectional Height (m)			**3.8**		**2.75**	**4.0**		**3.9**	Varies
Floor plate Shape	1.Compact blocks with external core		-	X	-	-	X	X	-
	2.Bars		-	-	-	-	-	-	-
	3.Deep space small central core		-	-	-	-	-	-	-
	4.Shallow space large central core		-	-	X	X	-	-	-
	5.Pavilions		X	-	-	-	-	-	-
	6.Wings		-	-	-	-	-	-	X
Floor plate Depth	A Type (< 6m)		-	X	-			-	-
	B Type (6 m-12 m)		-	-	X			-	X
	C Type (> 12 m)		X	-	-	X	X	X	-
Plan Type	Cellular plan		-	-	-	-	-	-	-
	Open plan		-	-	-	-	X	-	-
	Landscape plan		-	-	-	-	-	-	-
	Combi -office plan		X	X	X	X	-	X	X

1. **Commerzbank Headquarters, 1997**
2. **RWE Headquarters, 1996**
3. **30st Mary Axe/ Swiss Re Headquarters, 2004**
4. **Condé Nast Building, 1999**
5. **Menara Bousted, 1983-1987**
6. **Menara Mesiniaga, 1992**
7. **Elephant & Castle Ecotower, 2010**

4. TECHNOLOGY-ORIENTED DESIGN CRITERIA OF IBs

In this thesis study, the proposed Human-centered IB design approach also includes the opportunities of technological developments (intelligent systems, services, and materials) to respond to changing user needs. Hence, IB needs to be designed in full integration with “Environment-oriented” and “Technology-oriented” design criteria to be responsive, adaptive, and flexible to user requirements.

To be defined as Human-centered, IB design should have learning, adapting, analyzing skills to be able to respond to user behaviors. This can be achieved through used intelligent systems, services and materials if fully integrated with “environmental” design criteria and “user needs” from the beginning stage of the design process.

In this thesis study, Building Rating Method parameters (Appendix A: 265) have been taken as a base by extending some of the design criteria while formulating the technology-oriented design criteria for IBs. Technology-oriented design criteria of Human-centered IBs are categorized under three main components which are: “services-oriented”, “systems oriented”, “materials-oriented” criteria. The selected technology-oriented IB design criteria can be extended based on the requirements of the user and the building program. In the following part, the selected design criteria and their impact on the user needs are discussed.

4.1 Services-Oriented IB Criteria

In advanced IB designs, building control services such as HVAC, lighting, lifts, access control, telecommunication, data processing, fire, and security systems are integrated for increasing cost effectiveness and productivity of the users through local control systems (Figure 4.1). In comparison to traditional buildings, IBs should be able to reduce energy consumption, maintenance and service operation costs.

The IB services such as; telecommunications, data, building operation controls, audiovisual, and security are commonly introduced as separately operating systems (Harrison, 1997).

The integration between the intelligent systems is the key factor in IB design. The users of the building can access to comfort, safety, and security issues provided by systems like BAS, OA, EMS, EE, II, IT, through integrated building services.

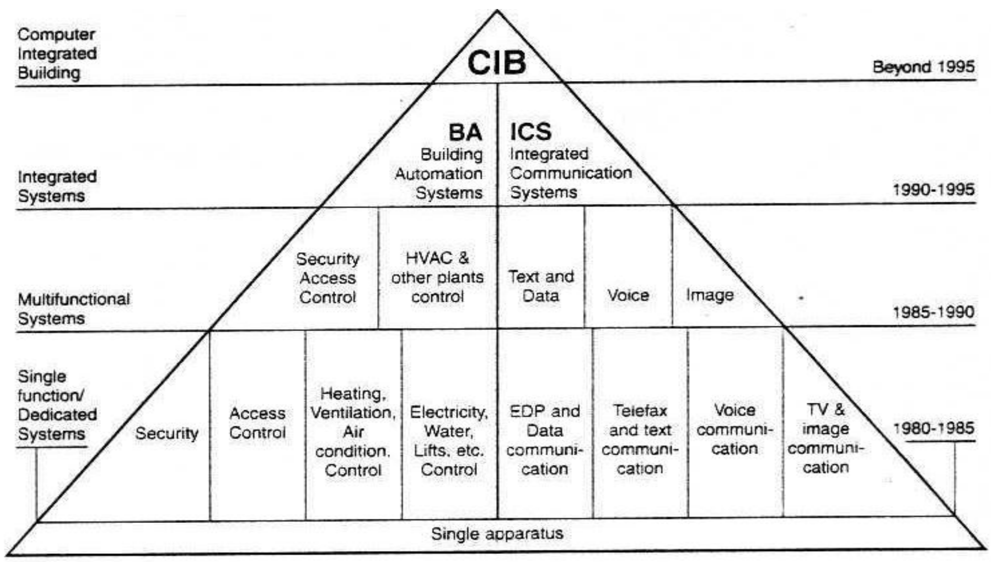


Figure 4.1 : The IBE Integration Pyramid, adapted from Harrison (1997).

Integrated building systems now have the capability to use the same structured cable network and enable interoperability across all systems. The IT systems are designed to include the structured cable system network that enables the user's technology systems and the building operating systems to function in an integrated manner (Harrison, 1997). The integration of the services and systems is critical for the productivity and success of IB technologies.

Building services have impact on physical, psychological and social, and economic needs of the user. Their integration and collaborative working principle with passive design criteria are highly critical for the user comfort and productivity in Human-centered IBs. In Table 4.1, the main building services used in IB designs are highlighted which are briefly explained in the following sections.

IB technologies can increase the user satisfaction and productivity by establishing a highly flexible design that is responsive and adaptive to changing user needs.

Table 4.1 : Table for Services-oriented IB Criteria.

SERVICES-ORIENTED IB CRITERIA	
HVAC	Heating Method(electricity, gas, oil or other)
	Chillers
	Heaters
	AHU
	VAV
	Natural Ventilation
	Mixed mode use and Control systems
Lighting	Type of user control
	Photoelectric cell for daylight control
	Occupancy sensors
	Local control via telephone
	Dimming
Electrical Power	UPS, generators, fuel cells, PV, etc.
Lifts and Escalators	Passenger handling capacities, cab capacity,
	Speed
	Drive mechanism
	Door monitoring
	Configuration of different lift groups
	Integration of movement sensors
Access Control	CCTV, turnstiles, smart card systems for personnel, retina control, fingerprint, etc.
Fire safety	Type of fire protection (sprinklers, CO_2, Halon, etc.)
	Intelligent sensors
Telecommunication	Internet, e-mail, fax, audio-visual systems, etc.

4.1.1 HVAC

Most of the complaints and problems in IBs are caused by inappropriate HVAC design and the users' not given any personal control over his/her workspace. The user should be provided with individual air and temperature controls at his/her workspace to overcome this problem. This can be achieved by zoning HVAC services integrated with air and temperature control system to ensure optimal thermal comfort performance,

The term HVAC refers to the three disciplines of Heating, Ventilating, and Air-Conditioning. There is also a fourth discipline; "controls" which pervades the entire HVAC field. Controls determine how HVAC systems operate to meet the design criteria of comfort, safety, and cost-effective operation. Below are the explanations for these four terms:

- HVAC: refers to the three disciplines of Heating, Ventilating, and Air-Conditioning. A fourth discipline, Controls, pervades the entire HVAC field. Controls determine how HVAC systems operate to meet the design goals of comfort, safety, and cost-effective operation.
- Ventilating maintains an adequate mixture of gases in the air we breathe (e.g. not too much CO_2), controls odors, and removes contaminants from occupied spaces.
- Air-conditioning refers to the sensible and latent cooling of air. Sensible cooling involves the control of air temperature while latent cooling involves the control of air humidity.
- Controls ensure occupant comfort, provide safe operation of the equipment, and in a modern HVAC control system enable cautious use of energy resources (Graham, 2009).

Heating System Controls

The first three systems explained below controls increase energy efficiency by reducing on/off cycling of boilers. The fourth improves the efficiency during operation. These controls are as follows:

- Modulating flame: The heat input to the boiler can be adjusted continually (modulated) up or down to match the heating load required.

- Step-fired: The heat input to the boiler changes in steps, usually high/low/off.
- Modular boilers: Another energy-efficient measure is to assemble groups of smaller boilers into modular plants
- Oxygen trim systems: They continuously adjust the amount of combustion air
- to achieve high combustion efficiency. They are usually cost-effective for large boilers that have modulating flame controls (Graham, 2009).

Ventilation System Controls:

In recent years, ventilation control systems have become more complex and, if installed and maintained properly, more dependable. Among the recent developments are:

- Direct digital control (DDC) systems using digital-logic controllers and electrically-operated actuators are replacing traditional pneumatic controls. Pneumatic systems use analog-logic controllers and air-pressure actuators. DDC systems are repeatable and reliable, provide accurate system responses, and can be monitored from a central computer station.
- Constant Air Volume (CAV) systems should have controls to reset the supply air temperature at the cooling coil to provide the warmest air possible to the space with the highest cooling load. This reduces reheat throughout the system.
- VAV systems can now be designed to serve areas with as little as six tons of cooling load. Inlet vanes or, better yet, variable speed fans should be used to control air volume. In systems that have supply and return fans, airflow monitoring stations should be used to maintain the balance between supply and return airflow.
- CO_2-based control systems control the amount of outside air required for ventilation. These systems monitor the CO_2 in the return air and modulate the outside air damper to provide only the amount of outside air required to maintain desired levels (Graham, 2009).

In order to reach a certain level of quality for thermal and ventilation comfort, the below principles should be taken into consideration during HVAC design for IBs:

- Room configurations and HVAC distribution layouts should be analyzed to ensure that all parts of a room are receiving adequate ventilation, especially spaces where teams or groups meet. Also, individual environmental controls should be provided in these rooms,
- Incorporate natural ventilation if possible,
- Consider providing a temperature and humidity monitoring system to ensure optimal thermal comfort performance,
- Evaluate the use of access floors with displacement ventilation for flexibility, personal comfort control, and energy savings,
- Provide individual air and temperature controls at each workstation,
- Utilize CO_2 sensors to assess the air quality of spaces to adjust ventilation.

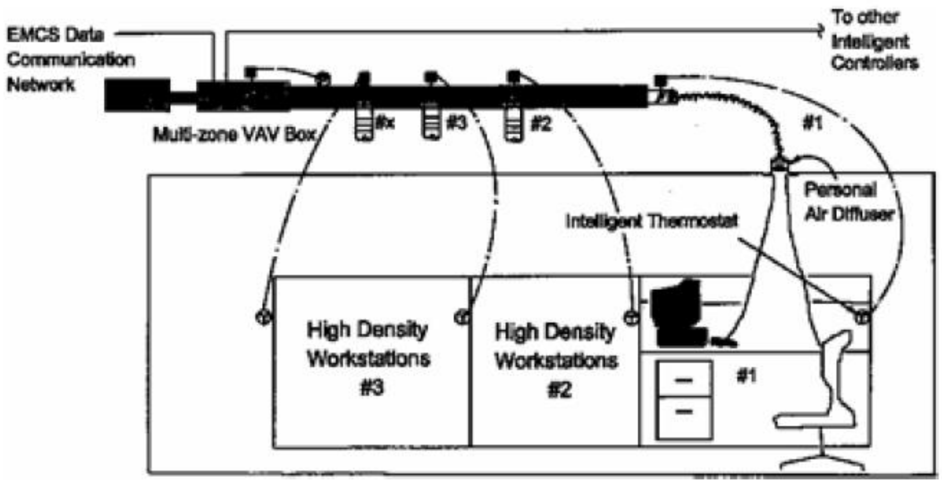


Figure 4.2 : Personal air-conditioning Control Alternative, adapted from WBDG, (2009).

As shown in Figure 4.2, by enhanced ventilation terminal control system with multi-zone VAV box terminal controls and individual airflow controls (personal air-conditioning), personal AC for adjusting thermal and ventilation comfort can be provided to the user (Heerwagen, 2010). By making available the user control in HVAC systems, the integration of intelligent technologies and user needs can be achieved.

4.1.2 Lighting

Electric lighting controls are used in lighting design projects to achieve a high quality energy efficient lighting system. A layered, daylight-integrated lighting and control system gives the occupants control of the lighting while providing appropriate lighting levels, minimizing glare, balancing surface brightness, and enhancing the surrounding space.

If the electric lighting controls are used properly, energy will be saved by reducing the amount of power used during the peak demand period by automatically dimming lights or turning them off when they are not needed. Also, with a proper lighting control, the internal heat gains can be reduced by cutting down the lighting use, which allows for a reduction in HVAC system size and in the building's cooling needs. One of the most effective ways to save energy in IB is to allow the occupants to use controls to lower light levels.

The most common form of electric lighting control are:

- Standard on/off switch.
- Occupancy sensors (passive infrared, ultrasonic, and dual technology sensors),
- Daylight sensors,
- Clock switches,
- Manual and automatic dimming devices (blinds, light shelves etc.)
- Centralized controls (DEGW, 1999).

Among these lighting control systems, occupancy sensors (including passive infrared, ultrasonic, and dual technology sensors) serve three basic functions: to automatically turn lights on when a room becomes occupied, to keep the lights on without interruption while the controlled space is occupied, and to turn the lights off within a preset time period after the space has been vacated.

The occupancy sensor placement in IB is very important for the successful implementation of the control design intent. Occupancy sensors must be located to ensure that they will not detect movement outside of the desired coverage area. For example, the ultrasonic devices are sensitive to air movement and should not be placed near an HVAC diffuser, where air movement may cause false tripping.

Occupancy controls can also be used in conjunction with dimming or daylight controls to keep the lights from turning completely off when a space is unoccupied, or to keep the lights off when daylight is plentiful and the room is occupied. This control scheme may be convenient when occupancy sensors control separate groups of luminaries in a large open office space. In these situations, the lights can be dimmed to a predetermined level in one specific area when the space is unoccupied (Nelson, 2009).

4.1.3 Electrical Power

The electrical power is the hearth of IB systems and services. It is highly recommended to merge all low voltage systems, including data and voice, through distributed Ethernet-IP networks with centralized backup. For providing the flexible IB infrastructure, the below electrical design criteria is highly recommended:

- Provide distributed Uninterrupted Power Supply (UPS) for clean and reliable power,
- Design accessible, modifiable, vertical power, and telecom cores (with appropriate open riser space, secure, high-speed access to the desktop for data, voice, security, and environmental information),
- Provide distributed modular cabinets with plug and play interfaces,
- Provide re-configurable plenum systems,
- Select terminal units that provide services such as: data, power, and voice in reconfigurable boxes for just-in-time modifications (Heerwagen, 2008).

4.1.4 Lifts and Escalators

In the IBs, the lifts control can be quite complex, especially with multiple elevator groupings and traffic patterns. Most of the IB lift designs integrate access control cards and closed circuit surveillance. For example, through an effective access control system permit, certain floors may not be accessible even with an approved access card based on the use of the selected floor.

The average waiting time of the lift determines the elevator efficiency and quality. In the office buildings, the average waiting time is between 20-25 seconds (Eisele et al., 2003). The escalators can save energy by slowing down or stopping when there is no movement detected by the sensors. This will provide energy savings together with the maintenance cost reduction of the mechanical equipment.

4.1.5 Access Control

There has been a general trend towards integrating various stand-alone security systems, integrating systems across remote locations, and integrating security systems with other systems such as communications, and fire and emergency management. Some CCTV, fire, and burglar alarm systems have been integrated to form the foundation for access control. The emerging trend is to integrate security systems with facility and personnel operational procedures (Url-15).

To protect the IB from unsearched persons is an important part of any security and access control system. The systems that are used for security design of IBs are:

- Building access control:
    - Control perimeter: Fences, bollards, anti-ram barriers
    - Traffic control, remote controlled gates, anti-ram hydraulic drop arms, hydraulic barriers, parking control systems
    - Forced-Entry-Ballistic Resistant (FE-BR) doors, windows, walls and roofs
    - Barrier protection for man-passable openings (greater than 96 square inches) such as air vents, utility openings and culverts
    - Mechanical locking systems
    - Elimination of hiding places
    - Multiple layer protection processes
- Intrusion Detection systems:
    - Clear zone
    - Video and CCTV surveillance technology
    - Alarms
    - Detection devices (motion, acoustic, infrared)
    - Personnel identification systems
    - Access control, fingerprints, biometrics, ID cards

- Credential management
- Tailgating policies
- Primary and secondary credential systems (Url-15).

4.1.6 Fire Safety

The fire safety (life safety) systems are driven by code considerations and this prevents the flexibility in design parameters. As a result of the new technological developments such as advanced multi-function sensors, computer vision systems and wireless sensors, real-time control via the Internet, and integrated BMS, the capability of fire systems to discriminate between fire and non-fire threats improved (Liu et al., 2001).

Intelligent systems developed in the IBs offer opportunities to meet the fire safety requirements more effectively, efficiently and economically. New sensors will produce earlier and more reliable fire detection. Wireless systems will eliminate the need for cabling and offer opportunities for fire fighters to work out firefighting strategies before arrival at the fire scene. Also, integrated building systems bring forth the potential to reduce false alarms, speed up the building evacuation and assist in firefighting. These technological improvements will create new ways to provide fire safety and new markets for fire detection, alarm and firefighting systems (DEGW et al., 1989). As a result of the developments in IB technologies used in the buildings, lighting system of the building can be turned on during the fire, and networks can enhance information flow to the users through emergency broadcast messages.

There are several studies to develop multi-function sensors for simultaneously detecting fire and monitoring indoor air quality (IAQ). Multi-function sensors combining inputs from several different chemicals or physical processes would be expected to reduce the rate of false alarms and increase the speed of detection of real problems together with the total system costs reduction. The chemical gas sensor has potential for this type of application. Chemical sensor techniques are now available for measuring almost any stable gaseous species emitted from materials and prior to or during combustion (Grosshangler, 1992). The major issue in any sensor system is to differentiate between different causes of the events being detected. When separate sensors installed in the building for fire safety, thermal comfort control and environmental monitoring can be integrated, sensitivity to fires and false alarm can be significantly enhanced. These sensors are located in different positions in the building and once a fire occurs, the system can take multiple fire signatures and the spatial relationship and status of adjacent detectors into account in making decisions. These sensors transmit the separate fire sensitivity information to a control panel where fire signal processing and alarm and fault determinations are made. The use of a powerful central processing unit (CPU) in the control panel would also allow the system to use complex algorithms and advanced signal processing for fire signature identification (Grosshangler, 1992). Today's fire detection and alarm systems have been partially integrated with other building systems. Once a fire occurs in a building, fire detection and alarm systems in some buildings activate various fire safety systems, such as smoke control, and various pressurization and smoke exhaust system (Buckley, 1985). The integration of fire detection and alarm systems with other building systems should also increase fire safety in the building.

4.1.7 Telecommunication

The communication infrastructure must be designed to support all possible applications in IBs. These include voice and data systems, BAS, lighting systems and all other systems to create an IB. The classical telephone systems, amplificators, satellite dish antenna for communication, cordless phones, communication through microwave are the devices that need the telecommunication infrastructure in the building. The main telecommunication systems are:

- The Internet and broadband,
- Audio-visual systems, etc.
- PABX,
- ISDN, and LAN

Other programs providing building control and monitoring for effective functioning of Telecommunication services, recommended actions to be done are as follows (DEGW, 1999):

- Update computer hardware and software periodically.
- Provide interchangeable voice/data cabling,

- Consider telecommunication equipment back-up systems (battery power, etc.),
- Consider wireless systems, where feasible, to promote internal mobility and access to emergency services (Url-16).

After briefly explaining about the building services, in the following part, major IB systems are discussed in the following part.

4.2 Systems-Oriented IB Criteria

IBs implement new technologies of building systems to improve the building environment, comfort conditions, and productivity of the users. IBs should easily adapt to changing occupant needs and use the integrated technology in order to provide safer, healthier and more comfortable working conditions. Intelligent building promoters also believe that these buildings will improve worker productivity through improved work environments. As a result, it can be stated that Human-centered IBs have to use technological developments to serve rather than dominate and create a new set of problems to its user. IB systems use sensors to identify how a particular person tends to react to particular circumstances and to learn different behaviors for different people. The number of sensors required to obtain this type of functionality is quite high, especially since one of the major goals of intelligent buildings is to allow individualized control of an environment. This need will increase the cost of intelligent buildings and make it difficult to manage the resulting large amount of data. Development of cost-effective sensors has consequently been identified as a key need for intelligent buildings. Fortunately, many of the properties that need to be monitored can be used for multiple purposes. Security systems that can track the entry and exit of occupants from an office building can also be used to ensure complete evacuation of a building during a fire or even, in more advanced forms, determine where occupants may be trapped and unable to escape. Similarly, parameters such as temperature and air movement are as relevant to fire detection as the maintenance of the indoor working environment. Dual use sensors and sensor systems that are flexible enough to interpret data from different events are key factor to making cost efficient intelligent buildings (Liu et al., 2001). The integration among different services and systems is the key criteria for the success of IB design.

