

**PERFORMANCE BASED BUSINESS MODEL OF ENERGY EFFICIENT
INTELLIGENT BUILDINGS**

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Structural Technologies**

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**ENERJİ ETKİN AKILLI BİNALARDA PERFORMANSA DAYALI İŞ
MODELİ**

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FOREWORD

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ABBREVIATIONS

AFA	: Addressable Fire Alarm
AHP	: Analytic Hierarchy Process
ANP	: Analytic Network Process
ASHRAE	: American Society of Heating, Refrigerating and Air-Conditioning Engineers
DEGN	: Common Gateway Interface
DALI	: Common Gateway Interface
EIBG	: Error sum-of-squares
EMS	: Energy Management System
EPE	: Error sum-of-squares
HVAC	: Heating Ventilation Air Conditioning
IAQ	: Indoor Air Quality
IBE	: Intelligent Building Institute
ITS	: Intelligent Technology System
LAN	: Local Area Network
LCC	: Life Cycle Cost
LS	: Lift system
MCDM	: Multi Criteria Decision Making
PV	: Photovoltaic Panel
PLEC	: Soil and Water Assessment Tool
WAN	: University of Minnesota

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PERFORMANCE BASED BUSINESS MODEL OF ENERGY EFFICIENT INTELLIGENT BUILDINGS

SUMMARY

Every project start with an idea and then processes are achieved by a successful strategy that is considered comprehensively. This strategy should be managed efficiently and it should have a control system as a feedback mechanism to view the situations, benefits, advantages or disadvantages in business sector. This is called as business model that helps to define. In recent years, the term of intelligent building has become very popular, however it is known as a building that is equipped fully with automation systems. In reality, if a building is intended to be constructed as intelligent building, it should be designed based on energy efficient design strategies in order to reduce energy consumption with also integrated by automation systems that are installed efficiently and sufficiently.

It is important to reduce the energy consumption, not only during the life-cycle period of a building, but also during the design period, construction period should be taken into consideration. If a building requires more energy during all the periods (design, construction and life-cycle) than a simple building, how it can be an intelligent building. So, all the parameters should be taken into consideration when designing and constructing an intelligent building.

In order to manage all the phases of a building, a business model is required. However there is not enough interest on business models in construction sector. In this study, a conceptual performance based business model is designed and this model intended to be a unique study that will be an example for future studies.

The main idea that is implemented to emphasize is that, the term of energy efficient intelligent buildings will have more value if they have a performance based business from the beginning of the building requirement to the demolition of the building. Business model will draw a roadmap for intelligent building that is intended to be energy efficient in every stage of feasibility research, design period, construction period and operating period and the stakeholders will be able to control the model via the feedback mechanism. If an efficient performance based business model can be performed for an energy efficient intelligent building, then the building will have a unique value in the value network between the buildings that has been designed by the same concept decision.

ENERJİ ETKİN AKILLI BİNALARDA PERFORMANSA DAYALI İŞ MODELİ

ÖZET

Son yıllarda popülerlik kazanan akıllı bina kavramı genelde tümüyle otomasyon sistemine sahip olan binalar olarak tanımlanmaktadır. Aslında akıllı binaların temelde enerji etkin tasarım stratejileri benimsenerek gerekli ve yeterli otomasyon sistemleri ile entegre edilmiş olarak tasarlanmış olmaları gerekmektedir.

Akıllı binalarda sadece yaşam dönemi maliyeti değil aynı zamanda tasarım ve yapım aşaması maliyetlerinin de düşürülmesi izlenmesi gereken yöntem olmalıdır. Eğer akıllı olarak nitelendirilmiş bir bina, daha önce aynı amaç ve şartlarda inşa edilmiş herhangi bir binadan daha fazla enerjiye gereksinim duyuyorsa bu binaya akıllı sıfatını vermek doğru bir tanımlama olmayacaktır. Buna ek olarak, akıllı bina sadece yapım aşamasında enerjiyi etkin kullanan ve teknolojik sistemlerle yapılmış olan bina değil, aynı zamanda binanın ilk tasarım aşamasından itibaren projedeki tüm paydaşların etkin olarak görevlendirilmesi, etkin kaynak kullanımı, disiplinler arası etkin koordinasyon gibi tüm parametreleri kontrol edilmiş binalardır diye tanımlayabiliriz. İşletme aşamasının başlaması ile de her sistemin beklenen performansı gösterebilmesi için kullanıcı eğitimine ihtiyaç vardır. Akıllı binanın akıllı olarak işletilebilmesi etkin bir kullanıcı-işletici ilişkisine bağlıdır.