Table 4.2 : Table for Systems-oriented IB Criteria.

Systems-Oriented IB Criteria	
Building Automation System (BAS)	Type of BAS: BACNet, LonWorks PC/mini computer/custom developed systems
	Integrated systems with BAS: security, lifts, fire, lighting, access control
	Energy monitoring (gas, electricity, oil, water)
Energy Management System (EMS)	These systems provide cost control for energy use during the operation while increasing comfort conditions and BAS
Communication Management System (CMS)	PABX room, Main Distribution Frame, PTT room
	External routes for incoming cables
	Risers : vertical distribution of communication cables
Information Technologies (IT)	Text and data, voice, image, wireless systems, Internet, data networks, computer technology
Office Automation (OA)	Telephone, Fax, computers, word processors, audio-visual conferences, etc.
Intelligent Interfaces	User Adaptivity: user-system interaction to be adapted to different users
	User Modeling: system for maintaining a knowledge about the user
	Natural Language Technology: system that interprets or generates natural language in text or in speech
	Dialogue Modeling: system maintaining a natural language dialogue with the user
	Explanation Generation: system to explain its results to the user
Embedded Electronics	Electronics, electro-mechanical and structural elements, and softwares

Some of the selected design parameters for “systems-oriented” IB Criteria are listed in Table 4.2 which is explained in the following sections.

4.2.1 Building Automation System (BAS)

The proper BAS system shall be selected which will meet the needs of the user in most cost-effective way. Through the sensors integrated, BAS monitor and manage control of the following systems: HVAC, energy recovery, lighting, building access, security, fire suppression, and smoke alarm. They are remotely accessible by facilities managers to determine problem locations and monitor environmental conditions without disturbing work.

Open controls protocols such as LonTalk and BACNet, which allow communication between different types of building services (HVAC, lighting, security, fire alarm, and power), are being adapted to an increasing number of products. This will enable a wider range of cost-effective communication possibilities for user control over a common network.

BACNet, is a data communication protocol developed by ASHRAE. It can be defined as a Building Automation Network. BACNet helps different building systems and different supplier suppliers to work together. LonWorks is a special technology consisting of "neuron chip" and "LonTalk" protocol aiming to reduce the general network cost (DEGW, 1999).

BAS controls and monitors:

- Security
- Fire safety
- Lighting
- HVAC systems
- Room temperatures
- Vertical transportation.

In the beginning, it was not possible to provide integration between these services in IB design, but nowadays there are ongoing studies for integration of these different building services. BAS requires a serious programming effort and the most difficult part is to "adapt and renew itself to each individual's changing behaviors". From technology-oriented design criteria part, highly adaptive, responsive and flexible

Human-centered IB design can be reached through an effective customization and social interaction between the user and intelligent systems established.

4.2.2 Energy Management System (EMS)

Energy efficiency and management is among the most critical aspects of IBs, and centralized EMS monitors energy consumption and provides various data for operational decisions. Energy conservation shall be provided for creating sustainable and healthy environments. Most of the advanced IBs started to work on the solutions to provide energy efficient and environmentally responsive approach by keeping the human comfort and productivity as the main target to be achieved.

The most widely used Energy Management Programs within commercial buildings are time switch control, self-learning optimum start/stop and night cycle programs for the primary services. By the support of these programs, IBs can provide self-learning techniques based on the past building performance, and accumulate within the processor to calculate the latest possible time the equipment can be started to reach the required comfort levels at occupancy. Similarly the processors are able to learn to provide the early shut down (Atkin, 1988). But the user shall also be given the control of their surrounding space so that they do not feel like they have no control over the space and start to fight against the design parameters of EMS.

4.2.3 Communication Management System (CMS)

In comparison to traditional buildings, IBs greatest advantage comes from their integration of communication infrastructures. The CMS in IBs have impact on many other aspects of the building systems such as; fire and life safety systems, HVAC systems management, elevators, access control systems, lighting, electrical power, tele-communication and data management.

- CMS includes:
- PABX room,
- Main Distribution Frame,
- PTT room,
- External routes for incoming cables,
- Risers: vertical distribution of communication cables (DEGW, 1999).

4.2.4 Information Technology (IT)

All organizations must be adaptable to a high rate of change, and IT is one of the most rapidly changing aspects of technologically advanced societies. IT has a central role in the operation of organizations and how they use the space (i.e. wireless data communications, internet, and electronic mail). IT can support a new kind of decentralization to promote flexibility. Businesses gained great advantages in timing and accessibility of data and knowledge as a result of the development of IT. Information systems become the center of organizations, maintaining history, experience and expertise (Harrison et al., 1998). As the new IT technologies are introduced, building and IT infrastructure design must be flexible and adaptable to accommodate future new technologies. For a flexible IB design to accommodate IT, below items should be taken into consideration:

- Adequate power for future building/system expansion including emergency power supply,
- Adaptable power and telecommunication cores,
- Adaptable dedicated electrical and telecommunications spaces,
- HVAC delivery to dedicated IT spaces,
- Network security,
- Strategically located branch take offs and utility stubs,
- Adaptable plenum systems - either overhead or under floor, coordinated with space needs for parallel HVAC, power, lighting, and fire protection systems,
- Overhead exposed cable trays integrated with parallel HVAC, power, lighting, and fire protection systems (Kretchmer et al., 2010).

The growth in the IT is essential for better integrated, accessible information networks collected under a flexible building skin incorporating service areas. Also, there is greater demand for increasing the quality of workplaces in terms of local personal control of space, efficiency and productivity. For example, the pattern of building services such as HVAC, power, lighting, sanitary, acoustical control etc. are changing from the generalized systems providing average environmental conditions into local area response systems that can provide the particular conditions selected by users.

For increasing the building performance, efficient and easily operable and repairable economical solutions should be preferred. Davies (1988) proposes a unified theory of building services in which the "building shell", "building services" and "IT systems" become a single intelligent organism. He explains the way to achieve this as follows:

> "If the truly high technology building is to come about and provide a more responsive and adaptable working environment, our task as architects, developers, scientists, engineers and manufacturers is to elaborate the dynamically interactive building, that is, the design of the intelligent environment" (Davies, 1988: 48-54).

IT brought the question of the idea of "workspace" and "how it should be designed". Information and communication technology (ICT) has redefined relationships and altered the way people interact with their built environments. ICT is creating a huge evolution in the office design, affecting where, how, when, and what work is performed. It has changed the traditional working patterns. At a physical level, one of the major features of the modern office building has been the use of technology, especially the Internet, email, and computer network systems. The new office space will be required to provide higher levels of flexibility and adaptability than conventional designs, to enable existing ICT systems to be reconfigured with ease in response to changing organizational requirements. The organizations seek to improve their performance and ICT has a dominant role in guiding new working patterns.

Real-time control via the Internet will extend the monitoring and control of building service systems out of the building, which will increase the efficiency and reduce costs for building management operations. It will discriminate more efficiently between threats and non-threats, and increase the time available for property and life protection.

Most of the organizations using IT systems have a very high rate of change. If the communication system for the building is intelligently designed, these changes can be simply and quickly carried out for the future needs. IT has also challenged the conventions of workplace design.

Work is no longer contained to the office building and the office is becoming a networked environment that can support the mobile workers. For this reason, the design of the physical IB space must be re-considered and re-valued by integrating adaptive, responsive and flexible parameters.

4.2.5 Office Automation (OA)

OA improves the operational efficiency and employee productivity. The key features of OA are:

- Communications (E-mail, electronic bulletin boards, audio-visual conferencing)
- Databases (telephone directories, information libraries, etc.)
- Office Administration
- Office Production (document processing and transfer) (Kim, 1996).

4.2.6 Intelligent interfaces

The interface design research for intelligent interfaces lies in *"cognitive psychology"* (the theory of human thought), and intelligent interfaces are designed "to be adapted to the user's way of thinking, and to some extent understand how the user thinks" (Waern, 1997). These types of adaptive interfaces can be developed by repeating tests with the users in order to refine their designs. By this way, the properly functioning and malfunctioning parts of these interfaces will be displayed and revised in other applications.

The user-machine interface enables the users to acquire information, explore alternatives, execute plans, and monitor results. The sensory modalities of sight, sound, and touch are major channels for the human. Integration of these modalities can support human judgment, but the technologies for sight (visual presentation, spatial organization, gesture, gaze tracking, image recognition), sound (speech recognition, text-to-speech synthesis, speech store-and-forward, non-speech audio), and touch (manual gesture, two-handed input, grasp, force feedback) are incompletely developed (Flanagan et al., 1997). Development of multimodal interfaces is therefore a central concern of Human-centered intelligent systems and it takes time to develop sensory behaviors for the machines.

In intelligent systems, the intelligence does not necessarily show itself in a user interface. "An intelligent system does not necessarily have an intelligent interface and, a well-designed interface is not necessarily intelligent." There are several approaches to develop easy-to-use and effective interfaces defined by standards. But such standards impose arbitrary restrictions in the behavior of the interface in order to make it easy to learn.

They do not always lead to optional behaviors, which are essential in some applications, such as virtual reality environments (Waern, 1997). The establishment of the necessary infrastructure for customization of the interfaces can be a solution to this standardization problem. There are two definitions for the intelligent interfaces: the ones that mimic human dialogue, and adaptive ones. The definition of intelligent interfaces as "mimicking human behavior" is restrictive and it may emphasize the characteristics of human communication that may be of little use in computer communication.

There are also studies to use *natural languages* in human-computer interaction. But human language is an ambiguous subject and words and sentences mean different things in different situations. This type of interaction may be affective in human-to-human communication, as it requires different levels of interpretation from both partners. But the same type of interaction cannot be expected from a computer (Waern, 1997). There are AI studies for natural languages, which are still going on, but the targeted level of human-machine interface has not been achieved yet.

Today, different techniques applied in intelligent interfaces can be summarized as follows:

- User Adaptivity: user-system interaction to be adapted to different users;
- User Modeling: system for maintaining a knowledge about user;
- Natural Language Technology: system that interprets or generates natural language in text or in speech;
- Dialogue Modeling: system maintaining a natural language dialogue with a user;
- Explanation Generation: system to explain its results to a user (Waern, 1997).

These interface techniques can be used for establishing an interactive communication medium between the intelligent systems of the building and its user. For example, one of the most typical application areas of these intelligent interfaces is "information filtering". While searching in Internet, the user will be overloaded with the information flow and it is hard to find the appropriate information among them. By the help of this information-filtering interface, the system selects the relevant information for the user.

According to Russal and Wefal, an ideal interface can be defined as an interface that always gives the optimal response, and an intelligent interface is the one that has limited capabilities, but gives the optimal response within these limitations (Russel et al., 1991). The reasoning power of an interface needs to be in continuous progression even in these limitations to reach a better interface.

4.2.7 Embedded electronics

Integration of the wireless technologies with consumer products provided the distribution of embedded technologies in building environment. These devices know and communicate with each other.

The design of software-based digital electronics systems is a growing field and they are referred as "*embedded electronics*". Embedded products consist of electronics, electro-mechanical and structural elements, and software which play the most important role as the basic source of product functionality and versality. The smart products of the future will think and by anticipating and adapting to human needs, and link by communicating with each other. The embedded electronics revolution is being driven by what Motorola calls *"the third wave of rapid electronics growth."* The first wave of the growth was driven by the mainframe; the second, by the PC. The third wave is being driven by embedding Internet Protocol and computing power in everything from the car and the television to the cellular phone and the refrigerator. 'Smart' consumer products are revolutionizing the way we live. From cars and cameras to mobile phones, internet devices and home-entertainment systems, digital technology is evolving far beyond the personal computer.

In 1997, Intel and Microsoft began promoting the integration of personal computer (PC) software platforms with in-vehicle technologies. In this PC architecture, the driver will be connected to the Internet, e-mail, cell phone, fax/pager, as well as weather and traffic information. The computer would be able to run entertainment and security systems or contact to emergency services. (Little, 1997) Customization is an attractive feature for vehicle accessories, which allows customers to individualize their vehicles. Today, the main problem encountered by embedded system designers is:

> "the rapid prototyping of application-specific embedded system architecture when different combinations of programmable processor components, library hardware components, customized hardware components must be integrated together, while ensuring that the hardware and software parts communicate correctly" (Vercauteren**,** 1997: 359).

In relation to embedded electronic market, telecommunication and multi-media computing are among the fastest growing segments today. At the same time programmability is becoming increasingly important for facilitating *flexible* designs that can be *customized* with differentiating features for use in multiple products. To facilitate flexible low-cost designs in short design time, emerging designs are based on heterogeneous embedded system architectures. They integrate software programmable components, together with customized and pre-designed hardware processing components on a custom Integrated Circuit-microchip (Vercauteren, 1997).

The most time consuming and complex part of embedded electronics is to interface the hardware and software components together and provide an effective communication between them.

This interface design in embedded electronics (Figure 4.3) is very important for the usability of intelligent systems by human. This mirror not only reflects your image, but the weather, the news and your vital signs

Figure 4.3 : Intelligent mirror, adapted from Url-17.

If we apply the embedded intelligent features in to buildings, there should be established a robust communication chain between IB and the user. K. Oosterhuis explains this in comparison to modern cars communicating with the conditions of the road in real time. The small smart devices control the conditions of the road in real time, by sending signals through the embedded CPUs. He goes one step further and mentions about an interactive and programmable road-car system. In this system, all the smart devices in the cars will send signals to other devices embedded in other cars, and the road will send signal about its conditions to the cars (Ooesterhuis, 2002). If we apply the same principles to architecture, traditionally independent building elements could start to work together.

The users will communicate with the IBs wirelessly connected through their mobile phones and this type of communication between the user and the building creates a new architecture. K. Ooesterhuis explains this as follows:

> "…architecture can no longer be static; it can no longer be regarded as a fixed-end product. Materials will become programmable; materials will become as unpredictable as the weather" (Ooesterhuis, 2002: 98).

The interior climate, sound, image and the architectural form become dynamic elements forming an active part of a network just like the materials. This technological invasion in the architectural design will make the design process unpredictable and dynamic. The embedded electronics is everywhere, and it can be used in a wide range including intelligent clothing to IBs. Intelligent clothing combines advanced technologies with new textile materials having special properties. The integrated fabric sensors can monitor and display blood pressure, body temperature as well as interact with microchips in the building (Clements-Croome, 2001). These microchips can be embedded into materials making them responsive to changes in requirements.

Future developments in embedded electronics offer exciting possibilities for wireless intelligent spaces. Through developments in embedded sensor technology, everything can be recorded and controlled. For example, sensors in the fabric will allow local controls to be established between the occupant and his local area.

4.3 Material-Oriented IB Criteria

Today, most of the buildings are constructed from a multitude of materials, each with very specific functional demands and complex assembly requirements. Climate is one of the most important factors to consider in material and assembly selection. Also, most of the time buildings are designed by not evaluating the local environmental conditions. As a result of this fact, the buildings perform poorly and fail to keep the occupants comfortable without excessive energy use and completely rely on mechanical systems to rectify the poor construction decisions. There has to be established a dynamic relation between the smart materials and building skin. Wireless sensors would be embedded in building envelope materials to monitor performance and possible deterioration over time, and then give O&M management early notice of potential problems. In Table 4.3, "material-oriented" design criteria for IBs are categorized in three main parameters:

- Intelligent skins
- Smart materials and nano-technology
- Recyclable materials usage.

Table 4.3 : Table for Material-oriented IB Criteria.

Material-Oriented IB CRITERIA	
Intelligent Skins	Double skin
	Shading Devices
	Solar Collectors (PV)
	Tinted glass
Smart Materials - Nano-technology	Property Changing Smart Materials:
	Thermochromic
	Magnetorheological
	Thermotropic
	Shape memory
	Energy Changing Smart Materials:
	Photovoltaic
	Thermoelectric
	Piezoelectric
	Photoluminescent
	Electrostrictive
Recyclable Materials Usage	Re-used facade
	Re-used masonry

As an important component of Technology-oriented design criteria, detailed explanation of intelligent skins, smart materials & nano-technology, and recyclable materials usage are defined in the following section.

4.3.1 Intelligent Skins

Some sustainable design issues for energy saving and environmental responsiveness can be applied in IBs. Intelligent skin that is part of an overall building system is adaptive and responsive to changing exterior and interior conditions, and provides energy savings**.** Nowadays, IBs use intelligent skin systems that consist of double skin that can receive the weather data information and arrange the interior heating, cooling lighting levels according to this received data. The double skin is a system that consists of a second glazed envelope, which can maximize daylight and support energy performance. During the summer time, the double facade reduces the solar gains and heat loads of the buildings can be lessened by ventilated cavity. There will be a natural "stack effect" and absorbed solar radiation through glass, structure and blinds can be re-radiated. During the wintertime, the double facade will act as a buffer zone between the building and the outside by minimizing heat losses. (Wigginton et al., 2002) Double façade is among the most important parameters of IB design melting the passive and active design parameters in the same pot to increase the comfort conditions of the user.

Professor D. J. Clemens-Croome, defines the ultimate IB as the one that has *"an environmentally responsive envelope and this skin will control the transmission of heat, light, and sound"* (Clements-Croome, 2001). As a result of technological developments, the building skins become a set of dynamic building fabrics in which materials and building services are united in the form of active building skins. These skins become intelligent in terms of energy efficiency, using alternative passive energy sources such as the sun and the wind.

The building envelope will be affected by the development of new technologies. The facades integrating emerging technologies will have an inherent "intelligence" and be able to respond automatically or through human intervention to contextual conditions & individual needs (Kroner, 1997). Smart building materials have also given the chance to control the different forms of energy through their surface properties.

The intelligent facades can be centrally controlled in addition to manual occupant system. The intelligent skin system will respond to climatic conditions by optimizing heating and cooling loads, daylight and natural ventilation. It will also respond to environmental conditions by modifying its texture and color (Kroner, 1997).

Most of the architects create analogies between human body and building skin during the design process. They analyze the biological functioning principles of human skin and abstract some key concepts and apply them to building shell (Figure 4.4). At this point, it is relevant to mention about different approaches to human body (natural) and buildings (artificial) relation.

K. Ooesterhuis regards the building body as the extensions of the human body just like cars, computers, and other tools. He says: *"if clothes are our second skin, buildings form a third skin around our vulnerable bodies"* (Ooesterhuis: 2002: 150). The analogy between human and building skin can be helpful while searching for an adaptive, responsive and flexible skin design. The intelligent skin should be able to learn, adapt and cope with the changing environmental conditions just like the human skin. As stated by K.Ooesterhuis, the interactive architecture requires a "flexible skin" that is made up of completely new materials contradicting with the conventional cladding systems. This new skin is seamless, continuous and soft (Ooesterhuis, 2002: 77). The human body communicates through a sensory skin and the building body acts similar to human body.

According to Kas Ooesterhuis, the sensory building skin is "an intelligent membrane enveloping and protecting the building body as a cell. It is the interface between body and environment and hence between the body and its users. The users play the body as instrument. Architecture will evolve into the programming of instrumental bodies" (Ooesterhuis, 2002: 87). As the building skin is the one to take the first impacts from nature, it can be used as a climatic moderator between human body and the environment.

The IB skin should be not only designed to use minimum energy, but also it should reduce the energy output. It is difficult to evaluate the performance of energy efficient features of intelligent skins of the buildings.

Figure 4.4 : The double skin system on the facades of Helicon Building, adapted from Hawkes et al. (2002).

The ecological energy principles can provide useful bases for the evaluation of the performance of energy efficient intelligent features such as: “learning facility”, “weather data”, “responsive lights”, “sun tracking facility”, “occupant override”, “self-energy generation”, “night cooling”, “solar water heating” (Elkadi, 2000). In this study, intelligent skin refers to intelligent energy efficient systems used in combination with smart materials and climatic concerns.