Tasarım aşamasından yaşam dönemi sonuna kadar her bir fazın yönetilmesi için bazı yöntemlere ihtiyaç duyulmaktadır. Bu yöntemlerden biri de iş modeli yöntemidir. Henüz inşaat sektöründe çok fazla yaygın olmayan iş modeli yöntemi akıllı binalar için performansa dayalı olarak ayrıntılı bir şekilde binanın henüz tasarımı başlamadan hatta akıllı bina ihtiyacı doğması aşamasında yapılandırılırsa: tüm paydaşlar tek tek tanımlanır, etkin bir fizibilite çalışması yapılır, hedef tüketici belirlenerek istekleri binanın konsept tasarımında girdi oluşturur ve her aşamanın değer-kar kontrolü ile binada etkin bir yönetim mekanizması sağlanmış olur. Ayrıca, eğer bu iş modeli binanın ömrünü tamamlayacağı süreye kadar tüm aşamalarının tek tek paydaşlara fayda sağlayacak şekilde ve sürekli geri besleme mekanizması ile kontrol edilecek şekilde tasarlanır ise binanın değerini önemli bir şekilde arttıracaktır. Bu çalışmada örnek bir iş modeli konsepti geliştirilmiş ve örnek binanın analizleri bu sisteme göre yapılmıştır.

1. INTRODUCTION

Every project has a model to get an idea of qualities and quantities of the project in different scales and in different ways. A model can be defined as a 3D model for architecture, or it can be a simple simulation for engineering disciplines, or it can be only a schematic diagram for business sector. The main idea is to get an overview about the project and to control in every detail to prevent the mistakes by considering formerly. So, it can be said that a business model is a conceptual tool that takes an overview on a project from many perspectives and controls the mechanisms to take cautions formerly and also to get more benefit for stakeholders via feedback strategies. A model is required to provide a framework for identifying interactions between all the diverse sectors that form the construction, or built environment, industries.

It is becoming increasingly indispensable to be able to question and improve one's business model in today's global and highly competitive business landscape even in traditional and established industries. Companies are now operating in industries that are characterized by multiple and co-existing business models. Competitive advantage is achieved through focused and innovative business models. When you analyze the airline, music, telecom or banking industry you can see that in each one there are different business models competing against each other. For example, in the airline industry you have the traditional flag carriers, the low-cost airlines, the business class only airlines and the fractional private jet ownership companies. Each business model accentuates different characteristics and competes on different aspects(www.arvetice.com).

In construction sector, an innovative business model is required for energy efficient intelligent buildings to define the intelligent building industry comprehensively, to enable the industry and other stakeholders to take a longterm view. A model would help understanding of where value is, or can be, added. This would make it easier to improve the degree that value is added. Models would assist in clarifying the concept

of value and where this emerges, or is added, in the supply chain (both physical and intellectual) and in the lifetime of construction.

Every project starts from the beginning of an idea and each of them have different process and procedures since their requirements and parameters are specified individually. The term of “business model” has become popular and valuable since they define the process of projects, define stakeholders of a project and also defines the relationships between all disciplines of the project. In addition, they can be a guide of the project to define value propotion and revenue generation

Nowadays the term of “intelligent building” has become very popular. The term “intelligence in buildings” can create excitement among architects and developers as the ultimate design solution, a building that knows how to adapt to every situation, liberating the designer from the duty of finding passive solutions to design problems, and implying that conflict resolution is delegated from the designer to the end product itself. Since an intelligent being uses the least energy possible to survive, prospects for sustainable climatic design in any climate seem high. (Capeluto, 2007) However it is still difficult to find an exact definition on intelligent buildings since their intelligence depends on various parameters.

Another term that has become also popular is the term of “energy efficiency”, since the energy cirisis has convinced people to reduce the consumption of energy. In order to provide a considerable reduction in consumption of energy usage in buildings, there is various researches that has been completed or still in progress.

According to the researches energy efficiency should be the basic strategy of intelligent building design strategies because intelligent buildings should use energy sources intelligently so this means energy efficiency should be taken into consideration.

Buildings affect people in various ways. They can help us to work more effectively; they also present a wide range of stimuli for our senses to react to. If there is to be a common vision then it is essential for architects, engineers and clients to work closely together throughout the design, construction and operational stages of the conception, birth and life of the building. This means consultants, contractors, manufacturers and clients share a common vision and value system from the outset. There has to be an understanding of how patterns of work are best suited to a

particular building form served by an appropriate environmental system. There are a host of modern technologies emerging that help these processes but in the end it is how we think about achieving responsive buildings that matters. *Intelligent buildings can cope with social and technological change and are adaptable to short-term and long-term human needs.* This is the fundamental meaning of the term intelligent building. (Croome, 2001)

It is not enough to define the term of intelligent buildings and energy efficiency. Moreover, there should be a model to define intelligent buildings that is based on performance criteria according to design parameters. This model should also integrate all the mechanism of building components and check the availability of systems that will be installed to the building. For this reason it is clear that designing an intelligent building is also designing a mechanism by means of a model that is called performance model.

Designing highly energy efficient buildings may require more time and money than usual constructed buildings, however their life-cycle cost will be much more less if an efficient performance model is provided. The way to provide this is to specify a business model that is based on energy efficient performance model. Although there is not enough exact definition about business models in construction sector, it can be composed for intelligent buildings with analysing the strategies and design steps to integrate all the systems and all the stages of design and also the construction.

In order to have a unique study about intelligent buildings, the terms of “business model” and “intelligent building” are tried to be analysed separately and the analysis are integrated by means of having a clear definition in mind to specify the basic model including all the required components.

In this study a conceptual business model is defined from the beginning of design step to the life-cycle period, in addition a case study is analysed according to this conceptual model to show the performance of a building that is intended to be an energy efficient building and also an intelligent building with the integration of automation systems and passive solar energy strategies. However, it requires a comprehensive study on energy efficiency parameters and intelligent building parameters to specify a conceptual business model, so they are defined step by step and then they are integrated as a synthesis based on performance models.

1.1 Purpose of the Thesis

The aim of this study is to emphasize the importance of business models for energy efficient intelligent buildings to overview the relations between all disciplines and reporting the reduction of energy consumption and also to save energy with passive solar design strategies and mechanical systems together. Since there is very few studies on performance based business models for construction sector, this study aims to define a conceptual business model by integrating the related researches and case studies in order to provide more efficiency for future projects.

1.2 Scope Of The Thesis

Energy efficiency is defined based on scientific researches, and it is emphasized that energy efficiency is not a trend which has become popular in recent years, in contrast it is a requirement for intelligent buildings and their performances. The meaning of intelligence building and the term of “intelligence” in buildings are also defined in order to analyse the components of the systems both for the passive energy design strategies and the automation systems. Performance models of intelligent buildings are analysed and the result of the analyses are listed to provide a guide for performance models that will be composed in future. Since to manage the system a business model is required for the intelligent buildings, a conceptual energy efficient intelligent building business model is designed based on performance models. This business model is very important to define the value proposition and view the revenue generations and benefits for all the stakeholders. The case study building is analyzed through the conceptual performance based business model including simulation tool results and the measured data comparison to view the value of the building and define the revenue generation by reduced energy consumption.

According to the aim and the scope of this study, a general approach to business models and energy efficiency is expressed to give basic informations before defining intelligent buildings, performance models for intelligent buildings and conceptual performance based business models of energy efficient intelligent buildings.

2. GENERAL APPROACH TO BUSINESS MODELS AND ENERGY EFFICIENT DESIGN THROUGH INTELLIGENT BUILDINGS

In this section the term of business models will be defined with their basic functions and components. Their advantages will also be emphasized in order to express the importance of business models in energy efficient intelligent buildings in the next parts of this study. This section will draw a general view of business models and their benefits basically to understand the role of them for energy efficient intelligent buildings.

In addition, the term of energy efficiency will be defined to specify energy efficient design. Advantages of energy efficient design will be demonstrated since intelligent buildings should be designed depending on energy efficiency concept as it is explained in next parts of this thesis. Moreover, the main factors of energy efficient design will be defined with their interrelations between other factors. This section will help to understand intelligent building design parameters in order to analyse performance models of intelligent buildings from energy efficiency aspect.

2.1 General Approach To Business Models

A dependable business model would be a powerful tool for government and industry to evaluate the impact of policy and practice changes on construction industry. It is an innovation to improve an efficient business model for intelligent buildings. It is essential to develop a new, innovative, efficient business model for energy efficient intelligent buildings for five basic reasons:

- It helps to define the intelligent building industry comprehensively in order to understand the process of all the stages that begins from design demand to building demolition.
- It helps to define what we need to know in terms of quantifiable data. A model is required to provide a framework for identifying the data required to characterise the interplay and interactions between all the diverse sectors that form the construction, or built environment, industries.

- It is needed to inform and influence government policy and decisions. Policy and economic levers are pulled without the government having any, or much, idea about the consequences. A model or models would improve this situation.
- It is needed to enable the industry and other stakeholders to take a longterm view. Models would enable industry and society to run different scenarios and test their consequences.