4.3.2 Smart materials and nano-technology

There are research studies and laboratory experiments being done for developing smart materials that will support the sustainable development. By using nano-technology, engineers and architects can design materials to have specific characteristics to suit their requirements. Clements-Croome believes that building form and materials will dominate services in the near future. The smart materials can be separated into two groups as “passive” and “active” ones. For example, the electrochromic glasses are passive smart materials. Whereas an active system is controlled not only by external forces, but also by some internal signal. The “shape memory alloys” (SMAS) are active smart materials which will return to their former shape after deformation. When these smart materials are heated, the crystal structures of SMAS change. They are mostly used for applications which require heat to be converted into mechanical action (Smith, 2003: 131-132).There are smart materials being produced for sustainable development and recycling issues. For example, Pilkington's electrochromic glass avoids the overheating and solar glare and can save up to %50 of the energy required for air-conditioning. As a process, a low voltage electric is passed across a microscopically thin coating to the glass activating an electro chromic layer, which can darken in different stages (Smith, 2003).

In 2002, Pilkington introduced a self-cleaning "hydrophilic" glass to building market. After exposure to ultraviolet light in daylight, the coating reacts chemically in two ways. First, it breaks down the organic deposits like tree sap, bird droppings, etc., and by introducing extra oxygen molecules. Second, the coating causes the glass to become hydrophilic, which means that droplets of rain combine to form sheets of water and remove the dirt particals while sliding down the glass. The real smart aspect of this product is that the coating stores enough ultraviolet energy during the day to support the process during the night (Smith, 2003).

A new ultra-thin, polymer based material named SmartWrap has been developed by Kieran Timberlake Associates LLP, which could change the prevailing building skin understanding. The compound consists of a substrate and printed and laminated layers that have been roll-coated into a single film. The smart technology embedded in SmartWrap (Figure 4.5) allows the material to integrate and physically compress a wall's segregated functions. It is cheaper and quicker to put up a single sheet of film than it is to construct a brick wall. Also, the heating, lighting, information display and energy collection technologies can be incorporated into this smart material and removes the need to add them separately. The window and facade understanding will be changed as SmartWrap doesn't require conventional windows to let in light or allow vistas. Instead of this, the patterns printed on SmartWrap's surface can be changed. By this way, one can not only create windows, but also changes their locations or apply different visual patterns (McCormack, 2003).

The spatial identity of the workspace interior is not only a shell covering the intelligent technologies. They can be transferred into an integrated system of structure and media. For example, SmartSlab is a multimedia display system that is extremely durable modular tile. By different combinations, the units can create small or huge installations.

Figure 4.5 : The structures covered by SmartWrap, Kieran Timberlake Asc., adapted from McCormack (2004).

Zaha Hadid's Tokyo Guggenheim Art Gallery (Figure 4.6) will feature a 600 m^2 SmartSlab display for art and information built into the surface of the building (Bullivant, 2005b). This gives an idea about how pervasive computing will proceed in the near future. The intelligent skins of the buildings will become media facades communicating through light, video and voice systems and the interactive spaces will be enriched by interactive skins.

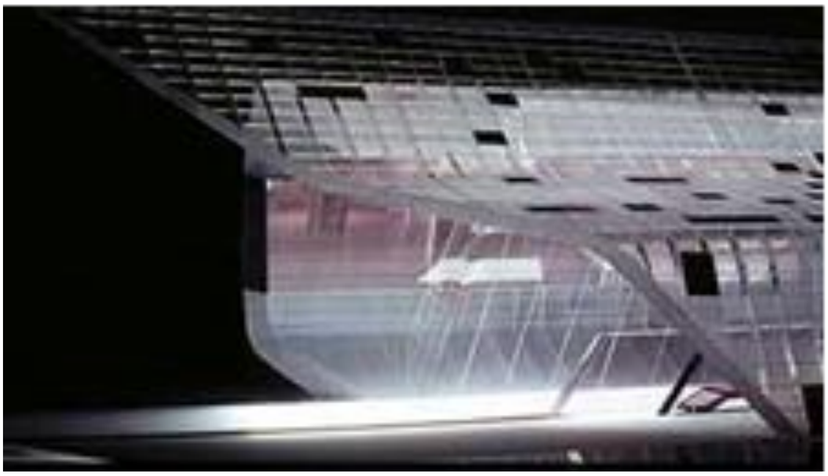


Figure 4.6 : Tokyo Gugenheim Art Gallery Project, adapted from Bullivant (2005b).

4.3.3 Recyclable materials usage

The three key factors for Energy Efficient Buildings are; "Climate", "Energy", and "Material" (Figure 4.7). Involving issues such as; daylight, solar gain, natural ventilation, recyclable materials and green energies during the design process contribute to the development of an 'environmentally responsive approach'.

Ken Yeang emphasizes the three aspects of environmentally responsive design as; variability in facade and building performance in response to 'climate' and "location of the building"; use of natural lighting and ventilation whenever possible for “energy savings”; and “material selection” based on ecological principles (Yeang, 1994). Yeang tries to conceive a more ecologically and humanly responsive architecture by creating a balance between natural and artificial environments.

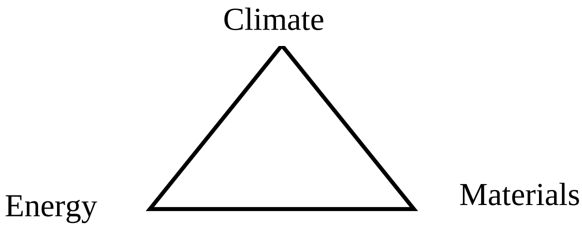


Figure 4.7 : Three aspects of environmentally responsive design, adapted from (McElroy, 1996).

Ken Yeang’s ecological high-rise building design started with energy conservation issue, but in his later works, he stressed the low environmental impact of material sourcing, and the recycling of materials (Powell, 1999).

For ecological and environmentally responsive architecture, the materials used should be robust, easy to maintain, harmless to nature, renewable and recyclable at the end of its life. The skin of intelligent high-rise buildings is extremely important for energy use and work efficiency. In order to benefit from natural sunlight, the latest technological developments in material science and nano-technology can be used.

There exists a direct relation between the building mass and embodied energy in its materials. The lower the building’s mass, the lower the total value of its overall embodied energy. While evaluating the materials’ embodied energy, the energy that will be used for their re-cycling should be taken into consideration. For example, aluminum has higher embodied energy than steel as a first cost, but at the end of its useful life, it consumes less energy than steel in its recycling process (Powell, 1999).

The energy used in the construction of the building should be considered together with the one that will be used for the production of materials. This brings forth a serious consideration for the quantity and weight of the materials that will be used for the building. The selected materials have direct impact on spatial, thermal, air, aural, and visual quality of the designed workspace, and affect the psychological, social and economic needs of the user. Technology-oriented design criteria are mainly designed to respond to changing user needs by integrating intelligent building systems, services and materials.

Building “services”, “systems”, and “materials”, have direct impact on the physical, psychological and social, and economic needs of the user. For example, HVAC and lighting design parameter as part of building “services”, they can affect the productivity and well-being of the user. If the user is given personal control over his/her workspace by providing individual air, temperature, and lighting controls, this creates a positive impact on spatial, thermal, air, aural and visual quality level of the workspace. These positive physical design parameters have impact on psychological and social needs of the user by reducing stress level, by increasing autonomy/privacy, and habitability aspects. Also, it affects the space, material, energy and investments if control limits between intelligent building systems and the user designed properly as part of an integrated Human-centered IB approach. Also, energy can be saved by reducing the amount of power used during the peak demand period by automatically dimming lights or turning them off when the user do not need it. Another energy saving system is occupancy controls which can be used together with dimming and daylight control, turning off the lights when there is no user in the workspace.

Technology-oriented design criteria discussed in this section consist of selected common design parameters that can be used as a design basis for Human-centered IBs, but it is not exhaustive and can be extended according to changing user requirements. In this thesis study, it is aimed to develop a design tool that can be used as a common design basis for reaching a Human-centered IB. It has an integrated approach for the design of “technology”, “environment”, and “user” oriented parameters. In the next Chapter, this design tool is discussed in details through checklists implemented on one sample building.

5. A DESIGN TOOL FOR HUMAN-CENTERED IBs

The aim of this research study is to propose an integrated design approach for the major components of IB which are formulated as; "User-oriented", "Environment-oriented", and "Technology-oriented" design criteria. In this proposed integrated design approach, Human-centered IB design which is adaptive, responsive and flexible to cope with changing "user needs" are supported by passive design criteria (environment-oriented) and active building systems design criteria (technology-oriented).

In the proposed integrated design approach, "user-oriented design criteria" is taken as a focal point, and supported by "environment" and "technology" oriented design criteria. G. Blachere's (1972) classification of the user requirements in four categories: "physiological", "psychological", "sociological", and "economical" requirements to meet the comfort conditions is taken as a base while formulating the user-oriented design criteria for IBs. The physical needs of the user described under four design parameters as: "spatial", "thermal", "air", "aural" and "visual" quality is based on ABSIC total building performance criteria (Appendix A) and POE studies.

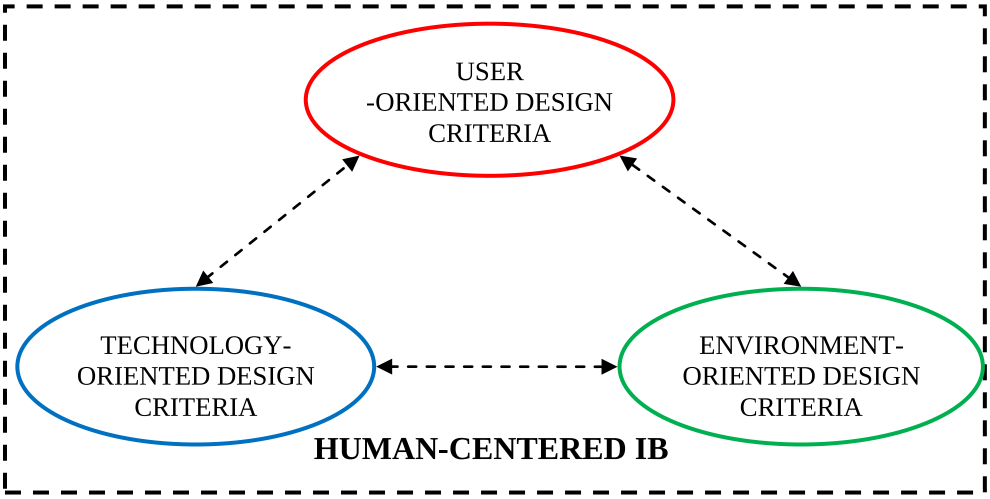


Figure 5.1 : Integration between User, Technology and Environment- Oriented design criteria for Human-centered IB

In order to formulate the design basis for “environment-oriented” design criteria of Human-centered IBs, seven sample buildings are selected and reviewed in Chapter 3. In the selected intelligent buildings, “environment-oriented” design criteria are categorized under three main parameters: “building orientation and climate”, “building skin” and “building shell” which have been formulated based on Building Rating Method (Appendix A). Following this categorization, specified environment-oriented passive design parameters (i.e. climate, building form, core location, natural ventilation, natural lighting, floor plate area, type and shape, structural planning, and plan type) are converted into a checklist to which new design parameters can be added and/or some existing ones removed based on the requirements of different projects. For the selected intelligent building (Deutsche Commerzbank Headquarter) to display the impact of environment-oriented design criteria on user requirements, extensive information reached through Post-Occupancy Evaluation studies are used.

The third major component of Human-centered IB design is “technology-oriented design criteria” which are categorized under three main parameters: building “services”, “systems” and “materials”. While formulating the technology-oriented parameters, building services and systems are based on Building Rating Method (Appendix A) whereas materials are added by the researcher.

Human-centered IBs must be able to respond to the individual, organizational and environmental requirements, and be flexible to cope with the dynamic interaction between changing user needs and technological progression. The integration between “User-oriented”, “Environment-oriented”, and “Technology-oriented” design criteria is the key factor for reaching a Human-centered IB design. In order to achieve a highly responsive, adaptive and flexible Human-centered IB design that can cope with the changing user requirements, a design tool (checklists) is developed to establish a common design basis for IBs. The various number of correlation matrices that can be established between the “user-oriented”, “technology-oriented” and “environment-oriented” design criteria are displayed in Figure 5.2.

The proposed design tool for Human-centered IB design is not a rigid and closed model. Also, these sample checklists do not include all of the design parameters for IBs. But, it is flexible enough to make the necessary adjustments like opening and/or closing, and/or extending design parameters according to the building type and program requirements of each IB.

The designer/architect can select among several layers of correlations established for IB design criteria by opening and/or closing the relevant parameters. The design parameters for Human-centered IBs can be developed in a responsive, adaptive and flexible manner if the user requirements (physical, social, psychological and economic) are integrated as the most important part of an IB design parameters from the initial design stage. In order to cope with changing user requirements, the most appropriate "technology-oriented" and "environment-oriented" criteria combination can be selected through checklists.

5.1 Human-centered IB Design Criteria Checklist

Main goal of this research study is to integrate the major components of a Human-centered IB design which are; "user-oriented", "environment-oriented" and "technology-oriented" design criteria in order to develop a design tool for Human-centered IBs which has learning, adaptive, responsive skills to cope with changing user requirements.

During the research studies, it is realized that there is no integrated design tool to be taken as a common design basis before starting the design of IBs. In these checklists, different parameters belonging to "user-oriented", "environment-oriented", and "technology-oriented" design criteria are correlated with each other. By formulating checklists as a design tool for Human-centered IBs, some generalizations can be developed to reach a common design basis for IBs. For this reason, the researcher proposed some sample checklists displaying the integrated design criteria approach for Human-centered IBs that can be used by other Architects/Designers before starting IB design.

Among the seven reviewed buildings in Chapter 3 for "environment-oriented" design criteria, Deutsche Commerzbank Headquarters in Frankfurt is selected as a sample building to be checked for the proposed IB design tool. Formulated correlation matrices can be implemented into other selected buildings, but by considering the amount of excessive information and research studies done for Deutsche Commerzbank Headquarters, it is decided to be the most appropriate sample to check the proposed design tool. Also, there is extensive amount of Post Occupancy Evaluation (POE) studies done for this building through which control checks can be done.

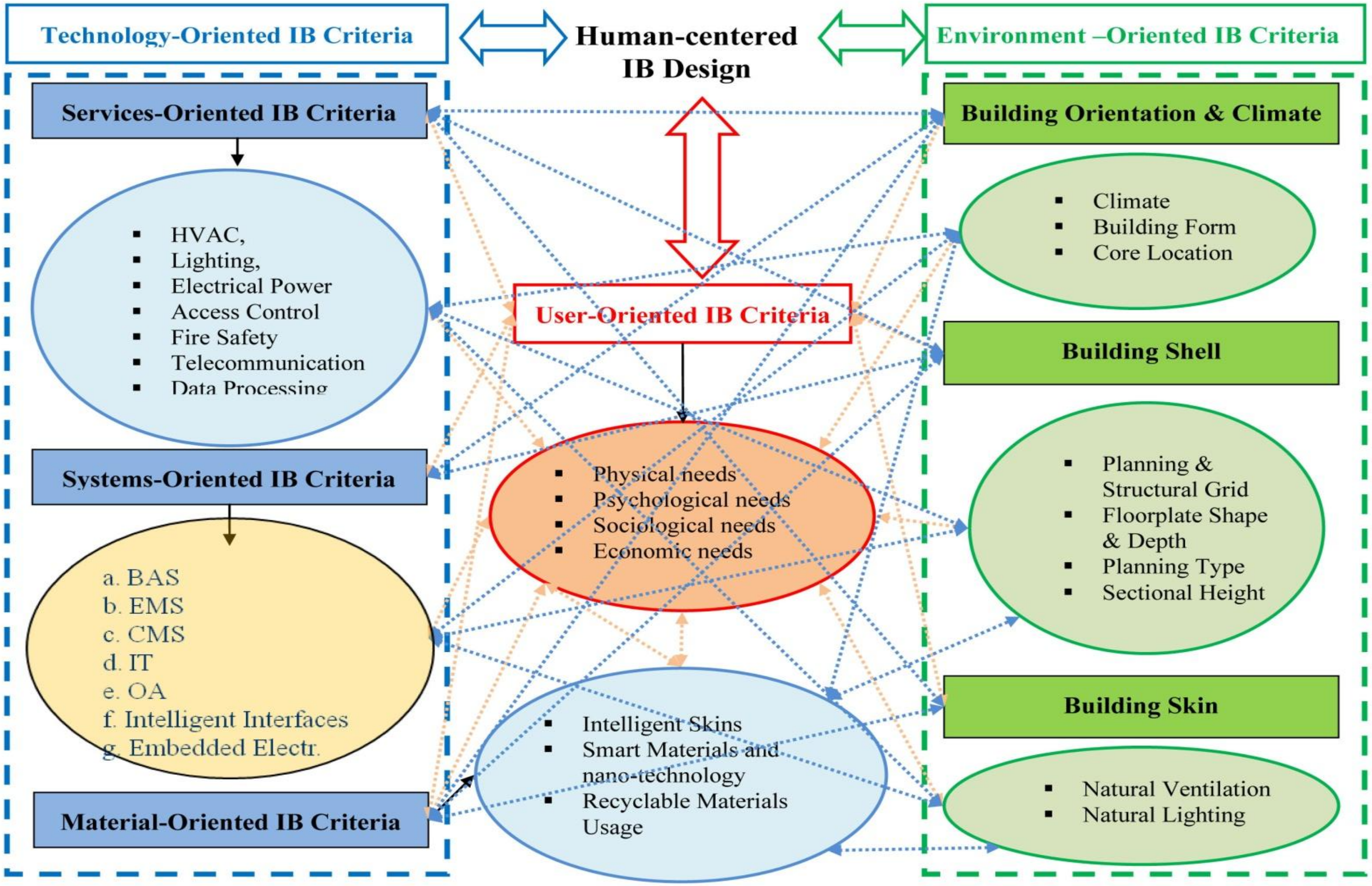


Figure 5.2 : Human-centered IB Design Integration Matrix.

By formulating these checklists based on the requirements of the user/client starting from the initial design stage of IBs, an integrated design approach which is the key for a successful Human-centered IB can be reached.

In this research study, Checklists displaying the correlation matrices between the specified three main design criteria of Human-centered IB (user, environment, technology) are formulated in two stages which can be categorized as Phase 1 and Phase 2.

- **Phase 1 Checklists:**

IB Design criteria matrix established between three major components of Human-centered IB are as follows:

1. User-oriented and Technology-oriented Design Criteria Matrix (Table 5.1)
2. User-oriented and Environment-oriented Design Criteria Matrix (Table 5.2)
3. Environment-oriented and Technology-oriented Design Criteria Matrix (Table 5.3)

Phase 1 Checklists are mainly focusing on formulating correlation matrices between design parameters of IBs for displaying the impact of "environmental" and "technological" design criteria on each other and the "user needs".

- **Phase 2 Checklists:**

IB Design criteria matrix established between "technology-oriented" and "environment-oriented" criteria are correlated in terms of their impact on physical, psychological and social", and "economic" needs of the IB user in details to display which design parameters are opened and closed by analyzing through Deutsche Commerzbank Headquarters building. IB Design criteria matrix established between three major components of Human-centered IB are as follows:

1. User-oriented IB Design criteria/Physical Needs Impact Matrix (Table 5.4-Table 5.8)
2. User-oriented IB Design criteria/Psychological and Social Needs Impact Matrix (Table 5.9-Table 5.13)
3. User-oriented IB Design criteria/Economical Needs Impact Matrix (Table 5.14-Table 5.17)

In reference to definition of Human-centered IB design used in this thesis study, an IB must be able to respond to user requirements and to cope with changes. To be able to do this, Human-centered IB should have “learning”, “adapting”, “responding” skills from its user and flexible design.

For this reason, the impact of “environment-oriented” and “technology-oriented” design criteria are checked in details for the user needs in terms of physical, social and psychological and economical parameters in Phase 2 checklists.

5.1.1 Phase 1 Checklists

In Table 5.1, “user-oriented” and “technology-oriented” Design Criteria are correlated to display which design parameters of technology-oriented design effect the user’s physical, psychological and social, and economic needs for the selected sample building (Deutsche Commerzbank Headquarters).

In IBs, building “services”, “systems”, and “materials”, have direct impact on the physical, psychological and social, and economic needs of the user. For example, HVAC and lighting design services directly affect the productivity and well-being of the user. If the user is given personal control over his/her workspace by providing individual air, temperature, and lighting controls, this creates a positive impact on spatial, thermal, air, aural and visual quality level of the workspace. These positive physical design parameters have impact on psychological and social needs of the user. They help to reduce the stress level, by increasing autonomy/privacy, and habitability aspects. Also, it affects the space, material, energy and investments conservation if control limits between intelligent building systems and the user designed properly as part of an integrated Human-centered IB approach.