A model would help understanding of where value is, or can be, added. This would make it easier to improve the degree that value is added. Models would assist in clarifying the concept of value and where this emerges, or is added, in the supply chain (both physical and intellectual) and in the lifetime of construction (www.ncrisp.org.uk)

2.1.1 Business model definitions according to previous researches

According to Cambridge Learner's Dictionary (Cambridge, 2003), the term of business means the activity of buying and selling goods and services, or a particularly company that does this, or work you do to earn money.

Model is a representation of something, either as a physical object which is usually smaller than the real object, or as simple description of the object which might be used in calculations. In general, the purpose of creating a model is to help understand, describe, or predict how things work in the real world by exploring a simplified representation of a particular entity or phenomenon.

A business model is a conceptual tool that contains a set of elements and their relationships and allows expressing a company's logic of earning money. It is a description of the value a company offers to one or several segments of customers and the architecture of the firm and its network of partners for creating, marketing and delivering this value and relationship capital, in order to generate profitable and sustainable revenue streams (Osterwalder, 2004).

Timmers thinks that a business model as the architecture for the product, service and information flows, including a description of the various business actors and their roles and a description of the potential benefits for the various business actors and a description of the sources of revenues (Osterwalder, 2004).

Weill and Vitale (Weill and Vitale, 2002) define a business model as a description of the roles and relationships among a firm's consumers, customers, allies and suppliers and it identifies the major flows of product, information, and money, as well as the major benefits to participants.

Like Petrovic, Kittl et al. (2001), Applegate (2001) perceives a business model as a description of a complex business that enables the study of its structure, of the relationships among structural elements, and of how it will respond to the real world. In this regard Stahler reminds that a model is always a simplification of the complex reality. It helps to understand the fundamentals of a business or to plan how a future business should look like (Osterwalder, 2004).

Magretta (2002) adds that a business model is like a story that explains how an enterprise works. And like Stahler she distinguishes the concept of business models from the concept of strategy.

Tapscott, Ticoll et al. (2000) do not directly define business models, but what they call business webs. A business web is a business on the internet and represents a distinct system of suppliers distributors, commerce service providers, infrastructure providers, and customers that use the Internet for their primary business communications and transactions. Amit and Zott describe a business model as the architectural configuration of the components of transactions designed to exploit business opportunities. Their framework depicts the ways in which transactions are enabled by a network of firms, suppliers, complementors and customers. Rappa defines a business model as the method of doing business by which a company can sustain itself- that is, generate revenue (Osterwalder, 2004).

2.1.2 Definitions synthesis to specify business models for intelligent buildings

To summarize the definitions on business models it can be described that a business model of performance based energy efficient intelligent buildings is a conceptual tool that directs to know the fundamentals of an efficient business by creating, marketing and delivering value with service and information flows. It is a whole complex of elements that composes the business and their relationships including business actors and the potential benefits for the various business. In addition to these descriptions, the business model provides the value suggestion, determines a market sector, defines the structure of the firm's value chain, designates the revenue generation

mechanisms, defines the situation of the firm and also systematize the process in order to get a competitive strategy.

2.1.3 Basic components of business models

The basic components of a business model are defined in six categories; customer segments, value propositions, channels, customer relationships, partner network and stakeholders.

2.1.3.1 Customer segments

Customers are the livelihood of every company since the revenue streams come from them. Successful organizations are able to understand their customers. They strive to propose them an adequate offer that caters to their needs. They recognize how to create value for them. They know how to reach them and they are aware of which relationships to build with them. Most importantly, from the enterprise perspective, successful companies know how to turn satisfied customers into revenue streams.

A clear description and understanding of a company's customers is an integral part of every business model. More precisely every company must ask itself if it is serving distinct customer groups with different needs or characteristics. Visualizing the characteristics of one of existing customers can help the firm to come up with a generic description for each of the segments (Osterwalder, A., M. Rossi, et al., 2002).

2.1.3.2 Value proposition

Value proposition is a value that customers are willing to pay for. This value can be described as a value proposition for each customer segment. It portrays a specific bundle of products and services. A business model may consist of one or several value propositions for each of its customer segments (Osterwalder, A., Y. Pigneur, 2003). Key questions to identify the *value proposition* building blocks:

- What do the firm offer the market?
- What is the specific bundle of products and services firm offer each of the customer segments?
- Which customer needs does each value proposition cover?
- Do the firm offer different service levels to different customer segments?

Components of value proposition part of business models

These components are; reasoning, value level, price level and life cycle of value proposition. In this part this four value proposition components will and also their sub-components will be defined in order to create a specific performance based energy efficient intelligent building business model.

Reasoning attributes captures the reasoning on why the firm thinks its “Value Proposition” or a specific elementary offering could be valuable to the customer.

- Use: Value is produced when assumed customer value matches perceived customer value after the consumption of a “Value Proposition” or a specific elementary offering.
- Risk: Value can be created by reducing the customer's several risks. This can simply be a financial fear that the price of a purchased good will go down in the future or that the price of a good purchased through a long-term contract might go up
- Effort: Companies must also think of new and innovative ways of making their customers' life as easy as possible. Reducing his efforts means creating value through lower search, evaluation and acquisition costs, but also easier and cheaper maintenance, operations and training.

Value level is measuring the utility for the customer by measuring the value level of a company's offer allows a firm to compare itself to its competitors.

- Innovative imitation: It means that a company imitates an existing “Value Proposition” or elementary offering, but improves value by adding innovative elements.
- Excellence: Excellence means that value is pushed to its extremes.
- Innovation: Innovation means that a firm introduces either a completely new product or service or are voluntary combination of products and services. Recent research has shown that consumers highly value innovation and would be willing to pay for new value propositions (Nunes and Johnson, 2002).

Price level attribute compares the value proposition's price level with the one's of their competitors.

- Economy: This is the low-end of the price scale where a company offers a price that is more attractive than the one of the bulk of its competitors. Often, but not

necessarily this goes hand in hand with a lower value level. In order to be able to offer attractive prices over a sustained period of time a firm has to streamline other elements in its business model, such as its activity configuration or its complementary revenue streams.

- **Market:** Pricing at the market simply means little price demarcation from the rest of the market. Nevertheless, a market price can still seem attractive if special features or attributes of the value proposition signal additional value.
- **High End:** Represents the upper boundary of the price scale. High-end prices are usually found in luxury goods, but also for new and innovative value propositions that still allow charging a Premium (Linder and Cantrell, 2000).

Life cycle value proposition:

- **Value Creation:** Based on agile manufacturing and with the help of companies can integrate their customers into the value creation process and create additional value.
- **Value Purchase:** Value is also created by making the appropriation phase as smooth as possible and streamline purchase and delivery to the customers satisfaction
- **Value Use:** The main value of a value proposition comes from its actual use. Value is maximized when the value proposition's attributes match the customer's needs.
- **Value Renewal:** Value can be renewed or updated after its consumption, its expiry, or after it becomes obsolescent. Value can also be created by adding new features to the existing value proposition. Sometimes it may also be interesting to create additional value by adding new features to an existing value proposition (e.g. new titles for a game console). Finally, value renewal could also mean gradually updating value, general updates or major upgrades to newer versions increase customer value relationships to build with them. Most importantly, from the enterprise perspective, successful companies know how to turn satisfied customers into revenue streams.

A clear description and understanding of a company's customers is an integral part of every business model. More precisely every company must ask itself if it is serving distinct customer groups with different needs or characteristics. Visualizing the

characteristics of one of existing customers can help to firm to come up with a generic description for each of the segments.

2.1.3.3 Channels of business model

A company reaches its customers through various communication and distribution channels. They represent the interface between a company, its value propositions and its customers. These customer touch points include advertising, retail outlets, sales teams, websites, conferences, sales affiliates and many more. The means a company can use to reach its customers have multiplied over the years. This has left managers with a large set of design choices to reach their customers.

Communication and distribution channels have become increasingly important in business model design. A good and integrated channel design can be a powerful tool for differentiation and competitive advantage. For example, cost intensive channels should be used for very profitable clients, while unprofitable clients should be served through cost efficient channels (Osterwalder, A., M. Rossi, et al., 2002).

2.1.3.4 Customer relationships

Getting relationship management right in our business model is crucial today to satisfy customer's expectations. For instance, customers paying a high price for a product or service will expect a high touch relationship, while customers paying a cheap price do not expect more than automated, yet customized relationships. A sound business model has a clear strategy for customer relationship management for each customer segment (Osterwalder, A., M. Rossi, et al., 2002).

2.1.3.5 Partner network

Today's Business Models are more and more the result of a network of partnerships, joint ventures, cooperation and alliances between different companies. Partners are involved, for example, to complement the value proposition, to bring in specialist competencies or to help deliver to clients.