This checklist is a preparatory one for displaying which technology-oriented IB criteria from building systems, services and materials are used in the building. Based on each project, these technology-oriented design parameters extend or some of them can be removed.

In Table 5.2, “user-oriented” and “environment-oriented” design criteria are correlated to display which design parameters of environment-oriented design effect the user’s physical, psychological and social, and economic needs for the selected sample building (Deutsche Commerzbank Headquarters).

Environmental design criteria have a direct impact on "physical", "psychological", social" and "economic" requirements of the user. For example, if we focus on "natural ventilation" and "natural lighting" design parameters under the "building skin" criteria, it can be seen that they have a direct impact on the spatial, thermal, air quality, aural and visual quality of the physical space. Most of the Post Occupancy Evaluation studies displayed that the passive environmental design parameters affect the productivity and well-being of the user.

The passive design parameters used in this checklist are extracted from Table 3.2 in Chapter 3, in which seven building are reviewed to formulate the design basis for passive environment-oriented design criteria.

In Table 5.3, "environment-oriented" and "technology-oriented" design criteria are correlated to display which combination of integrated Human-centered IB design parameters are used for the selected sample building (Deutsche Commerzbank Headquarters).

For example, "technology-oriented" design criteria can be correlated to "environment-oriented" design criteria based on the requirements of the user. If the natural ventilation design sub-parameters like cross ventilation, operable windows, double skin, sky-courts, atriums are taken, and correlated with HVAC design parameter of services-oriented criteria, by considering the climate zone and orientation of the building, an integrated design approach for Human-centered IB design can be reached. This integrated design approach can increase the user comfort conditions and productivity in physical, social, psychological and economic terms which is among the most important target to be achieved in Human-centered IBs.

In this integration matrix, the design criteria are specifically reviewed for Commerzbank Headquarters building, but can be implemented to other IBs by opening and closing the relevant design parameters for technology and environment-oriented design criteria.

All correlation matrices explained in Phase 1 Checklists (Table 5.1, Table 5.2, and Table 5.3) is used as design basis criteria for Phase 2 Checklist which is explained in the following part. For Phase 2 stage of the IB design checklist, there are prepared sample matrices displaying the impact of "environment-oriented" and "technology-oriented" design criteria on the "physical", "psychological and social" and “economical needs” of the user. These checklists are important for displaying which design parameter correlations needed for reaching Human-centered IB.

The specified environment-oriented and technology-oriented design parameters can be extended according to the requirements of the user/client in each project. The Architect/Designer can open and/or close some design parameters and/or add new ones based on the requirements of each IB project.

Table 5.1 : User-oriented and Technology-Oriented Design Criteria Matrix for IBs.

PHASE 1 **BUILDING NAME: COMMERZBANKHEADQUARTERS**

TECHNOLOGY-ORIENTED DESIGN CRITERIA

Services-Oriented Criteria

USER-ORIENTED DESIGN CRITERIA	HVAC				Light.		Electr. Power					
	Chillers	Heaters	VAV	FCU, AHU	Occupancy Sensor	Dimming	PV	Fuel Cells	Access Control	Lifts	Fire Safety	Telecommunication
	X	X	-	X	X	X	-	-	X	X	X	X
Physical Needs												
Spatial Quality	√	√		√	√	√			√	√	√	√
Thermal Quality	√	√		√								
Air Quality	√	√		√								
Aural Quality	√	√		√								√
Visual Quality				√	√	√			√	√		
Psychological &Social Needs												
Privacy/Autonomy	√	√		√	√	√			√	√		√
Interaction									√	√		√
Habitability	√	√		√	√	√			√	√	√	√
Mental Health/Stress	√	√		√	√	√			√	√		√
Security/Territoriality					√	√			√	√	√	√
Economical Needs												
Space Conservation	√	√			√	√			√	√	√	√
Material Conservation	√	√									√	
Energy Conservation	√	√		√	√				√	√	√	√
Investment Conservation	√	√		√	√				√	√	√	√

Systems-Oriented Criteria

USER-ORIENTED DESIGN CRITERIA	Building Automation			Office Automation					Information Technologies (IT)						Communication Management Sys.						
	BACNet	Lonworks	Integrated System (HVAC, fire etc.)	Telephone	Fax	Computers	Word Processors	Audio Visual	Tele-working	Wireless	Text and Data Voice	Image	Internet	Data Networks	PABX	Main Distribution Frame	External Routes for Coming Cables	Risers for Com. Cables	Energy Management System (EMS)	Intelligent Interfaces(II)	Embedded Electronics (EE)
	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-
Physical Needs																					
Spatial Quality	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√		
Thermal Quality	√	√	√																√		
Air Quality	√	√	√																√		
Aural Quality	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√		
Visual Quality	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		
Psychological &Social Needs																					
Privacy/Autonomy	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		
Interaction	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		
Habitability	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		
Mental Health/Stress	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√				√		
Security/Territoriality	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		
Economical Needs																					
Space Conservation	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		
Material Conservation	√	√	√																√		
Energy Conservation	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		
Investment Conservation	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√		

Material-Oriented Criteria

USER-ORIENTED DESIGN CRITERIA	Intelligent Skins					Smart Materials (Nanotechnology)									Recyc. Materials	
						Prop. Change				Energy Chang.						
	Advanced Glasses	Shading Devices	Solar Collector	Daylight Adjustment	Temperature Control	Thermochromie	Magnetorheological	Thermotropic	Shape Memory	Photovoltaic	Thermoelectric	Piezoelectric	Photoluminescent	Electrostrictiv	Re-used facade	Re-used Masonry
	X	X	-	X	X	-	-	-	-	-	-	-	-	-	-	-
Physical Needs																
Spatial Quality	√	√		√	√											
Thermal Quality	√	√		√	√											
Air Quality	√	√			√											
Aural Quality	√															
Visual Quality	√	√		√												
Psychological &Social Needs																
Privacy/Autonomy		√		√												
Interaction	√	√														
Habitability	√	√														
Mental Health/Stress				√	√											
Security/Territoriality	√	√														
Economical Needs																
Space Conservation																
Material Conservation	√			√												
Energy Conservation	√	√		√	√											
Investment Conservation	√	√		√	√											

Table 5.2 : User-oriented and Environment-Oriented Design Criteria Matrix for IBs.

PHASE 1	BUILDING NAME: COMMERZBANKHEADQUARTERS																																			
USER-ORIENTED DESIGN CRITERIA	**ENVIRONMENT-ORIENTED DESIGN CRITERIA**																																			
	Building Orientation and Climate									**Building Skin**									**Building Shell**																	
	Climate				**Bldg. Form**		**Core Location**			**Natural Ventilation**					**Natural Lighting**						**Structural Planning**			**Floor plate Shape**						**Floor plate Depth**			**Plan Type**			
	Cool	Temperate	Arid	Tropical	Fragmented	Compact	Side	Central	Dispersed	Cross Ventilation	Operable Windows	Double Skin	Atriums	Landscaping	Light Wells	Passive Shading Devices: Blinds	Passive Shading Devices: Louvre	High-efficiency Glazing	Floors	GIA Area (m^2): 85.503	Structural Grid	Planning Grid	Sectional Height(m)	Compact blocks with External Core	Bars	Deep Space Small Central Core	Shallow Space Large Central Core	Pavilions	Wings	A Type (< 6m)	B Type (6m-12m)	C Type (>12m)	Cellular Plan	Open Plan	Landscape Plan	Combi-Office Plan
	-	X	-	-	-	X	X	-	-	X	X	X	X	X	X	X	-	X	56				3,8	-	-	-	-	X	-	-	-	X	-	-	-	X
Physical Needs																																				
Spatial Quality		√				√	√			√	√	√	√	√	√	√		√	√	√			√					√				√				√
Thermal Quality		√				√	√			√	√	√	√	√	√	√		√	√	√			√					√				√				√
Air Quality		√				√	√			√	√	√	√	√				√	√	√			√					√				√				√
Aural Quality						√	√			√	√	√	√	√				√	√	√			√					√				√				√
Visual Quality						√	√			√	√	√	√	√	√	√		√	√	√			√					√				√				√
Psychological &Social Needs																																				
Privacy/Autonomy											√	√		√					√	√			√					√				√				√
Interaction						√	√				√	√	√	√	√				√	√			√					√				√				√
Habitability										√	√	√	√	√	√			√	√	√			√					√				√				√
Mental Health/Stress										√	√	√	√	√	√			√	√	√			√					√				√				√
Security/Territorialty						√	√				√	√							√	√			√					√				√				√
Economical Needs																																				
Space Conservation						√	√				√	√	√	√	√	√			√	√			√					√				√				√
Material Conservation						√	√			√	√	√				√		√	√	√			√					√				√				√
Energy Conservation		√				√				√	√	√	√		√	√		√	√	√			√					√				√				√
Investment Conservation		√				√				√	√	√	√	√	√	√		√	√	√			√					√				√				√

Table 5.3 : Environment-Oriented and Technology-Oriented Design Criteria Matrix for IBs.

PHASE 1 **BUILDING NAME: COMMERZBANK HEADQUARTERS**

ENVIRONMENT-ORIENTED DESIGN CRITERIA			TECHNOLOGY-ORIENTED DESIGN CRITERIA																																															
			Services Oriented Criteria												System Oriented Criteria																					Materials Oriented Criteria															
			HVAC				Light.		Elect Power						Building Auto.Systm			Office Automation					Information Technologies (IT)						Communication Management Syst.							Intelligent Skins					Smart Materials (Nanotechnology)									Rcycl. Mat.	
																																								Property Chg.				Energy Changing						
			Chillers	Heaters	VAV	FCU, AHU	Occupancy Sensor	Dimming	PV	Fuel Cells	**Access Control**	**Lifts**	**Fire Safety**	**Telecommunication**	BACNet	Lonworks	Integrated Sys. (HVAC, fire et.)	Telephone	Fax	Computers	Word Processors	Audio Visual	Tele-working	Wireless	Text , Data Voice	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes for Coming Cables	Risers for Com. Cables	**Energy Management System (EMS)**	**Intelligent Interfaces (II)**	**Embedded Elect. (EE)**	Advanced Glasses	Shading Devices	Solar Collector	Daylight Adjustment	Temperature Control	Thermochrom.	Magnetorhe	Thermotropic	ShapeMemory	Photovoltaic	Thermoelectr.	Piezoelectric	Photolumin	Electrostrict.	Re-used facade	Re-used Masonry
			X	X	-	X	X	X	-	-	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-	X	X	-	X	X	-	-	-	-	-	-	-	-	-	-	-
Building Orientation and Climate																																																			
Climate	Cool	-																																																	
Climate	Temperate	X	√	√		√	√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Climate	Arid	-																																																	
Climate	Tropical	-																																																	
Bldg. Form	Fragmented	-																																																	
Bldg. Form	Compact	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Core Location	Side	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Core Location	Central	-																																																	
Core Location	Dispersed	-																																																	
Building Skin																																																			
Natural Ventilation	Cross Ventilat	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Natural Ventilation	Operable Win	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Natural Ventilation	Double Skin	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Natural Ventilation	Atriums	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Natural Ventilation	Sky-courts	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Natural Lighting	Light Wells	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Natural Lighting	Passive	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Natural Lighting	High eff.glaz	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Building Shell																																																		
	# Floor	56	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Struct. Plan	Structural Grid																																																		
Struct. Plan	Planning Grid																																																		
Struct. Plan	Sectional	3.9	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Floor Plate Shape	Comp. Bl. Ext.	-																																																	
Floor Plate Shape	Bars	-																																																	
Floor Plate Shape	Deep Space	-																																																	
Floor Plate Shape	Shallow space	-																																																	
Floor Plate Shape	Pavilions	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Floor Plate Shape	Wings	-																																																	
Fl. Plate Depth	A Type (<6m)	-																																																	
Fl. Plate Depth	B Type (6m-	-																																																	
Fl. Plate Depth	C Type (>12m)	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											
Plan Type	Cellular Plan	-																																																	
Plan Type	Open Plan	-																																																	
Plan Type	Landscape	-																																																	
Plan Type	Combi-Office	X	√	√			√	√			√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√	√			√	√		√	√											

5.1.2 Phase 2 Checklists

Evaluation of the IB Design Criteria Checklists for Physical Needs of the user

In Table 5.4, the impact of "technology-oriented" and "environment-oriented" design parameters matrix on "**spatial quality**" is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate-Building Services, Systems, and Materials impact on Spatial Quality:**

- Climate, Building Form and Core Location - Services, Systems, and Material correlation:

  Compact triangular building form in a temperate climate, with the side core location reduces the heating and cooling loads of the building. Through BAS and EMS, HVAC will be adjusted according to weather condition data for providing the optimum user comfort conditions.

2. **Building Skin-Building Services, Systems, and Materials impact on Spatial Quality:**

- Natural Ventilation – Services, Systems, and Material correlation:

  Passive Design parameters such as cross ventilation, operable windows, double skin, sky-courts and atriums are used together with computerized BAS system for cooling, and heating services in the building. There are two operating modes for this building for natural ventilation. In the first operation mode, the building climate is artificially controlled with closed windows, air conditioning and cooling fully operational. In the second operation mode, that is low energy option of natural ventilation by motorized opening of the windows and deactivating the air conditioning.

  BAS has full control of the interior space, and the building can still turn to an 'optimum' state (in energy and comfort terms) after a given time period or in response to occupancy sensors. Also, Sky-courts act as solar collectors and thermal buffers and warmed with exhaust air from the offices and under floor heating. These design parameters combination has a positive impact on the spatial quality of the workspace increasing the productivity and well-being of the user by providing flexible space working modes according to different requirements.

- Natural Lighting – Services, Systems, and Material correlation:

  Natural lighting is achieved through operable perimeter windows. Lighting in the office areas are controlled by BAS according to daylight and occupancy. Also, indirect daylight received from sky-courts to some offices, is an added design value increasing space quality.

- Natural Ventilation & Natural Lighting – Intelligent skin correlation

  Double skin, operable windows integrated with advanced glasses, shading devices and daylight adjustment opportunity that can be done both manually and automatically increase the space quality through the integration of intelligent skin. Also, by implementing intelligent skin systems in Atrium and Sky-courts the ventilation, heating and cooling requirements of the space are reduced.

  High-efficiency glazing designed by the use of advanced glasses, shading devices and manual and automatic daylight adjustments increase the space quality by providing the maximum control of the lighting conditions to increase productivity and effectiveness of the user.

3. Building Shell-Building Services, Systems, Materials impact on Spatial Quality:

- Floor plate Depth, shape and area – Services, Systems, and Material correlation:

  The floor plate depth of 16.5 m allows natural ventilation through operable windows, atrium and sky-court space which has a positive impact on space quality. Space quality is also affected by the window size used in the project and proximity from the window. The floor plate depth that can be naturally lit increase the space quality by providing flexible workspace adjustments.

- Plan type – Services, Systems, and Material correlation:

  The Combi-office type planning of the office space consisting of cellular and open plan allows flexible adjustment of the space, adjustable for different working types and organizational changes. This has a positive impact on the easy modifications due to changes.

Table 5.4 : User-Oriented IB Design Criteria / Spatial Quality Impact Matrix.

PHASE 2 **BUILDING NAME: COMMERZBANK HEADQUARTERS** **■ Open Parameters**

PHYSICAL NEEDS/ SPATIAL QUALITY		TECHNOLOGY-ORIENTED DESIGN CRITERIA																																	
		Services-Oriented Criteria									Systems-Oriented Criteria																			Material-Oriented					
		HVAC			Lightg						Build Auto Sys (BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate	■	■	■							■	■	■																■	■	■	■	■		
Build Form	Compact	■	■	■	■	■	■	■	■		■	■	■								Closed								■	■	■	■	■		
Core	Side	■	■	■	■	■	■	■	■		■	■	■																■	■	■	■	■		
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■	■	■	■				■	■	■																■	■	■	■	■		
	OperableWindw	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
	Double Skin	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
	Atriums	■	■	■	■	■	■		■		■	■	■								Closed								■	■	■	■	■		
	Sky-courts	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
Natural Lighting	Light Wells	■	■	■	■	■			■		■	■	■																■	■	■	■	■		
	Pas.ShadingDev	■	■	■	■	■					■	■	■																■	■	■	■	■		
	High ef.Glazing	■	■	■	■	■					■	■	■																■	■	■	■	■		
Building Shell																																			
	# Floor	■	■	■		■	■	■	■	■	■	■	■																■	■	■	■	■		
	Sectional Height	■	■	■	■	■	■	■	■	■	■	■	■																■	■	■	■	■		
Fl.Pl.Shape	Pavilions	■	■	■	■	■	■	■	■	■	■	■	■								Closed								■	■	■	■	■		
Fl.Pl.Depth	C Type (>12m)	■	■	■	■	■	■	■	■	■	■	■	■																■	■	■	■	■		
Plan.Type	Combi-Office	■	■	■	■	■	■	■	■	■	■	■	■																■	■	■	■	■		

In Table 5.5, the impact of "technology-oriented" and "environment-oriented" design parameters matrix on **"thermal quality"** is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate - Building Services, Systems, and Materials impact on Thermal Quality:**

- Climate, Building Form and Core Location - Services, Systems, and Material correlation:

  Compact triangular building form in a temperate climate, with the side core location reduces the heating and cooling loads of the building. The thermal quality is positively impacted by passive design criteria and HVAC services integration. Full integration with EMS, the intelligent skin with advanced glass, shading devices and daylight adjustment have positive impact on adjusting thermal quality needs.

2. **Building Skin - Building Services, Systems, and Materials impact on Thermal Quality:**

- Natural Ventilation – Services, Systems, and Material correlation:

  Natural Ventilation design parameters such as cross ventilation, operable windows, double skin, sky-courts and atriums have direct correlation with HVAC planning to decide on thermal quality of the space. The fire strategy design and Access Control system have impact on the thermal conditions together with natural ventilation. For good thermal quality, they should work supporting each other.

  There are temperature control units for user intervention and adjustment of user comfort condition. The artificially controlled and low energy option of natural ventilation gives the flexibility to control the thermal conditions to user. The risk of reducing the optimum thermal conditions is prevented by BAS which has full control of the interior space.

  Also, Sky-courts act as solar collectors and thermal buffers and warmed with exhaust air from the offices and under floor heating. These design parameters combination have a positive impact on the thermal quality of the workspace by providing flexible thermal range for different type of requirements.

- Natural Lighting – Services, Systems, and Material correlation:

  Natural lighting is achieved through operable perimeter windows. Each window has an integrated motorized blind for solar shading and permitting. Lighting in the office areas are controlled by BAS according to daylight and occupancy. This has a positive impact in reducing the thermal load caused by the lighting design.

- Natural Ventilation & Natural Lighting – Intelligent skins correlation

  Double skin, operable windows integrated with advanced glasses, shading devices and daylight adjustment opportunities integrated under intelligent skin that can be controlled both manually and automatically help to increase the thermal quality of the building. Also, by implementing intelligent skin systems in Atrium and Sky-courts, the ventilation, heating and cooling requirements of the space reduced supporting thermal comfort conditions.

  High-efficiency glazing designed by the use of advanced glasses, shading devices and manual and automatic daylight adjustments increase thermal quality and provide maximum control of the natural lighting.

3. Building Shell - Building Services, Systems, Materials impact on Thermal Quality:

- Floor plate Depth, shape and area – Services, Systems, and Material correlation:

  The floor plate shape and depth allows natural ventilation through operable windows, atrium and sky-court space which has a positive impact on thermal quality. The floor plate depth of 16.5 m from a window that can be naturally lit through the operable perimeter windows; sky-courts and atrium reduce the thermal load by designing appropriate floor plate depth and shape.

- Plan type – Services, Systems, and Material correlation:

  The Combi-office type planning consisting of cellular and open plan offices with the individual room control units for temperature, window openings and blind positions to adjust the indoor air quality of the space.

Table 5.5 : User-Oriented IB Design Criteria / Thermal Quality Impact Matrix.