Every company should ask itself if and how it can leverage its own business model by partnering with other companies. This includes the question of what a company wants to do by itself and what it wants to do with partners. It also includes the question of leveraging one's own value proposition by combining it with the value proposition of strategic partners. In case study part of this thesis, the partner network

will be emphasized to build an energy efficient intelligent building (Osterwalder, A., M. Rossi, et al., 2002).

2.1.3.6 Stakeholders

Stakeholders are an integral part of a project. They are the end-users or clients, the people from whom requirements will be drawn, the people who will influence the design and, ultimately, the people who will reap the benefits of a completed project. It is extremely important to involve stakeholders in all phases of your project for two reasons: Firstly, experience shows that their involvement in the project significantly increases your chances of success by building in a self-correcting feedback loop; Secondly, involving them into the project builds confidence in the product and will greatly ease its acceptance by target customer. The stakeholders for energy efficient intelligent buildings will be defined in detail specially while defining a conceptual business models for energy efficient intelligent buildings (Osterwalder, A., M. Rossi, et al., 2002).

2.2 General Approach To Energy Efficiency In Buildings

“Efficiency” is the ability of minimizing energy consumption. Since cost and applicability change for all buildings, this term is changeable according to the location and time. To nominate a system as efficient, the system should minimize the energy consumption and also should prevent the energy losses. The factors to define the efficiency are: human power, materials, energy and capital cost. Minimizing all factors efficiently provides an optimum solution for buildings.(Economic Commission for Europe, 1991)

2.2.1 Advantages Of Energy Efficient Design

First of all energy-efficient buildings provide a marketing edge, making it possible for speculative developers to offer competitive lease rates. Second advantage of energy efficient design is that life-cycle energy savings allow for an attractive return on investment for owner-builders. Improvements with a simple payback of two years can yield a return on investment of percent or more. The benefits of energy-efficient building design can justify higher fees for architects and engineers. From another aspect, reduced utility costs offer multiple benefits to property managers. They can

pass some of the savings on to tenants through lower lease rates. Those lower rates, coupled with enhanced comfort from better design, can help attract and retain building tenants. The portion of the energy savings retained by the property manager will improve the building's net operating income. In addition to this advantages comfortable, attractive, energy-efficient workspaces will bring benefits to tenants as well businesses not only incur reduced overhead costs, but they are likely to see improved employee morale and better productivity. In fact, enhanced productivity is one of the most compelling but overlooked benefits of improved building design. (Economic Commission for Europe, 1991)

The benefits of passive solar environments include:

- reductions in non-renewable energy consumption and CO₂ emission;
- savings in the cost of purchased energy generally;
- savings in space and water heating costs;
- amenity and social benefits to occupants;
- prestige benefits to organisations;
- natural environment benefits for individual users;
- improved human comfort, well-being, and performance.

In practice, low-energy environments are achieved through a combination of measures that include:

- the application of environmental regulation and policy;
- the application of environmental science and best practice;
- mathematical modelling and simulation;
- environmental design and engineering;
- construction and commissioning;
- management and modifications of environments in use.

2.2.2 Energy Efficient Design Principles

All of the buildings require energy along their life-cycle period, the required energy depends on building's qualities. Energy efficient design means the design that is based on minimizing the required energy for the building. The prior factors are: human factor, environmental factor, economic factors, architectural design, building elements and applications. It is essential to integrate all these factors based on

function and required performance efficiently, to nominate a building as energy efficient building. (Economic Commission for Europe, 1991)

Energy efficient building design is a process that purposefully brings together the work of various design and engineering disciplines to produce buildings that cost less to operate; are easier to maintain; and are more attractive, comfortable, and marketable than buildings designed through the more traditional, compartmentalized approach.

The benefits of energy efficient integrated building design can often be achieved with little or no increase in first costs. The process aligns the all-too-often conflicting objectives of developers, financiers, architects, engineers, specialty consultants, building managers, leasing agents, building operators, owners, and tenants to yield a positive outcome for all stakeholders.

Since energy efficient design provides ability of control to the building, energy gains and losses can be controlled by the technology used in the building. In order to provide this, the technology should be installed efficiently to control gains and losses. In addition to this, the system should be chosen by designer according to environmental factors in order to provide an efficient system installation. (Economic Commission for Europe, 1991)

There are two main strategies to provide energy efficient design; passive solar energy strategies and active solar energy strategies. In passive solar design, energy is saved and circulated in needed spaces. In a building that is designed based on passive solar design strategies, direct heat gain is provided by large scaled windows and indirect heat gain is provided by thermal mass. In addition, an innovative system can be also developed by designer. This strategy works with same principles as passive solar energy strategies, but they need extra energy inputs. This additional input can be provided by simple fan systems and also by complex systems as photovoltaic panel systems. (Economic Commission for Europe, 1991)

In summary, achieving low-energy building requires comprehensive strategy that covers, not only building designs, but also considers the environment around them in an integral manner. Major elements for implementing such a strategy are as follows.

Efficiency use of energy

- climate responsiveness of buildings;
- good urban planning and architectural design;
- good housekeeping and design practices;
- passive design and natural ventilation;
- use landscape as a means of thermal control;
- energy efficiency lighting;
- energy efficiency air conditioning;
- energy efficiency household and office appliances;
- heat pumps and energy recovery equipment;
- combined cooling systems;
- fuel cells development.

Utilize renewable energy

- photovoltaics;
- wind energy;
- small hydros;
- waste-to-energy;
- landfill gas;
- biomass energy;

Reduce transport energy

- reduce the need to travel;
- reduce the level of car reliance;
- promote walking and cycling;
- use efficient public mass transport;
- alternative sources of energy and fuels.

Increase awareness

- promote awareness and education;
- encourage good practices and environmentally sound technologies;
- overcome institutional and economic barriers;
- stimulate energy efficiency and renewable energy markets.

3. ENERGY EFFICIENT INTELLIGENT BUILDINGS

As it is mentioned in part two, value proposition is one of the main components of a business model. So, as a priority, energy efficient intelligent buildings, their performance models should be defined exactly. to define the value proposition of energy efficient intelligent buildings and to emphasize the importance of a business model to get revenue generation.

In this section, “Energy Efficient Intelligent Buildings” will be defined and their performance models will be analysed in order to provide inputs for the “Performance Based Business Model of Energy Efficient Intelligent Buildings”. The most efficient parts of performance models will be integrated with the business model to get a performance based business model that works efficiently. A comprehensive search about energy efficient intelligent buildings is made to get five basic benefits :

- A high-performance energy efficient intelligent building will provide operational cost efficiency, so it will have more value in market segment, will be honoured by value network, will be easier to sell and may command a higher market valuation,
- It will enhance the health and well-being for users, so this property will attract to the target customer,
- Better buildings will improve the employee productivity for an office building
- Technologic developments of equipments will be adapted to the building then the building will be upgraded according to the conditions
- Sum of the system efficiency will demonstrate the energy and cost efficiency of the building, so any cautions to hold energy losses will be taken.

3.1 Intelligent Building Definitions

Since in recent years “Intelligent Building” concept has become popular in construction technology, there are many definitions about intelligent buildings and many ideas to define performance requirements of energy efficient based intelligent

buildings. The first definition was mentioned by the former Intelligent Building Institution in Washington: "An intelligent building is one which integrates various systems to effectively manage resources in a coordinated mode to maximise: technical performance; investment and operating cost savings; flexibility" (T. D. J., 1997).

However, it is still difficult to find an exact definition about intelligent buildings because of the difference in strategy approach. Some of the technology developers define intelligent buildings as fully automated buildings that integrated with mechanical and electrical systems by technological systems. According to the research conducted by Wigginton and Haris, there exist over 30 separate definitions of intelligence in relation to building. Early definitions of intelligent building focused almost entirely centered on technology aspect and did not suggest user interaction at all. Cardin (cited in Wigginton, 2002) defined intelligent building as 'one which has fully automated building service control systems'.

The Intelligent Building Institution in Washington (cited in Kroner, 1997) defined intelligent building as 'one which integrates various systems to effectively manage resources in a coordinated mode to maximize: technical performance, investment and operating cost savings, flexibility'.

According to Clements-Croome, the building environment affects the well-being and comfort of human in the workplace, and in turn it influences human's productivity, morale and satisfaction. According to H. Arkin and M. Paciuk's research's it is defined as multidisciplinary effort to integrate and optimize the building structures, systems, services and management in order to create a productive, cost effective an environmentally approved environment for the building occupants (T. D. J., 1997).

The Intelligent Building Institute has proposed: "an intelligent building is one that provides a productive and cost-effective environment through optimisation of its four basic element structure, systems, services and management and the interrelationships between them. Intelligent buildings help business owners, property managers and occupants to realise their goals in the areas of cost, comfort, convenience, safety, long-term flexibility and marketability." (<http://www.coggan.com/intelligent-building.html>).

The Intelligent Building Institute of the United States defines an intelligent building as ‘one which provides a productive and cost-effective environment through optimization of its four basic elements including structures, systems, services and management and interrelationships between them’ (Chen, 2005).