PHASE 2 **BUILDING NAME: COMMERZBANK HEADQUARTERS** **■ Open Parameters**

PHYSICAL NEEDS/ THERMAL QUALITY		**TECHNOLOGY-ORIENTED DESIGN CRITERIA**																																	
		Services-Oriented Criteria									**Systems-Oriented Criteria**																			**Material- Oriented**					
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lift	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasses	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	pe Mater
Building Orientation and Climate																																			
Climate	Temperate	■	■	■			■		■		■	■	■																■	■	■	■	■		
Build Form	Compact	■	■	■			■		■		■	■	■								Closed								■	■	■	■	■		
Core Loc.	Side	■	■	■			■		■		■	■	■																■						
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■			■		■		■	■	■																■	■	■	■	■		
	OperableWindw	■	■	■			■		■		■	■	■																■	■	■	■	■		
	Double Skin	■	■	■			■		■		■	■	■								Closed								■	■	■	■	■		
	Atriums	■	■	■			■		■		■	■	■																■	■	■	■	■		
	Sky-courts	■	■	■			■		■		■	■	■																■	■	■	■	■		
Natural Lighting	Light Wells	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
	Pas.ShadingDev	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
	High ef.Glazing	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
Building shell																																			
	# Floor	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
	Sectional Height	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
Fl.Pl.Shape	Pavilions	■	■	■	■	■	■		■		■	■	■								Closed								■	■	■	■	■		
Fl.Pl.Depth	C Type (>12m)	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
PlanType	Combi-Office	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		

In Table 5.6, the impact of “technology-oriented” and “environment-oriented” design parameters matrix on **“air quality”** is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate - Building Services, Systems, and Materials impact on Air Quality:**

- Climate, Building Form and Core Location - Services, Systems, and Material correlation:

  Compact triangular building form in a temperate climate, with the side core location reduces the heating and cooling loads of the building. The indoor air quality is positively impacted by passive design criteria and HVAC services integration.EMS is designed based on the principle of utilizing natural ventilation for large portion of the operation of the building which has positive impact on indoor air quality of the space.

2. **Building Skin - Building Services, Systems, and Materials impact on Air Quality:**

- Natural Ventilation – Services, Systems, and Material correlation:

  Natural Ventilation design parameters such as cross ventilation, operable windows, double skin, sky-courts and atriums have direct correlation with HVAC design in providing good indoor air quality. The fire strategy design, lifts and Access Control system have impact on the air quality mainly in occupational loads. Natural ventilation is done by BAS controlled perimeter windows. For reaching a good indoor air quality, both passive design parameters and active systems should work in full collaboration.

  The artificially controlled and low energy option of natural ventilation gives the flexibility to control the air quality to user. The risk of reducing the optimum air quality is prevented by BMS which has full control of the interior space.

  Also, Sky-courts at the periphery of the building which have 14m height facades can be opened in good weather to ventilate the atrium space and indirectly provide fresh air to the offices facing atrium space.

- Natural Ventilation – Intelligent skins correlation

  Double skin, operable windows integrated with advanced glasses, shading devices and daylight adjustment opportunities integrated under intelligent skin that can be controlled both manually and automatically help to increase the air quality of the building. Also, by implementing intelligent skin systems in Atrium and Sky-courts, the ventilation, heating and cooling requirements of the space reduced providing good indoor air quality.

3. Building Shell - Building Services, Systems, Materials impact on Air Quality:

- Floor plate Depth, shape and area – Services, Systems, and Material correlation:

The floor plate shape and depth allows natural ventilation through operable windows, atrium and sky-court space which has a positive impact on air quality.

Fresh air, fresh air distribution, restriction of mass pollution, restriction of energy pollution, and occupancy factors/controls are critical items for air quality. Access Control, lifts and fire safety design which are interrelated to occupancy factors have impact on good indoor quality together with the floor plate design.

BAS is affective design criteria for the integration of all these systems to have good indoor air quality.

- Plan type – Services, Systems, and Material correlation:

Combi-office type planning consisting of cellular and open plan allows flexible adjustment of the space.

There are individual room control units to control temperature, window openings and blind positions to adjust the air quality of the space.

Table 5.6 : User-Oriented IB Design Criteria / Air Quality Impact Matrix.

PHASE 2		BUILDING NAME: COMMERZBANK HEADQUARTERS																												■ Open Parameters					
PHYSICAL NEEDS / AIR QUALITY		**TECHNOLOGY-ORIENTED DESIGN CRITERIA**																																	
		Services-Oriented Criteria									**Systems-Oriented Criteria**																			**Material-Oriented**					
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate	■	■	■			■	■	■		■	■	■																■				■		
Build Form	Compact	■	■	■			■	■	■		■	■	■								Closed								■				■		
Core	Side	■	■	■			■	■	■		■	■	■																■				■		
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■			■	■	■		■	■	■																■				■		
	OperableWindw	■	■	■			■	■	■		■	■	■																■				■		
	Double Skin	■	■	■			■	■	■		■	■	■								Closed								■				■		
	Atrium	■	■	■			■	■	■		■	■	■																■				■		
	Sky-courts	■	■	■			■	■	■		■	■	■																■				■		
Natural Lighting	Light Wells																																		
	Pas.ShadingDev																																		
	High ef.Glazing																																		
Building Shell																																			
	# Floor	■	■	■			■	■	■		■	■	■																■				■		
	Sectional Height	■	■	■			■	■	■		■	■	■																■				■		
Fl.Pl.Shape	Pavilions	■	■	■			■	■	■		■	■	■								Closed								■				■		
Fl.Pl.Depth	C Type (>12m)	■	■	■			■	■	■		■	■	■																■				■		
Plan Type	Combi-Office	■	■	■			■	■	■		■	■	■																■				■		

In Table 5.7, the impact of “technology-oriented” and “environment-oriented” design parameters matrix on “**aural quality**” is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate - Building Services, Systems, and Materials impact on Aural Quality:**

- Climate, Building Form and Core Location – Services, Systems, and Material correlation:

  Compact building form with core locations on each corner is a design supporting good aural quality with less noise level in main working area. Access Control system, lifts, fire strategy is affective together with core location and building form to reach a good aural quality in the workspace.

  Within this compact form, aural quality is affected by IT, CMS and EMS integrated through BAS. All IT and communication systems create background noise in the offices which needs to be compensated by passive design solutions to reach a good level of aural quality.

2. **Building Skin - Building Services, Systems, and Materials impact on Aural Quality:**

- Natural Ventilation – Services, Systems, and Material correlation:

  Natural Ventilation design parameters such as cross ventilation, operable windows, double skin, sky-courts and atriums create some background noise level based on the occupancy load, frequency of the action etc. In addition OA, IT , CMS facilities are effecting the aural quality of the workspace together with natural ventilation. So, these technical and environmental design parameters should be integrated to find a solution to mitigate noise level. BAS can find a solution to the aural problems in the office by shutting down the noise factor.

3. **Building Shell - Building Services, Systems, Materials impact on Aural Quality:**

- Floor plate Depth, shape and area, Sectional Height – Services, Systems, and Material correlation:

The floor plate shape and depth allows natural ventilation through operable windows, atrium and sky-court space which create noise level because of the high occupancy level and acoustics of the space. It has to be solved in full collaboration with intelligent building systems to avoid and mitigate the reverse effects on aural quality.

Background noise caused by HVAC systems need to be minimized which has a direct impact on aural quality of the space and efficiency of the worker.

- Plan type – Services, Systems, and Material correlation:

The Combi-office type planning consisting of cellular and open plan type offices and the noise level disturbance is one of the most critical design problems to be solved. The occupancy factors/controls needs to be analysed for access control, lifts, and firefighting design parameters which is effective in aural quality of the space.

There has to be provided some opportunities for privacy and concentration in open plan offices by using partition heights, sound absorbing materials and background noise masking.

Table 5.7 : User-Oriented IB Design Criteria / Aural Quality Impact Matrix.

PHASE 2 **BUILDING NAME: COMMERZBANK HEADQUARTERS** **■ Open Parameters**

PHYSICAL NEEDS/ AURAL QUALITY		TECHNOLOGY-ORIENTED DESIGN CRITERIA																																	
		Services-Oriented Criteria									Systems- Oriented Criteria																			Material-Oriented					
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT – ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU.VAV.AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate																																		
Build Form	Compact							■	■	■	■	■	■			■	■	■	■	■	■		■	■	■	■	■	■	■						
Core	Side							■	■	■	■	■	■			■	■	■	■	■	■		■	■	■	■	■	■	■						
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■			■	■	■	■	■	■	■																■						
	OperableWindw	■	■	■			■	■	■	■	■	■	■			■	■	■	■	■	■		■	■	■	■	■	■	■						
	Double Skin	■	■	■			■	■	■	■	■	■	■			■	■	■	■	■	■		■	■	■	■	■	■	■						
	Atriums	■	■	■			■	■	■	■	■	■	■																■						
	Sky-courts	■	■	■			■	■	■	■	■	■	■																■						
Natural Lighting	Light Wells																																		
	Pas.ShadingDev																																		
	High ef.Glazing																																		
Building Shell																																			
	# Floor						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■						
	Sectional Height	■	■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■						
Fl.Pl.Shape	Pavilions	■	■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■						
Fl.Pl.Depth	C Type (>12m)	■	■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■						
Plan. Type	Combi-Office	■	■	■			■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■	■	■	■	■	■						

Closed

In Table 5.8, the impact of “technology-oriented” and “environment-oriented” design parameters matrix on “**visual quality**” is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate - Building Services, Systems, and Materials impact on Visual Quality:**

- Climate, Building Form and Core Location – Services, Systems, and Material correlation:

  Compact building form with core locations on each corner is a design supporting good visual quality with the offices having view from their windows. . Access Control system, lifts, fire strategy is affective together with core location and building form design to reach a good visual quality without obstructions. Intelligent skin consisting of advanced glass, shading devices and daylight adjustments are important for increasing the visual quality of the building by providing highly transparent office space with adjustment options on the facade.

2. **Building Skin - Building Services, Systems, and Materials impact on Visual Quality:**

- Natural Lighting & Natural Ventilation – Services, Systems, and Material correlation:

  Natural lighting taken through operable windows and double skin facade affect illumination distribution in a workspace, and may cause glare that prevent visual quality. Also, operable windows play an important role in providing visual contact with the urban environment and landscape while working.

  Smart materials are also other design criteria to be correlated with building skin properties and natural lighting. It is nor used in this building, but can be used for increasing visual quality of the building. Smart materials are not used in this building but in the general checklist of “technology-oriented” design criteria they are included and effect visual quality.

  Operable windows, atriums, sky-courts design parameters have an impact on BAS, OA, IT, CMS facilities for supporting visual quality of the space without the intervention on both passive and active design criteria. Any type of systems interface in these spaces, effect the visual perception of the user.

Natural lighting design has strong correlation with occupancy sensors perceiving the user movement and adjusts the artificial lighting and dimming parameters to adjust a good working environment with high visual quality.

Natural daylight improves the productivity of the workers and is used effectively by implementing appropriate shading and glare protection systems in the workspace increasing visual quality.

3. **Building Shell - Building Services, Systems, Materials impact on Visual Quality:**

- Floor plate Depth, shape and area, Sectional Height – Services, Systems, and Material correlation:

  The floor plate shape and depth allows natural lighting through operable windows, double skin, atriums and sky-courts space which has added value to the visual quality of the space. Depending on the occupancy load and access control, lifts and fire strategy design integrated to BAS, AO, IT and CMS, the office space can be designed in a visually flexible manner providing motivating environment to the user.

- Plan type – Services, Systems, and Material correlation:

  The Combi-office type planning consists of cellular and open plan type offices and the lighting level distribution reducing artificial light use. The occupancy factors/controls needs to be analysed for access control, lifts, and firefighting design parameters which is effective in visual quality of the space by integration of the associated routings, signage, and access control system.

  There is a visual continuity provided from sky-courts to atrium and inner facade offices work well with the floor plate shape and depth of this building. Sectional height (3.8m) is working well with the daylight admittance level and continuous access to landscape view.

Table 5.8 : User-Oriented IB Design Criteria / Visual Quality Impact Matrix.

PHASE 2		**BUILDING NAME: COMMERZBANK HEADQUARTERS**																														**■ Open Parameters**			
PHYSICAL NEEDS/ VISUAL QUALITY		**TECHNOLOGY-ORIENTED DESIGN CRITERIA**																																	
		Services-Oriented Criteria									**Systems- Oriented Criteria**																			**Material-Oriented**					
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate																																		
Build Form	Compact								■		■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
Core	Side				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
Building Skin																																			
Natural Ventilation	Cross Vent.																																		
	OperableWindw				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
	Double Skin										■	■	■																						
	Atriums	Closed			■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	Closed		
	Sky-courts				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
Natural Lighting	Light Wells				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
	PasShadingDev.				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
	High ef.Glazing				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
Building Shell																																			
	# Floor				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
	Sectional Height				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
Fl.Pl.Shape	Pavilions				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
Fl.Pl.Depth	C Type (>12m)				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			
Plan Type	Combi-Office				■	■	■	■	■	■	■	■	■			■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■			

Evaluation of the IB Design Criteria Checklists for Psychological and Social Needs of the user:

In Table 5.9, the impact of "technology-oriented" and "environment-oriented" design criteria on **"privacy/autonomy"** of the user is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate-Building Services, Systems, and Materials impact on Privacy/Autonomy**

- Climate, Building Form and Core Location – Services, Systems, and Material correlation:

  The location of lifts on each corner of the compact building form integrated with the access control and fire safety design principles considering the occupancy load and user flow in different part of the buildings, effect privacy/autonomy zone of the user.

  As the user is given the control of space in terms of daylight adjustment, glare control, responsive artificial lighting, heating and cooling control, and ventilation control, BAS integrating all these services plays a major role increasing privacy/autonomy of the user. EMS needs to provide the balance between the user autonomy and energy saving requirements of the buildings.

  IT and OA systems are important for providing the autonomy/privacy of the user to be able to work alone and communication.

2. **Building Skin-Building Services, Systems and Materials impact on Privacy /Autonomy:**

- Natural Ventilation – Services, Systems, and Material correlation:

  The user of the building is given individual control of his/her environment through operable windows the productivity and well-being of the user increases. The "operable windows", integrated with HVAC, BMS and EMS as a hybrid design give privacy/autonomy to the user in terms of adjusting his/her comfort conditions in his/her working zone.

- Natural Lighting – Services, Systems, and Material correlation:

  The passive shading devices used in the facade gives privacy/autonomy to the user to adjust his lighting conditions together with lighting design parameters of occupancy sensor and dimming.

- Natural Ventilation & Natural Lighting – Intelligent Skins correlation

  High-efficiency glazing implemented by the use of advanced glasses, shading devices and manual and automatic daylight adjustments allows more privacy/autonomy to the user to control the lighting conditions around his workspace. Also, operable windows with intelligent skin design give autonomy to user to adjust her ventilation requirement.

3. Building Shell-Building Services, Systems and Materials impact on Privacy /Autonomy:

- Floor plate depth, shape and area – Services, Systems, and Material correlation:

  The floor plate depth allows natural ventilation through operable windows, atrium, and sky-court space which has a positive impact on privacy/autonomy of the user.

  The lighting design is affected by the window size used in the project and proximity from the window. The floor plate depth of 16.5 m from a window that can be naturally lit increase the privacy/autonomy possibility allowing flexible adjustment of workspace. Also, intelligent skins supporting daylight adjustment with shading devices increase autonomy/privacy need of the user.

  Together with the integrated BAS, IT, and OA facilities support the creation of own autonomy/privacy zone of the user.

- Plan type – Services, Systems, and Material correlation:

  The Combi-office type planning of the office space consisting of cellular and open plan allows flexible adjustment of the space, adjustable for different working types and organizational changes. This has a positive impact complying with the privacy/autonomy that can be achieved in cellular offices that user can have a full control of the space.

Table 5.9 : User-Oriented IB Design Criteria / Privacy-Autonomy Impact Matrix.

PHASE 2		BUILDING NAME: COMMERZBANK HEADQUARTERS																												■ Open Parameters					
PSYCHOLOGICAL& SOCIAL NEEDS/ PRIVACY /AUTONOMY		**TECHNOLOGY-ORIENTED DESIGN CRITERIA**																																	
		Services -Oriented Criteria									**Systems-Oriented Criteria**																			**Material-Oriented**					
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate										■	■	■																■						
Build Form	Compact				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			Closed		■	■	■	■			
Core	Side				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■	■	■	■			
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■							■	■	■																■						
	OperableWindw	■	■	■			■	■	■		■	■	■																■	■	■	■			
	Double Skin	■	■	■							■	■	■																■						
	Atriums	■	■	■							■	■	■								Closed								■						
	Sky-courts	■	■	■							■	■	■																■						
Natural Lighting	Light Wells				■	■					■	■	■																■						
	PasShadingDevi				■	■					■	■	■																■	■	■	■			
	High ef.Glazing				■	■					■	■	■																■						
Building Shell																																			
	# Floor				■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■					■		■	■			
	Sectional Height				■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■					■		■	■			
Fl.Pl.Shape	Pavilions				■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■			Closed		■		■	■			
Fl.Pl.Depth	C Type (>12m)				■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■					■		■	■			
Plan Type	Combi-Office				■	■	■	■	■		■	■	■	■	■	■	■	■	■	■	■	■	■	■					■		■	■			

In Table 5.10, the impact of "technology-oriented" and "environment-oriented" design criteria on **"interaction"** of the user is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate-Building Services, Systems, and Materials impact on Interaction**

- Climate, Building Form and Core Location – Services, Systems, and Material correlation:

  Compact building form with core location on 3 sides has impact on the interaction pattern of the office workers. As a result the new IT applications, work can be done from everywhere, and reduce the necessity of face-to-face communication. This has a direct impact on workspace planning and common meeting areas where there is face to face interaction.

2. **Building Skin-Building Services, Systems and Materials impact on Interaction:**

- Natural Ventilation & Natural Lighting – Services, Systems, and Material correlation:

  The user of the building is given the option of social interaction spaces of atrium and sky-courts that is naturally ventilated and taking daylight. These sky-courts of 14 m height provide a breathing space to workers with landscaped seating areas improving the interaction among the workers. The user interacts with his environment by using passive shading devices, operable windows, atriums, sky-courts. These passive design parameters integrated with active systems strengthen the interaction level among people as well.

3. B**uilding Shell-Building Services, Systems and Materials impact on Interaction:**

- Floor plate depth, shape and area – Services, Systems, and Material correlation:

  The floor plate depth allows natural ventilation through operable windows, atrium, and sky-court space which has a positive impact on interaction of the user with his environment and the other staff.

Together with the integrated BAS, IT, and OA facilities support the creation of different interaction zones for different type of tasks. Especially IT and Office Automation systems increase the rate of virtual interaction rather than physical one.

- Plan type – Services, Systems, and Material correlation:

The Combi-office type planning of the office space consisting of cellular and open plan allows flexible adjustment of the space, adjustable for different type of interaction patterns. It has impact on the adjustment of IT, OA, EMS and BAS.

Table 5.10 : User-Oriented IB Design Criteria / Interaction Impact Matrix.

PHASE 2		BUILDING NAME: COMMERZBANK HEADQUARTERS																																	■ Open Parameters
PSYCHOLOGICAL& SOCIAL NEEDS/ INTERACTION		TECHNOLOGY-ORIENTED DESIGN CRITERIA																																	
		Services-Oriented Criteria									Systems-Oriented Criteria																		Material-Oriented						
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate										■	■	■																■						
Build Form	Compact				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Closed				■		■	■			
Core	Side				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■		■	■			
Building Skin																																			
Natural Ventilation	Cross Vent.										■	■	■																■						
	OperableWindw										■	■	■																■		■	■			
	Double Skin										■	■	■																■						
	Atriums						■	■	■	■	■	■	■									Closed							■		■	■			
	Sky-courts						■	■	■	■	■	■	■																■		■	■			
Natural Lighting	Light Wells						■	■	■	■	■	■	■																■		■	■			
	Pas.ShadingDev						■	■	■	■	■	■	■																■		■	■			
	High ef.Glazing										■	■	■																■						
Building Shell																																			
	# Floor				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■		■	■			
	Sectional Height				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■		■	■			
Fl.Pl.Shape	Pavilions				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Closed				■		■	■			
Fl.Pl.Depth	C Type (>12m)				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■		■	■			
Plan. Type	Combi-Office				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■					■		■	■			

In Table 5.11, the impact of “technology-oriented” and “environment-oriented” design criteria on **“habitability”** of the user is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate-Building Services, Systems, and Materials impact on Privacy/Autonomy**

- Climate, Building Form and Core Location – Services, Systems, and Material correlation:

  Compact triangular building form in a temperate climate, with the side core location reduces the heating and cooling loads of the building. Through BAS and EMS, HVAC will be adjusted and the user has the control of the comfort condition adjustment for habitability. By integrated occupancy sensors, the lighting of the space which is one of the basic needs for habitability is integrated into EMS.

  For the habitability, the common physical needs like natural ventilation and natural lighting are taken as a base. For this reason, IT, OA, and CMS design parameters are closed but they can be opened based on the habitability level definition on each project.

2. **Building Skin-Building Services, Systems and Materials impact on Habitability**

- Natural Ventilation – Services, Systems, and Material correlation:

  The user of the building is given individual control of his/her environment through operable windows and shading devices. The “operable windows”, integrated with HVAC, BMS and EMS as a hybrid design have positive impact in terms of improving the habitability level giving some options to the user for his physical needs.

- Natural Lighting –, Services, Systems, and Material correlation:

  HVAC combined with passive shading devices and high efficiency glazings have impact on the habitability of the space. Also, occupancy sensors following habitants movement pattern, is integrated to EMS for energy saving.

- Natural Ventilation & Natural Lighting – Intelligent Skins correlation

High-efficiency glazing implemented by the use of advanced glasses, shading devices and manual and automatic daylight adjustments increase the habitability conditions of the user in the building.

3. **Building Shell-Building Services, Systems and Materials impact on Habitability**

- Floor plate depth, shape and area – Services, Systems, and Material correlation:

  The floor plate depth allows natural ventilation through operable windows, atrium, and sky-court space which has positive impact habitability conditions of the user.

  The lighting design is affected by the window size used in the project and proximity from the window. The floor plate depth of 16.5 m from a window that can be naturally lit increase the habitability of the user. Also, intelligent skins supporting daylight adjustment with shading devices increase habitability by adjusting comfort conditions of the user.

- Plan type – Services, Systems, and Material correlation:

  The Combi-office type planning of the office space consisting of cellular and open plan allows flexible adjustment of the space, adjustable for different working types and organizational changes. This flexibility has a positive impact for habitability in which the user can feel that he can take control over workspace in cellular offices or work as a part of a team in open space

Table 5.11 : User-Oriented IB Design Criteria / Habitability Impact Matrix.

PHASE 2		**BUILDING NAME: COMMERZBANK HEADQUARTERS**																														**■ Open Parameters**			
PSYCHOLOGICAL& SOCIAL NEEDS / HABITABILITY		**TECHNOLOGY-ORIENTED DESIGN CRITERIA**																																	
		Services-Oriented Criteria									**Systems-Oriented Criteria**																		**Material-Oriented**						
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate	■	■	■	■			■	■		■	■	■																■	■	■	■	■		
Build Form	Compact	■	■	■	■			■	■		■	■	■								Closed								■	■	■	■	■		
Core	Side	■	■	■	■			■	■		■	■	■																■	■	■	■	■		
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■					■		■	■	■																■	■	■	■	■		
	OperableWindw	■	■	■			■		■		■	■	■																■	■	■	■	■		
	Double Skin	■	■	■					■												Closed								■	■	■	■	■		
	Atriums	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
	Sky-courts	■	■	■	■	■	■		■		■	■	■																■	■	■	■	■		
Natural Lighting	Light Wells																																		
	PasShadingDevi	■	■	■	■	■					■	■	■																■	■	■	■	■		
	High ef.Glazing	■	■	■	■	■																											■		
Building Shell																																			
	# Floor	■	■	■	■	■	■	■	■	■	■	■	■																■	■	■	■	■		
	Sectional Height	■	■	■	■	■	■	■	■	■	■	■	■																■	■	■	■	■		
Fl.Pl.Shape	Pavilions	■	■	■	■	■	■	■	■	■	■	■	■								Closed								■	■	■	■	■		
Fl.Pl.Depth	C Type (>12m)	■	■	■	■	■	■	■	■	■	■	■	■																■	■	■	■	■		
Plan Type	Combi-Office	■	■	■	■	■	■	■	■	■	■	■	■																■	■	■	■	■		

In Table 5.12, the impact of "technology-oriented" and "environment-oriented" design criteria on **"mental health/stress"** of the user is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate-Building Services, Systems, and Materials impact on Mental Health/Stress**

- Climate, Building Form and Core Location – Services, Systems, and Material correlation:

  The basic physical human needs like natural ventilation and natural lighting are taken as major design criteria impacting mental health rather than technological ones in this correlation.

  In this compact building, HVAC will be adjusted according to weather condition data for providing the optimum user comfort conditions by BAS. The impact on mental health/stress occurs when the user has no control over the adjustment of comfort conditions in the workspace. In this building, there is user control panels integrated into rooms and user has also control of the space.

  By integrating occupancy sensors, the lighting level of the workspace can be kept in optimum level without reducing the comfort conditions of the user and impacting mental health of the user.

2. **Building Skin-Building Services, Systems and Materials impact on Mental Health/Stress**

- Natural Ventilation – Services, Systems, and Material correlation:

  The user of the building is given individual control of his/her environment through operable windows and shading devices. The "operable windows", integrated with HVAC, BMS and EMS as a hybrid design have positive impact on mental health and reduce stress level. The user feels comfortable if he knows that he has got options to control his environment.

- Natural Lighting –, Services, Systems, and Material correlation:

  HVAC combined with passive shading devices and high efficiency glazing has impact improve the lighting level of the space.

A research study on daylight revealed that productivity is increased with window size and proximity as well as with view out. This building has got windows all around the periphery receiving daylight which has a positive impact on the user's mental health.

- Natural Ventilation & Natural Lighting – Intelligent Skins correlation

  High-efficiency glazing implemented by the use of advanced glasses, shading devices and manual and automatic daylight adjustments increase the mental health conditions of the user.

3. Building Shell-Building Services, Systems and Materials impact on Men

- Floor plate depth, shape and area – Services, Systems, and Material correlation:

  The floor plate depth allows natural ventilation through operable windows, atrium, and sky-court space which has positive impact on mental health conditions of the user. The users have breathing and socializing space like sky-courts where they can socialize, interact and release the stress of office environment with natural ventilation, lighting and landscape.

  The lighting design is affected by the window size used in the project and proximity from the window. The floor plate depth of 16.5 m from a window that can be naturally lit increase the efficiency and productivity of the user by providing a healthy environment. Also, intelligent skins supporting daylight adjustment with shading devices have positive impact on mental health by giving a chance to adjust the comfort conditions of the user.

- Plan type – Services, Systems, and Material correlation:

The Combi-office type planning of the office space consisting of cellular and open plan allows flexible adjustment of the space, adjustable for different working types and organizational changes. This flexibility has a positive impact on mental health but there are some stress creating factors like noise control, furniture layout, in open plan office part. For this reason, the workers are more stressed in open plan offices.

Table 5.12 : User-Oriented IB Design Criteria / Mental Health-Stress Impact Matrix.

PHASE 2 **BUILDING NAME: COMMERZBANK HEADQUARTERS** **■ Open Parameters**

PSYCHOLOGICAL& SOCIAL NEEDS / MENTALHEALTH /STRESS		**TECHNOLOGY-ORIENTED DESIGN CRITERIA**																																	
		Services-Oriented Criteria									**Systems-Oriented Criteria**																		**Material-Oriented**						
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate	■	■	■	■	■	■	■	■		■	■	■																■	■	■	■	■		
Build Form	Compact	■	■	■	■	■	■	■	■		■	■	■								Closed								■	■	■	■	■		
Core	Side	■	■	■	■	■	■	■	■		■	■	■																■	■	■	■	■		
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■	■	■	■	■	■		■	■	■																■	■	■	■	■		
	OperableWindw	■	■	■	■	■	■	■	■		■	■	■																■	■	■	■	■		
	Double Skin																																		
	Atriums	■	■	■	■	■	■	■	■		■	■	■								Closed								■	■	■	■	■		
	Sky-courts	■	■	■	■	■	■	■	■		■	■	■																■	■	■	■	■		
Natural Lighting	Light Wells	■	■	■	■	■	■	■	■		■	■	■																■	■	■	■	■		
	Pas.ShadingDev	■	■	■	■	■	■	■	■		■	■	■																■	■	■	■	■		
	High ef.Glazing	■	■	■	■	■	■	■	■		■	■	■																						
Building Shell																																			
	# Floor	■	■	■	■	■	■	■	■	■	■	■	■																■	■	■	■	■		
	Sectional Height	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Fl.Pl.Shape	Pavilions	■	■	■	■	■	■	■	■	■	■	■	■																■	■	■	■	■		
Fl.Pl.Depth	C Type (>12m)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Plan Type	Combi-Office	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		

In Table 5.13, the impact of "technology-oriented" and "environment-oriented" design criteria on **"security/territoriality"** of the user is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate-Building Services, Systems, and Materials impact on Security/Territoriality**

- Climate, Building Form and Core Location – Services, Systems, and Material correlation:

  In this compact building form with core location on 3 corners, security/territoriality impacted zones are taken as high occupancy circulation areas to be secured by passive design parameters and active intelligent systems.

  The working patterns have changed with the ongoing technological revolution. For this reason security/territoriality needs to be assured not only in physical space but also in virtual work platform. As a result the new IT applications, work can be done from everywhere, and reduce the necessity of face-to-face communication in office space which has an impact on security/territoriality needs. In this impact matrix, active technology-oriented design parameters are opened rather than passive environment-oriented design parameters in the checklist.

2. **Building Skin-Building Services, Systems and Materials impact on Security/Territoriality**

- Natural Ventilation – Services, Systems, and Material correlation:

  Occupancy, dimming and daylight adjustments have impact on security/territoriality of the operable office windows, atrium, and sky-courts that are using natural ventilation.

  These sky-courts of 14 m height provide a breathing space to workers with landscaped seating areas need to be secured in terms of intrusions, fire, access control etc,.

3. **Building Shell-Building Services, Systems and Materials impact on Security/Territoriality**

- Floor plate depth, shape and area – Services, Systems, and Material correlation:

The floor plate depth allows natural ventilation through operable windows, atrium, and sky-court space which has a positive impact on mental health and well being of the staff but bring the issue of security/territoriality problem of these public space.

Together with the integrated BAS, IT, and OA facilities support the creation of different security/territoriality zones for different type of tasks. Especially IT and Office Automation systems increase the rate of virtual security/territoriality rather than physical one.

- Plan type – Services, Systems, and Material correlation:

  In the office space, sense of territory is associated with feelings of belonging and ownership of the space. To meet this requirement, layout of the furniture, workstation and portioning walls need to be designer by integrating user requirements and task type.

  In this building, Combi-office type planning of space consisting of cellular and open plan allows flexible adjustment of the space, adjustable for different type of security/territoriality needs. To adjust this territoriality IT, OA, EMS and BAS have great influence on the arrangement of the workspace.

Table 5.13 : User-Oriented IB Design Criteria / Security-Territoriality Impact Matrix.

PHASE 2 **BUILDING NAME: COMMERZBANK HEADQUARTERS** **■ Open Parameters**

PSYCHOLOGICAL& SOCIAL NEEDS / SECURITY-TERRITORIALITY		TECHNOLOGY-ORIENTED DESIGN CRITERIA																																	
		Services-Oriented Criteria									Systems-Oriented Criteria																		Material-Oriented						
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate										■	■	■																■						
Build Form	Compact				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			
Core	Side				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			
Building Skin																																			
Natural Ventilation	Cross Vent.										■	■	■																■						
	OperableWindw				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			
	Double Skin										■	■	■																■						
	Atriums				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			
	Sky-courts				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			
Natural Lighting	Light Wells										■	■	■																■						
	PasShadingDev										■	■	■																■						
	High ef.Glazing										■	■	■																■						
Building shell																																			
	# Floor				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			
	Sectional Height				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			
Fl.Pl.Shape	Pavilions				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			
Fl.Pl.Depth	C Type (>12m)				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			
Plan Type	Combi-Office				■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		■	■			

Closed

Evaluation of the IB Design Criteria Checklists for Economical Needs of the user

In Table 5.14, the impact of "technology-oriented" and "environment-oriented" design parameters matrix on **"space conservation"** is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate-Building Services, Systems, and Materials impact on Space Conservation**

- Climate, Building Form and Core Location - Services, Systems, and Material correlation:

  The design parameters which are mandatory for providing user comfort conditions are taken as a base in the "space conservation" matrix. The workspace need to be designed in an effective manner to reduce occupancy costs by space conservation. Compact triangular building form in a temperate climate, with the side core location reduces the heating and cooling loads of the building which has a positive impact on space conservation as a result of an effective use of the space based on correct design criteria selection.

  In the formulated space conservation matrix, the space conservation need is based on passive design parameters affecting the user space, rather than intelligent building systems such as IT, OA, CMS. So, mainly these parameters are closed and environment-oriented design parameters' relation with building services like HVAC, lighting, BAS are focused.

2. **Building Skin-Building Services, Systems, and Materials impact on Space Conservation**

- Natural Ventilation – Services, Systems, and Material correlation:

  In the space conservation needs of the user, passive design parameters such as cross ventilation, operable windows, double skin, sky-courts and atriums are taken as base integrated with computerized BAS system for cooling, and heating services in the building. For example, the two operating modes of the ventilation system: "artificial one" and "motorized opening of the windows" support space conservation need by providing more flexible comfort conditions to workspace. Another example is the sky-courts acting as solar collectors and thermal buffers.

These design parameters combination has a positive impact on the spatial conservation and provide flexible working modes according to different spatial requirements.

- Natural Lighting – Services, Systems, and Material correlation:

  Natural lighting is achieved through operable perimeter windows. Lighting which one of the most important parameters effective in the quality of space is controlled by BAS according to daylight and occupancy level. Double skin, operable windows integrated with advanced glasses, shading devices and daylight adjustment opportunity that can be done both manually and automatically provide space conservation through natural ventilation. High-efficiency glazing designed by the use of advanced glasses, shading devices and manual and automatic daylight adjustments increase the space conservation in workplace.

3. Building Shell-Building Services, Systems, Materials impact on Space Conservation

- Floor plate Depth, shape and area – Services, Systems, and Material correlation:

  The floor plate depth of 16.5 m allows natural ventilation through operable windows, atrium and sky-court space which has a positive impact on space conservation. Also, the floor plate depth allows offices that can be naturally lit increase the space conservation by providing flexible workspace adjustments in the office space for different layouts.

- Plan type – Services, Systems, and Material correlation:

  The Combi-office type planning of office space consisting of cellular and open plan allows flexible adjustment of the space, adjustable for different working types and organizational changes. This has a positive impact on the easy modifications due to changes in organizational structure and user requirements. Also, Combi-plan type of this building supports continuous re-organization in changing workplace and there has to be flexible infrastructure for services and fit-out of the space.

Table 5.14 : User-Oriented IB Design Criteria / Space Conservation Matrix.

PHASE 2 **BUILDING NAME: COMMERZBANK HEADQUARTERS** **■ Open Parameters**

ECONOMICAL NEEDS / SPACE CONSERVATION		**TECHNOLOGY-ORIENTED DESIGN CRITERIA**																																	
		Services-Oriented Criteria									**Systems-Oriented Criteria**																			**Material-Oriented**					
		HVAC			Lightg						Build Auto Sys (BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Material	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
Build Form	Compact	■	■	■	■	■	■	■	■		■	■	■								Closed								■		■		■		
Core	Side	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
	OperableWindw	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
	Double Skin	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
	Atriums	■	■	■	■	■	■	■	■		■	■	■								Closed								■		■		■		
	Sky-courts	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
Natural Lighting	Light Wells	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
	PasShadingDev	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
	High ef.Glazing	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
Building Shell																																			
	# Floor	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
	Sectional Height	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
Fl.Pl.Shape	Pavilions	■	■	■	■	■	■	■	■		■	■	■								Closed								■		■		■		
Fl.Pl.Depth	C Type (>12m)	■	■	■	■	■	■	■	■		■	■	■																■		■		■		
Plan Type	Combi-Office	■	■	■	■	■	■	■	■		■	■	■																■		■		■		

In Table 5.15, the impact of "technology-oriented" and "environment-oriented" design parameters matrix on **"material conservation"** is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate-Building Services, Systems, and Materials impact on Material Conservation:**

- Climate, Building Form and Core Location – Services, Systems, and Material correlation:

  In this building, smart materials are not used as part of technology-oriented design criteria, and for this reason it is not listed among intelligent skin parameters. But, the Architect/designer can add and use this parameter for other buildings as an active one which can effect material conservation.

  Compact triangular building form in a temperate climate, with the side core location reduces the heating and cooling loads of the building which has a positive impact on material conservation.

  The formulated material conservation matrix is based on passive design parameters affecting the materials used in the building, rather than supporting intelligent building systems such as IT, OA, CMS. So, mainly these parameters are closed and environment-oriented design parameters' relation with building services like HVAC, lighting, BAS are focused.

2. **Building Skin-Building Services, Systems, and Materials impact on Material Conservation:**

- Natural Ventilation – Services, Systems, and Material correlation:

  In the material conservation needs of the user, passive design parameters such as cross ventilation, operable windows, double skin, sky-courts and atriums are taken as base integrated with computerized BAS system for cooling, and heating services in the building. For example, the two operating modes of the ventilation system: "artificial one" and "motorized opening of the windows" support material conservation.

BAS has full control of the interior space, and the building can still turn to an 'optimum' state (in energy and comfort terms) after a given time period or in response to occupancy sensors.

Also, Sky-courts act as solar collectors and thermal buffers and warmed with exhaust air from the offices and under floor heating. These design parameters have positive impact on the material conservation of the workspace, by adjusting the indoor environmental conditions appropriate for both the user and the materials used.

- Natural Lighting – Services, Systems, and Material correlation:

  Natural lighting is achieved through operable perimeter windows. Lighting in the office areas are controlled by BAS according to daylight and occupancy level which protects materials from the reverse effects of excessive daylight.

  Double skin, operable windows integrated with advanced glasses, shading devices and daylight adjustment opportunity that can be done both manually and automatically can be used to protect the materials from environmental reverse effects by natural ventilation. Also, High-efficiency glazing designed by the use of advanced glasses, shading devices, and manual and automatic daylight adjustments helps to protect the materials in high occupancy office space.

3. **Building Shell-Building Services, Systems, Materials impact on Material Conservation**

- Floor plate Depth, shape and area – Services, Systems, and Material correlation:

  The floor plate depth allows natural ventilation through operable windows, atrium and sky-court space which has a positive impact on material conservation by avoiding humidity and rust.

- Plan type – Services, Systems, and Material correlation

Combi-plan type of this building supports continuous re-organization in changing workplace and there has to be flexible infrastructure for services and fit-out of the space. The main services that have impact on material conservation are HVAC, lighting, access control, lifts, and fire safety. The offices have control units for temperature, window openings and blind positions to adjust the indoor air quality of the space which is effective in material conservation.

Table 5.15 : User-Oriented IB Design Criteria / Material Conservation Impact Matrix.

PHASE 2		BUILDING NAME: COMMERZBANK HEADQUARTERS																																	■ Open Parameters
ECONOMICAL NEEDS/ MATERIAL CONSERVATION		**TECHNOLOGY- ORIENTED DESIGN CRITERIA**																																	
		Services-Oriented Criteria									**Systems-Oriented Criteria**																			**Material-Oriented**					
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
Build Form	Compact	■	■	■	■	■		■	■		■	■	■								Closed								■	■	■	■	■		
Core	Side	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
	OperableWindw	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
	Double Skin	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
	Atriums	■	■	■	■	■		■	■		■	■	■								Closed								■	■	■	■	■		
	Sky-courts	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
Natural Lighting	Light Wells	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
	PasShadingDev	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
	High ef.Glazing	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
Building Shell																																			
	# Floor	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
	Sectional Height	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
Fl.Pl.Shape	Pavilions	■	■	■	■	■		■	■		■	■	■								Closed								■	■	■	■	■		
Fl.Pl.Depth	C Type (>12m)	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		
Plan Type	Combi-Office	■	■	■	■	■		■	■		■	■	■																■	■	■	■	■		

In Table 5.16, the impact of “technology-oriented” and “environment-oriented” design parameters matrix on **“energy conservation”** is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. Building Orientation and Climate-Building Services, Systems, and Materials impact on Energy Conservation:

- Climate, Building Form and Core Location – Services, Systems, and Material correlation:

  All the environment-oriented and technology-oriented criteria specified in the matrix have an impact on energy conservation to make the building work in energy efficient way.

  The building orientation, core location and climate design parameters integrated with the technology-oriented design services, systems and materials to reach energy efficient buildings. The building design is established on the principle of energy consciousness and all building services, systems and intelligent materials integrated with environment-oriented passive design criteria.

2. Building Skin-Building Services, Systems, and Materials impact on Energy Conservation

- Natural Ventilation – Services, Systems, and Material correlation:

  Passive Design parameters such as cross ventilation, operable windows, double skin, sky-courts and atriums are used together with computerized BAS system for cooling, and heating services in the building. There are two operating modes for this building for natural ventilation. In the first operation mode, the building climate is artificially controlled with closed windows, air conditioning and cooling fully operational. In the second operation mode, that is low energy option of natural ventilation by motorized opening of the windows and deactivating the air conditioning. BAS has full control of the interior space, and the building can still turn to an ‘optimum’ state (in energy and comfort terms) after a given time period or in response to occupancy sensors. Also, Sky-courts act as solar collectors and thermal buffers and warmed with exhaust air from the offices and under floor heating. These design parameters combination has a positive impact on the energy conservation of the building but at the same time increase the productivity and well-being of the user by providing a workspace that has occupant control units.

- Natural Lighting – Services, Systems, and Material correlation:

  In the office buildings, lighting is one of the most energy consuming design component. In this building, natural lighting is achieved through operable perimeter windows, and lighting in the office areas is controlled by BAS according to daylight and occupancy levels. Also, indirect daylight received from sky-courts to some offices, which are design parameters to provide energy conservation.

3. Building Shell-Building Services, Systems, Materials impact on Energy Conservation

- Floor plate Depth, shape and area – Services, Systems, and Material correlation:

  Building services and systems need to be designed in great flexibility to cope with changing user and organizational needs. As a result of the IT, OA, CMS and BAS, which enable to work in a wide variety of locations within or outside of the office, the office space planning understanding changed. While providing these facilities for the new working requirements, energy consumption is the most important criteria. In IBs, these building services consuming energy need to be balanced with passive design parameters such as natural lighting, natural ventilation, etc.

- Plan type – Services, Systems, and Material correlation:

  The Combi-office type planning of the office space consisting of cellular and open plan allows flexible adjustment of the space. All building system, services, materials and environment-oriented passive design criteria are effective in energy conservation of the building. The offices have control units for temperature, window openings and blind positions to adjust the indoor air quality of the space which has an impact on energy conservation.

  IBs need to be designed by being aware of the huge energy consumption rate by using all the possible passive design parameters to mitigate its impact on the environment.

Table 5.16 : User-Oriented IB Design Criteria / Energy Conservation Impact Matrix.

PHASE 2		**BUILDING NAME: COMMERZBANK HEADQUARTERS**																																**■ Open Parameters**	
ECONOMICAL NEEDS/ ENERGY CONSERVATION		**TECHNOLOGY-ORIENTED DESIGN CRITERIA**																																	
		Services-Oriented Criteria									**Systems-Oriented Criteria**																			**Material-Oriented**					
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasses	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Build Form	Compact	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Core	Side	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	OperableWind	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	Double Skin	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	Atriums	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Closed	
	Sky-courts	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Natural Lighting	Light Wells	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	PasShadingDev	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	High ef.Glazing	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Building Shell																																			
	# Floor	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	Sectional	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Fl.Pl.Shape	Pavilions	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Fl.Pl.Depth	C Type (>12m)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Plan Type	Combi-Office	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		

Evaluation of the IB Design Criteria Checklists for Economical Needs of the user

In Table 5.17, the impact of “technology-oriented” and “environment-oriented” design parameters matrix on **“investment conservation”** is formulated. Some correlations found for the selected building for which design criteria to be kept open or to be closed are as follows:

1. **Building Orientation and Climate-Building Services, Systems, and Materials impact on Investment Conservation**

- Climate, Building Form and Core Location – Services, Systems, and Material correlation:

  All the environment-oriented and technology-oriented criteria specified in the matrix have an impact on investment conservation to make the building work in the most efficient way.

  The building orientation, core location and climate design parameters integrated with the technology-oriented design services, systems and materials to reach energy efficient buildings. The building design is established on the principle of energy consciousness. The building services like HVAC, lighting, intelligent skin system, and buildings systems like BAS, OA, IT, CMS are designed integrated manner with passive design criteria.

2. **Building Skin-Building Services, Systems, and Materials impact on Investment Conservation**

- Natural Ventilation & Natural Lighting – Services, Systems, and Material correlation:

  Passive Design parameters such as cross ventilation, operable windows, double skin, sky-courts and atriums are used together with computerized BAS system for cooling, and heating services in the building. BAS has full control of the interior space, and the building can still turn to an ‘optimum’ state (in energy and comfort terms) after a given time period or in response to occupancy sensors. All these design parameters combination has a positive impact on the energy and investment conservation. The initial investment of providing user control on the building design increase the cost but at the same time increase the productivity and well-being of the user in long term. In this building this principle has been implemented by giving control to user.

In the office buildings, lighting is one of the most critical energy consuming design component. In this building, natural lighting is achieved through operable perimeter windows, and lighting in the office areas is controlled by BAS according to daylight and occupancy levels. Also, indirect daylight received from sky-courts to some offices, which are design parameters to provide energy conservation which has direct impact on investment conservation.

3. **Building Shell-Building Services, Systems, Materials impact on Investment Conservation**

- Floor plate Depth, shape and area – Services, Systems, and Material correlation:

Building services and systems need to be designed in great flexibility to cope with changing user and organizational needs. As a result of the IT, OA, CMS and BAS, which enable to work in a wide variety of locations within or outside of the office, the office space planning understanding changed and initial investments of the buildings, need to be done by considering these changes. In order to provide these facilities for the new working requirements, future provisions need to be tone for investment conservation. In IBs, building services and systems proposed consuming energy need to be balanced with passive design parameters such as natural lighting, natural ventilation to reduce investment costs in longer term.

- Plan type – Services, Systems, and Material correlation:

The Combi-office type planning of the office space consisting of cellular and open plan allows flexible adjustment of the space. All building system, services, materials and environment-oriented passive design criteria are effective in investment conservation of the building. For example, in the selected building, the offices have control units for temperature, window openings and blind positions to adjust the indoor air quality of the space which has an impact on user productivity. The long-term cost benefits of a properly designed, user-friendly work environment should be factored into any initial cost investments. Since the user is the most important resource and greatest expense of any organization, the long-term cost benefits of a properly designed IB should be factored into any initial cost considerations.

Table 5.17 : User-Oriented IB Design Criteria / Investment Conservation Impact Matrix.

PHASE 2	BUILDING NAME: COMMERZBANK HEADQUARTERS																																		■ Open Parameters
ECONOMICAL NEEDS/ INVESTMENT CONSERVATION		TECHNOLOGY-ORIENTED DESIGN CRITERIA																																	
		Services-Oriented Criteria									Systems-Oriented Criteria																			Material-Oriented					
		HVAC			Lightg						Build Auto Sys(BAS)			Office Automat. (OA)					Information Technologies (IT)						Communication Management Sys.					Intelligent Skins					
ENVIRONMENT - ORIENTED DESIGN CRITERIA		Chillers	Heaters	FCU,VAV,AHU	Occup. Sensor	Dimming	Access Control	Lifts	Fire Safety	Telecommunication	BACNet	Lonworks	Integrated Sys.	Telephone	Fax	Computers	Word Proc.	Audio Visual	Tele-working	Wireless	Text & Data V	Image	Internet	Data Networks	PABX	Main Disturb. Frame	Ext. Routes Coming Cables	Risers Com.Cabl	Energy Management System (EMS)	Advanced Glasse	Shading Devices	Daylight Adjustment	Temperature Control	Smart Materials	Recycled Materials
Building Orientation and Climate																																			
Climate	Temperate	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Build Form	Compact	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Core	Side	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Building Skin																																			
Natural Ventilation	Cross Vent.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	OperableWindw	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	Double Skin	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	Atriums	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	Closed	
	Sky-courts	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Natural Lighting	Light Wells	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	PasShadingDevi	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	High ef.Glazing	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Building Shell																																			
	# Floor	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
	Sectional Height	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Fl.Pl.Shape	Pavilions	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Fl.Pl.Depth	C Type (>12m)	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		
Plan Type	Combi-Office	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■		

Evaluation of the proposed decision support tool

In order to test the proposed decision support tool for Human-centered IB design, the researcher selected and focused on only one office building (Deutsche Commerzbank Headquarter). In this building, some of the common IB design features like “intelligent skin”, “smart materials”, and “Communication Management System” (CMS) are not used. The prevailing design criteria in Deutsche Commerzbank Headquarter building is to provide energy efficiency by using the lowest consumption level per m^2.

Also, most of the advanced technologies used in IB design are not used for reducing the construction and demolition costs of the building by considering the economic and environmental requirements. The researcher specifically selected this building to display the strong compromise between the “environment-oriented” and “user-oriented” design criteria rather than the technology-oriented ones.

Phase 2 Checklists display the impact of an integrated “environment” and “technology-oriented” design criteria on user’s physical, psychological and social, and economic needs, and there can be reached some generalizations for passive and active design parameters which can be kept open for reaching an adaptive, responsive and flexible Human-centered IB design.

They can be summarized in Table 5.18 as follows:

- Environment-oriented Design Criteria
    1. Natural Ventilation
    2. Natural Lighting
    3. Floor plate Depth & shape
    4. Sectional Height
- Technology-oriented Design Criteria
    1. Building Automation System (integrating all services and systems with passive design parameters)
    2. Energy Management System

By using these Checklists as a decision support tool for reaching an integrated design approach for Human-centered IB design, between “user”, “environment” and “technology” oriented design criteria, it is aimed to develop a common design basis which can be used by other architects/designers to create various options for IB design based on the requirements of different projects.

For future studies, the proposed decision support tool for Human-centered IB design can be used in two ways. The other researchers can use it both for creating the design parameters of the new IBs and for the evaluation studies of the existing IBs by attributing importance factor to the selected IB design parameters proposed in the checklists.

Table 5.18 : Summary Table for Human-centered IB Design criteria Matrix for the selected sample building (Table 5.4-Table 5.17)

SUMMARY MATRIX FOR SELECTED INTELLIGENT BUILDING (DEUTSCHE COMMERZBANK HEADQUARTERS)																									
USER-ORIENTED DESIGN CRITERIA	**TECHNOLOGY-ORIENTED DESIGN CRITERIA**															**ENVIRONMENT-ORIENTED DESIGN-CRITERIA**									
	HVAC, VAV, AHU	Lighting		Access Control	Lifts	Fire Safety	Telecommunication	Building Automation System (BAS)	Office Automation (OA)	Information Technologies (IT)	Communication Management System	Energy Management. System.	Intelligent Skins	Smart Materials	Recycled Materials	Climate	Building Form	Core Location	Natural Ventilation	Natural Lighting	# of Floors	Sectional Height	Floor plate Shape	Floor plate Depth	Planning Type s
		Occupancy Sensors	Dimming																						
Physical Needs																									
Spatial Quality									■	■	■			■	■										
Thermal Quality					■		■		■	■	■			■	■										
Air Quality		■	■				■		■	■	■		■	■	■										
Aural Quality		■	■										■	■	■	■	■	■			■				
Visual Quality	■													■	■	■	■	■							■
Psychological. &Social Needs																									
Privacy/Autonomy							■				■			■	■	■	■	■			■		■		
Interaction	■									■	■		■	■	■	■	■	■							
Habitability			■				■		■	■	■			■	■										
Mental Health/Stress									■	■	■			■	■										
Security/Territoriality	■												■	■	■	■									
Economic Needs																									
Space Conservation									■	■	■			■	■										
Material Conservation									■	■	■			■	■										
Energy Conservation														■	■										
Investment Conservation														■	■										
	■	Closed Parameters																							

6. CONCLUSIONS AND EVALUATIONS

In the 21^{st} century, information and communication technology has re-defined relationships and changed the way people interact with their built environments. The major revolution can be followed through changing work patterns to meet organizational needs, technological innovations, and changing business relationships. The changing nature of work means greater mobility for workers, a multiplicity of workplaces in the interior and exterior of the buildings, greater use of geographically dispersed work groups, and increased dependence on social networks.

The type of interaction and communication among people has changed the working patterns from face-to-face to online virtual communications as a result of newly emerging technologies. The exchange of information type has impact on the space arrangement of the buildings which can be clearly tracked in the design of the new office buildings. As the teamwork and collaborative work groups increase, there is more informal interaction between the workers, more supports for virtual individual and group work, and greater flexibility in work locations. In order to support this changing nature of work and social interaction patterns, buildings and their space planning should be flexible to support future requirements. The researcher believes that, Human-centered IBs can provide a flexible solution to changing space requirements, and cope with the changing user needs by providing highly adaptive and responsive design parameters. In fact, IBs should improve the comfort conditions and the productivity of the user by providing a highly interactive, responsive, adaptive and flexible environment. The user should be given a certain level of control in their activity area both for their physical and psychological comforts. It has also been proved that the good Indoor Environmental Quality (IEQ) can increase productivity and work efficiency of the occupants. It is a psychological need for the occupants to feel that, they have got all necessary tools to control their environments rather than being controlled by them. The social scientists strongly argue that it is a psychological necessity to have the ability to control their own environment for the building occupants. The individuals work more productive and feel better, if they are given the chance to control their environments rather than fixed central control systems. This can be the key design criteria in the success of Human-centered IBs of the future.

In this thesis study, Human-centered IB is defined as an integrated design approach that is adaptive, responsive and flexible to cope with changing “user needs” and supported by passive (environment-oriented) design criteria and active intelligent building systems (technology-oriented) design criteria. Human-centered IB design criteria focus on the changing user requirements, and the user is taken as a focal point rather than technology and environment-oriented criteria. In order to achieve an adaptive, responsive and flexible Human-centered IB design that can cope with the changing needs of the user, there has to be achieved a full integration between “environmental” and “technological” design criteria.

During this research study, it has been realized that there is no design tool for reaching an integrated design approach for Human-centered IB design, and the researcher proposes a decision support tool for Human-centered IB design that can be adaptive, responsive and flexible to cope with changing user requirements. As a method, checklists displaying the correlation matrices between the “user”, “environment” and “technology” are proposed which can act like a decision support tool for Human-centered IB design among other tools. By formulating these checklists based on the requirements of the user/client for each project starting from the initial design phase of IBs, an integrated design approach for Human-centered IB design can be achieved. The researcher identifies that; one of the major problems of IBs is the user requirements (physical, social, psychological and economical) not overlapping with the designed intelligent environments. By involving the user/client from the initial design stage of the IBs, and by selecting the relevant “environment and technology-oriented” design criteria based on “user” requirements including provisions for the future changes, an integrated Human-centered IB design can be achieved.

Most of the Post Occupancy Evaluation (POE) results reveal that there is a direct link between the physical, psychological and social and economic needs of the user, and the selected “environment-oriented” and “technology-oriented” design parameters. The decision support tool proposed for IB design is developed to provide a common design basis which can merge the environment and technology-oriented design parameters to increase the productivity and well being of the user.

Developments in technology and communication changed the social and cultural behavior patterns of the user together with the physical environments. The passive role of the user has changed as a result of the ongoing technological developments in IT and communication technologies. For assuring the flexibility of IB design, it is important to make future projections for changing user requirements and integrating "technology-oriented" and "environment-oriented" design criteria based on these provisions.

In the IBs of the future, the processing and transfer of the information and knowledge through intelligent environments will be the major role of the buildings. The information has a flexible and dynamic nature, and IB designs of the future need to be adaptive, responsive and flexible to cope with this changing nature of information processing. Human-centered IBs need to be designed by considering the necessary provisions for the future. They have to integrate the requirements of physical space, environmental conditions and intelligent systems to increase the user satisfaction and productivity.

IBs of the future will be designed just like living organisms which can observe and learn from the behaviors of the user, and be able to make forecasts for the next behavior of the user. In order to reflect these criteria to physical IB environment, relevant design parameters need to be selected as part of an integrated design approach. For example, the design parameters such as; "intelligent skin", and "smart materials", and "intelligent building systems" can be correlated with passive design parameters such as "building orientation and climate", "natural ventilation", "natural lighting", "floor plate depth and shape" to reach a responsive, adaptive and flexible Human-centered IB design. Also, by adapting the intelligent learning and communication skills, building skin can be designed to act like a sensitive human skin collecting all environmental information and responding to the user requirements by using the most appropriate intelligent systems. This can be achieved by using an integrated design approach that can adjust the comfort conditions of the user, and cope with changing nature of the environmental conditions by using active and passive design parameters. The intelligent skins of the future will not act like a conventional physical barrier between the exterior and the interior, but act like a transparent skin serving the continuous flow of information.

In this study, it is aimed to introduce an integrated design approach for the design of IBs which can provide a common design basis. In order to achieve this target, a decision support tool for Human-centered IB design is created through proposed sample checklists. As a research method, Checklists displaying the correlation matrices between the specified three main design criteria of Human-centered IB: “user”, “environment” and “technology” are used which are categorized as Phase 1 and Phase 2. The selected sample building is analyzed and tested through the proposed decision support tool for IBs.

Phase-1 Checklists are mainly focusing on correlation matrices between design parameters of IBs for displaying the impact of “environmental” and “technological” design criteria on each other, and the “user needs”. Whereas in Phase 2, the information produced by Checklists in Phase 1 are used as a design basis, and “technology-oriented” and “environment-oriented” criteria are correlated in terms of their impact on physical, psychological and social”, and “economic” needs of the IB user. By this way, it can be displayed which design parameters are kept open or closed, and which ones have an impact on the physical, psychological and social, and economic needs of the user.

In Phase-2 Checklists, Deutsche Commerzbank Headquarters Building is selected among seven buildings to test the design criteria formulated for Human-centered IB design. The results of the sample correlation matrices for the impact of technology and environment oriented design criteria on user needs are given in Table 5.18 in which average range of open and closed design parameters is summarized for the selected building. It has been realized that there are some parameters which need to be kept open as they have direct impact on the user needs such as; “natural ventilation”, “natural lighting”, “floor plate depth and shape”, “sectional height”, “Building Automation System” and “Energy Management System”. Whereas some of the most commonly used design parameters generally integrated into IB design such as; “intelligent skin”, “smart materials”, “Communication Management System” etc., are seen as closed parameters for Deutsche Commerzbank Headquarters. This is caused by the Client’s requirement of being provided energy efficient building integrated with the lowest consumption level per m^2. For this reason, it doesn't overlap with the common design parameters that are used in most of the IB design.

Following IB Design checklists formulated in Phase 2, there has been extracted a summary table displaying the overall range of design parameters for the selected building (Deutsche Commerzbank) to be opened or/and closed for reaching a Human-centered IB Design. From environment oriented-criteria; "natural ventilation", "natural lighting", "floor plate depth", and "sectional height", and from "technology-oriented criteria; "Building Automation System" and "Energy Management System" design parameters need to be kept open for achieving an adaptive, responsive and flexible Human-centered IB design. During the analysis, these parameters are kept open as they have positive impact on satisfying user needs.

If we search for a conceptual background behind the proposed decision support tool (checklists), it can be seen that the design parameters are opened and/or closed depending on the requirements of the user/client and the building type. For example, in one IB project, it can be cost effectiveness and energy saving which is the driving force behind the design. If this is the case, the user requirements and technology-oriented design parameters formulated in correlation matrices are selected to support the environment-oriented design criteria and economic needs of the user. Among the selected IBs; the environment-oriented design criteria are the driving force for the design of Deutsche Commerzbank Headquarters. For this reason, some of the common design parameters which are kept open in most of the IBs (intelligent skin, smart materials, recycled materials, Communication Management System etc.) are marked as closed parameters in the prepared sample checklists. Whereas in another IB design, the user satisfaction and productivity can be the driving force behind the design decisions and relevant parameters are opened.

Human-centered IB design parameters formulated in checklists can be extended according to the requirements of the user/client in each project together with "environment-oriented" and "technology-oriented" design parameters. The proposed design tool is flexible and the Architect/Designer can open and/or close some design parameters and/or add new ones based on the requirements of each project. By this way, the Architect/Designer can produce various design options for Human-centered IBs displaying the impact of each selected technology and environment-oriented design parameter on user needs (physical, psychological and social, and economic).

In the proposed checklists, the opening and/or closing of the design parameters depend on the original design decisions.

For this research study, office building type is selected for the review and analysis of the seven selected buildings, but these checklists created for Human-centered IB design include some common design parameters that can be applicable to other building types. The main reason behind the selection of office building type is that the changing user needs and work patterns can be easily tracked, and the user behavior can be observed and categorized in a more systematic way. By using these checklists as a decision support tool for Human-centered IB design, the Architect/Designer has the option of opening and/or closing specified design parameters. This gives the flexibility to create his/her checklists by considering the driving design criteria.

In the proposed checklists, user-oriented design criteria have subjective features whereas environment and technology-oriented design criteria have more objective ones. On one side, this may be perceived as a contradiction, but on the other side this gives flexibility to adapt both to the subjective and objective design parameters based on the requirements of different building types and the user/client. For example, in the hospital, hotel, office and residence buildings, the physical, psychological and social requirements for IB design are different from each other. In this study, office building type is specifically selected for testing the decision support tool for Human-centered IB design. The reason behind this choice is to reach some generalizations for users' "physical", "social", "psychological" and "economical" requirements by revealing the impact of "environment" and "technology" oriented design criteria through correlation matrices.

Whereas, in the residence building type, each user has specific physical, social, psychological and economical needs, and for these reason it is very difficult to reach a common design basis for IBs on this building type even though some design parameters can still be generalized.

The researcher is fully aware of the subjective parameters of the proposed method and for this reason defines these checklists as "a decision support tool for Human-centered IB design". This proposed decision support tool can be used for two purposes. Firstly, the designer/architect can use this common design basis at the beginning of design phase while formulating IB design criteria. Secondly, the researchers can use this decision support tool for the evaluation and comparison of the existing IBs by attributing an importance factor to the selected IB design parameters proposed in checklists. The advantage of the subjective properties of the proposed decision support tool is its open ended and flexible structure that allows additions and/or omissions of new parameters based on the new requirements of each project.

As the selected thesis topic is very extensive and requires multi-disciplinary studies for in-depth analysis, the researcher haven't been able to do a detailed survey study on different IB types and samples. In order to test the proposed decision support tool for Human-centered IB design, the researcher selected and focused on only one office building (Deutsche Commerzbank Headquarter). In this building, some of the common IB design features like "intelligent skin", "smart materials", and "Communication Management System" (CMS) are not used. The prevailing design criteria in Deutsche Commerzbank building is providing energy efficiency by lowest consumption level per m^2. Also, most of the advanced technologies used in IB design are not used for reducing the construction and demolition costs of the building by considering the economic and environmental requirements. The researcher is aware of the fact that, it is not the best sample to reflect the common design basis for Human-centered IBs. But, the researcher specifically selected this building to display the strong compromise between the "environment-oriented" and "user-oriented" design criteria rather than the technology-oriented ones promoted in most of the IBs.

In the thesis study, the selected IBs are mainly belonging to a period between 1997 and 2010, but majority of the selected buildings are not recently built samples. The researcher mainly selected the buildings which have extensive Post Occupancy Evaluation studies rather than the recently built ones because of the physical limitations to do a detailed survey study and make questionnaires. It could have been more effective for tracking the development of IBs if more recently built samples were selected and reviewed.

The formulation of the design parameters for IB design is directly related to the requirements set up during the initial design phase. For example, if the user's physical and psychological needs and satisfaction effecting productivity are the driving forces for design, then selected "environment-oriented" and "technology-oriented design" parameters shall be adaptive, responsive and flexible enough to cope with these user requirements. The lack of an integrated design approach for IB design is among the major problems behind the shortfalls of some of the IBs. For reaching an integrated design approach for Human-centered IBs, the researcher develops a decision support tool that can become a common design basis which can be specifically tailored according to the requirements of each project and user. In the checklists, by making some additions and/or omissions while opening and/or closing the relevant design parameters, there can be created various correlation matrices for future studies.

The Architect/Designer cannot use the proposed design tool autonomously by himself/herself as it requires multi-disciplinary team study including different decision makers like the investor, user/client, project team, behavioural scientist, system engineers, visionary projections team etc. There should be established an initial decision making team to set up the primary design parameters belonging to “user”, “environment” and “technology” oriented parameters. For this reason, it is more convenient to define this tool as a decision support tool for Human-centered IB design rather than a design tool which can be directly used by the designer/architect. There are various design parameters proposed in correlation matrices of the checklists which need to be assigned weight factor for providing the importance level of selected parameters. After getting all these initial data for IB design, the Architect/Designer can use this tool for deciding on which design parameters belonging to “user”, “environment” and technology need to be opened/closed and expanded.

In this study, the idealized design parameters may not always overlap with the open design criteria in the checklists. This is mainly related to which design parameters are given priority based on the user requirements and building program. Because of this relative selection of the parameters, there are some subjective design criteria involved that cannot be applicable for all IBs. The positive aspect of these open-ended, flexible checklists is that; they can be used as a decision support tool for Human-centered IB design along with the other tools.

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APPENDICES

APPENDIX A: IB performance Evaluation Methods

APPENDIX A

For the Evaluation of IBs, several methods have been produced which have been summarized in chronological order in (Table A.1) as follows:

Table A.1 : Summary of IB Evaluation Methods, adapted from Harrison et al. (1998).

Year	Research Agency	Evaluation Method
1983	DEGW	**Orbit 1-** multi-client study
1985	DEGW	**Orbit 2** – degree of matching between the buildings, the organizations occupying it and IT.
1988	Carnegie Mellon University	Measures of **quality, satisfaction and efficiency** (Using six performance criteria and five system integration criteria)
1991	Kuala Lumpur City Hall	Guidelines specifying features of office buildings based on "location", "design systems and services".
1992	IB Research Group	**Building IQ Rating Method**
1992	IB in Europe Project	**IB Rating** (Based on building shell, services and applications)
1995	DEGW	**Building Rating Method** (including five sections) (A) Building Site and Location; (B) Building Shell Issues; (C) Building Skin Issues; (D) Organizational and Work Process Issues; (E) Building Services and Technology
1997	Arkin and Paciuk	**Magnitude of Systems' Integration (MSI)**
1998	Harrison, Loe, and Reed	**Building Rating Method**
2002	Preiser and Schramm	**Post Occupancy Evaluation (POE)** Method **First Phase**: Planning POE requires close contacts with client, performance criteria, and planning the data collection process; **Second Phase:** Methods and instruments for data collection, monitoring and analyzing **Third Phase**: applying POE involves reporting findings, recommending actions.
2002	So and Wong	**IB Index (IBI)**: Quantitative assessment methods for IB originating from "**Quality Environmental Modules".**

- **Building Rating Method (BRM)**

The Building Rating Method further developed the IBE method and applied it to a wider set of issues covering "building site", "building shell", "building skin" and "building services and technology" (Figure A.1). The organizational and work process issues are given in a separate section. BRM consists of A, B, C, D, E sections.

Section A: Building site/location	**Section D: Organizational and work process issues**
A1 Locale	D1 Organizational complexity
A2 Site communications infrastructure	D2 Amount of relocation
A3 Provision of local amenities	D3 Routineness of work
A4 Access to site by public and private transport	D4 Individual or work group
A5 Access to carparks	D5 Work location
A6 Site and building security	D6 Need for privacy
A7 Aspect	D7 Use of information technology
	D8 Use of wide area communications
Section B: Building shell issues	D9 Control of the work environment
B1 Thermal shell strategy	D10 Concern about security
B2 Structural grid	D11 Access to workplace out of hours
B3 Planning and partition grids	
B4 Floor size and configuration	**Section E: Building services and technology**
B5 Floor shape	E1 HVAC zoning and control
B6 Space efficiency	E2 Small power supply
B7 Floor depth and sectional height	E3 Back-up power provision
B8 Imposed floor loadings	E4 Cable distribution system
B9 Provision of high load areas	E5 Communication systems
B10 Communications infrastructure	E6 Lighting sytems
B11 Staff and visitor access	E7 Building automation systems
B12 Goods access	E8 Space management systems
B13 Exterior/interior maintainability	E9 Business systems
B14 Atrium provision	E10 Access control and security
	E11 Furniture systems
Section C: Building skin issues	E12 Quality of finishes/installation and maintenance (fit-out)
C1 Services strategy	
C2 Solar control strategy	
C3 Natural ventilation	

Figure A.1 : The BRM Questions, adapted from Harrison et al. (1998).

The scoring system of 10 - 100 will be used. From 10-50 Low, from 50-100 High satisfaction level will be provided as per below site and shell scoring matrix (Figure A.2 and Figure A.3).

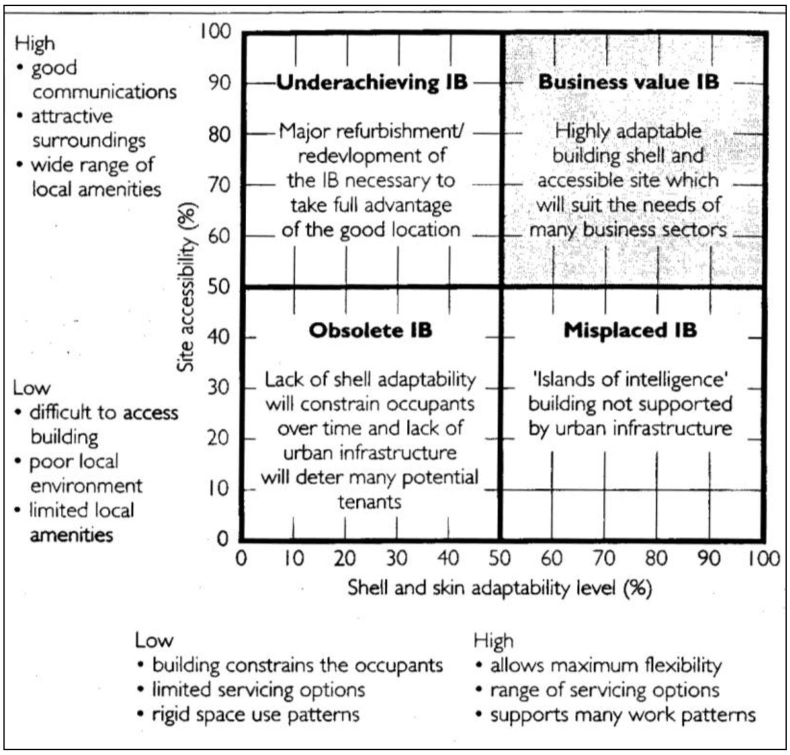

Figure A.2 : The BRM Site and Shell Scoring Matrix, adapted from Harrison et al. (1998).

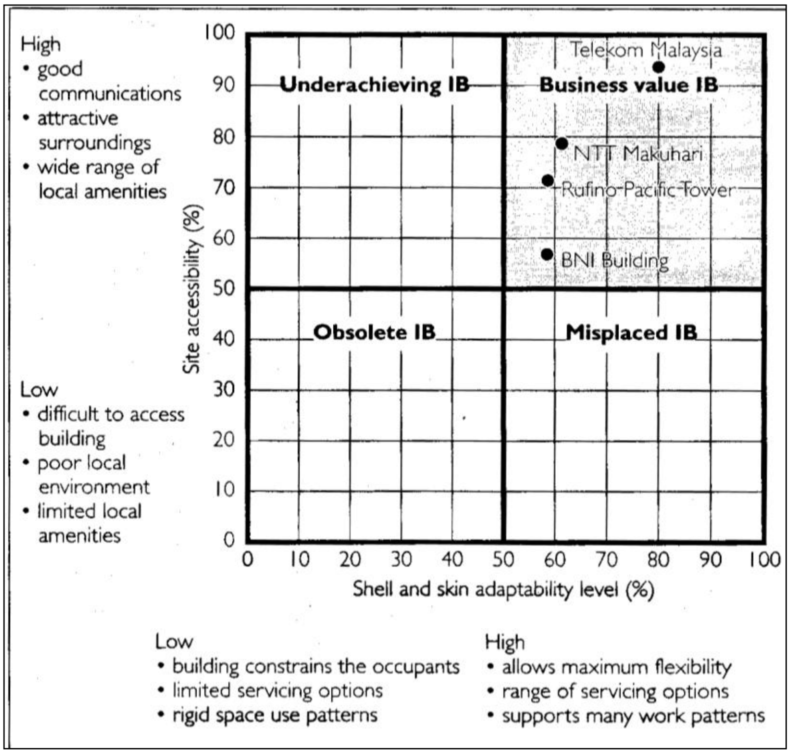

Figure A.3 : The BRM Site and Shell Scoring Matrix, adapted from Harrison et al. (1998).

- **ORBIT 1, DEGW in association with Eosys and Building Use Studies**

This multi-client study has been explored for exploring the impact of IT on office design. In this study, a number of building design criteria that were essential for an office building to absorb the increasing amount of IT.

The **ORBIT 1** study explained the impact that the new technology was having on the design of offices in England. It developed an expert-based method for evaluating existing and proposed buildings, and applied it to office buildings of various ages, sizes, shapes, heights and plan types, occupied by a variety of organizational types and functions (Duffy, 1983).

In 1985, a second study, **ORBIT 2** was carried by DEGW in conjunction with Harbinger and FRA (Cornell). In this study, a methodology for determining the degree of match between the building, the organizations, occupying it and the IT that is used in the building rather than a rating of building intelligence (Figure A.4). This study showed that many existing buildings in North America lacked the "intelligence" to effectively handle the information technology systems used by the businesses that were tenants in the buildings (Coggan, 2001).

Nine key organizational issues
1. Change in total staff size
2. Ability to attract or retain workforce
3. Communication of hierarchy, status and power
4. Relocation of staff
5. Maximising informal interaction
6. Human factors in the ambient environment
7. Image to the outside
8. Security to the outside
9. Security to the inside

Eight key information technology issues
10. Connecting equipment
11. Changing location of cables
12. Environmentally demanding equipment
13. Protecting hardware operations
14. Demand for power
15. Relocating heat producing equipment
16. Human factors; workstations
17. Telecommunications to or from outside

Figure A.4 : Orbit 2 - 17 Key issues for evaluation, adapted from Harrison et al. (1998).

- **Advanced Building Systems Integration Consortium (ABSIC), 1988**

In 1988, Carnegie Mellon University established a university-industry group partnership named ABSIC, with the objective of development and demonstration of integrated building systems and provided the building users with measures of "quality", "satisfaction" and "efficiency". As a part of this research study, they developed the performance evaluation tool of ABSIC (Figure A.5). The total building performance was seen as the sum of the performance and system integration criteria.

ABSIC performance criteria	ABSIC system integration criteria
Spatial quality	Structure
Thermal quality	Enclosure
Air quality	HVAC
Acoustic quality	PLEC
Visual quality	Interior systems
Building quality	

Figure A.5 : ABSIC total building performance criteria, adapted from Harrison et al. (1998).

- **Building IQ factors**

IQ style rating methodology was developed by David Boyd and Ljubomir Jankovic in 1992 at the IB Research Group, Birmingham Polytechnic. This IQ rating system consists of individual user needs, organization/owner needs and local and global environmental needs (Figure A.6).

Building IQ was seen as the ratio of an assessment score for a particular building and the mean assessment score for that particular type of building (based upon the performance profiles of 20 similar buildings).

The strength of this method is that; it includes a wide range of factors affecting both the building shell and the occupants of the completed building, deals with technologies and provides norms for different organizations. The weakness of this approach lies in the difficulty of gathering some of the data required for rating and the excluded basic building characteristics such as sectional height and floor depth.

Individual users' needs Air quality Noise control Thermal comfort Privacy Lighting comfort Spatial comfort Building noise control Amenities Health Motivation	**Organizational needs** Change in total staff size Attraction/retention of workforce Communication of hierarchy, status and power Relocation of staff Maximizing informal interaction Human factors (well-being of employees) High status image Security to outside Security to inside Connecting equipment and changing location of cables Adding or relocating environmentally demanding equipment Protecting hardware operations Demand for electric power Telecommunications Productivity Morale Health Attendance Work facilities
Local environmental needs Site wind effects Site noise effects Site daylighting effects Site shading effects Harmonization with local planning Resuse of existing site	**Global environmental needs** Greenhouse gas emission Low energy design Minimisation of air conditioning required Use of low-emission energy source Optimal control CFC emission Absence of CFCs in refrigeration cycles Absence of air conditioning Absence of CFC expanded foams Use of sustained material resources Total building energy consumption Climate factor

Figure A.6 : Building IQ factors, adapted from Boyd and Jankovic (1992).

- **The IB in Europe (IBE) Study (1991-1992)**

IBE project focused on the evaluation of "how buildings and technology can support an organization in achieving business objectives?". The IBE rating method consists of a number of key questions related to "building shell" and "building services and applications".

In IBE method, the building shell is rated in terms of its adaptability to meet changing needs over time. **In section A**, the IB shell design is rated and the respondent is asked to rate the level on 1-9 scale for seven key IB characteristics:

- Sectional height and floor depth
- Floor size and configuration
- Floor loading
- Planning and partition grids
- Communications infrastructure
- Building skin

The end result of Section A is six value scales comparing various objective measures to a rating value. The scoring of building shell is done by multiplying each score by a weighting based on DEGW research and experience.

In **Section B**, appropriate IB technologies is used to rate the building services and applications. However the weightings are now provided by the respondent rather than DEGW.

- Level of servicing
- Power supply
- Cable distribution
- Back-up power
- Wide area communications
- Lighting
- Building Automation Systems
- Space Management Systems
- Office Automation Systems
- Furniture Systems

In this section, the respondent must also decide about the level of constraint that the current level of the technologies used in his/her organization; how well suited each item to achieve the goals required by organization. The level is recorded using a 0-8 scale. For example, a score of "0" means that the level is satisfactory for both current and future needs. A mid-range score of "4" means that the level of provision meets most current needs, but it is likely to be constraining in the future. A score of "8" means the level is completely inadequate both for current and future requirements.

The respondent also has to determine the weightings to be placed into each question. The respondent assigns a weighting of 100 to fundamental questions for their organizations.

The disadvantage of IBE rating system is that; the normative weighting system worked well with the analysis of building shell issues but the method worked less successfully at the services and technology level.

- **IB Envelope Evaluation**

The IB envelope responds to dynamic character of external environment and internal occupant demands. IB skin (envelope) uses AI (Artificial Intelligence) to provide the dynamic heating, cooling, lighting and air supply of the indoor environment by providing a balance between occupant comfort and energy use (Aschehoug et al., 2002).

The intelligent behavior includes a form of adaptation and interaction with the environment; by the help of this adaptation, the problems will be solved and cope with the new situations. Interaction and adaptation are the key terms for IB envelope.

The environment that an IB envelope should cope with consists of three elements as shown in Figure A.7:

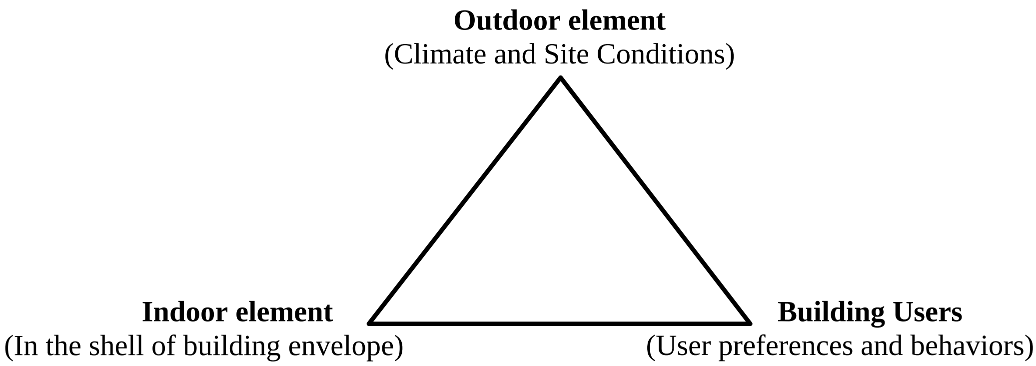

Figure A.7 : Three elements of IB Envelope, adapted from Aschehoug et al. (2002)

The building occupant is the main factor behind the variable and conflictive environment of IB envelope. For example, the use of glass in the building envelope brings forth variable and conflicting demands of transparency versus privacy, openness versus insulation, and access to daylight versus shading.

- **The PROBE Study (1995-1998)**

The PROBE (Post-Occupancy Review of Building Engineering) study that was undertaken in the UK during 1995-98 is perhaps the most comprehensive occupant survey that has been undertaken (Leaman and Bordass, 1999).

The PROBE study contains several indications that facade design is very important for occupant well-being. For example, the study concluded that high levels of occupant satisfaction were easier to achieve when the following features were present (Leaman and Bordass, 1999):

- Shallower plan forms and depths of space (workstations typically 6 m or less from a window);
- Thermal mass (provided the acoustics are satisfactory);
- Stable and comfortable thermal conditions;
- Freedom from distracting noise;
- Air infiltration under control;
- Operable windows close to the users;
- Views out;
- Effective controls with clear, usable interfaces.

Among the above explained evaluation methods, the researcher mainly focused on the parameters formulated by Building Rating Method (BRM) and taken it as a base while creating the “environment and technology-oriented” IB design parameters.

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