UK-based European Intelligent Building Group: 'An intelligent building provides a sustainable, responsive, effective & supportive environment within which individuals and organizations can achieve their objectives'. So the difference of UK definition is to be more focused on “user’s requirements” than to be focused on technologies that US defined.

The definition adopted by the European Intelligent Building Group (EIBG Promotional Pamphlet, 1994) is: An Intelligent Building 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, 1997).

Behind of all these definitions, the word “intelligent” was first used to describe buildings in the United States at the beginning of the 1980s. The concept of “intelligent building” was stimulated by the development of information technology and increasingly sophisticated demand for comfort living environment and requirement or increased occupant control of their local environment (Wong, 2005).

One view is that intelligence is considered to be an innate general cognitive ability underlying all processes of conventional reasoning. Piaget defines intelligence not as an attribute, but as a complex hierarchy of information processing skills, underlying an adaptive equilibrium between the individual and their environment (T.D.J., 1997).

The starting point of establishing a model of an intelligent building is people, because they determine the mind force of the building against which machines have to act. The effect of an environment at any moment is dependant on ones past experiences. People are not passive recipients of their environment but adapt physiologically and behaviourally.

The body has five basic senses -sight, hearing,touch, smell and taste. They are part of the physiological-psychological system which regulates the human response to environmental stimuli. People react individually and any response may be a transient one or one that becomes an experience stored in the long term memory. The building

and its environment, the social ambience, the work and its management process all trigger the response system. Senses are to be enjoyed but they are also employed to achieve fulfilment in work hence an intelligent building will be sensitive to this demand. (T. D. J., 2001)

The building, its services systems and management of the work process all contribute to the wellbeing of people within an organisation. Productivity relies on there being a general sense of high morale and satisfaction with the workplace. Health, wellbeing and comfort are all important. Intelligent buildings have a vital role to play in helping to achieve this by enhancing human resources, by providing environmental systems which support the productive, creative, intellectual and spiritual capacities of people. (T. D. J., 2001)

The growing investment on intelligent buildings and the greater demand for demonstrating its profitability of intelligent building have led to the investigation for methods and techniques that can be of assistance in evaluating intelligent building investments, preferably at the conceptual stage. (Wong, 2005)

Kell states that the intelligent building is increasingly viewed as one that provides a responsive, effective and supportive environment within which an organisation can meet its performance objectives. The technology, although still generally considered to be fundamental, is now seen as the enabler rather than as an end in itself.

CIB working group stated about Intelligent and Responsive Buildings that an intelligent building 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)
- Management (maintenance; performance)
- and interrelations between them. (CIB Working Group W98, 1995)

According to Markus, satisfaction and comfort can also be linked with better health and productivity, so virtuous clusters begin to emerge where comfort control, productivity and energy efficiency criteria, are ones that are well managed. (Markus, 1967)

A research that has done by DEGW claimed that there was a mismatch between what users expect from an intelligent building and what the suppliers are able to deliver. In addition, one of the main reason for this mismatch is that the intelligent building has generally been defined in terms of its Technologies, rather than in terms of the goals of the organizations which occupy it. An intelligent building can be described as 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 (IBE, 1992).

Intelligence needs to focus on user and organizational goals. The emphasis will shift from the integration of different Technologies towards integrating these and the Technologies of business and space management to serve the overall effectiveness or organisational performance. IBE believe this will require:

- .better user briefs;
- .more responsibility for suppliers to convince users of the benefits of intelligence
- better comparative performance data on both efficiency and effectiveness
- better understanding of user and building lifecycle interactions;
- new forms of procurement
- better relationship between systems (IBE, 1992)

3.2 Performance Models Of Energy Efficient Design Based Intelligent Buildings

The major purpose of this section is to analyze the existing performance models in the cause of pointing out the basic characteristics of these models and the missing parts that should be installed to analyze the intelligent buildings.

3.2.1 Modeling scenarios

This component is for demonstrating how performance modeling can improve business practices and efficiency, as well as the overall performance of systems (Giama, 2006).

3.2.2 Capacity planning

This component involves both business and engineering. If a company has determined an acceptable estimate for future growth, then the process of improving available resources follows close behind. Simply adding more hardware can mean that the additional resources do not equal more capacity and performance suffers, taking company profits along with it (Giama, 2006).

3.2.3 Bottleneck analysis

Evaluating a system that suddenly reaches a plateau and does not respond to hardware upgrades can be a frustrating process. Using performance modeling to detail each transaction and the associated hardware requirements for those transactions can expose bottlenecks. In advance of an actual performance failure, it can also be used to test with higher potential system load and predict the occurrence of a bottleneck, simultaneously showing ways to alleviate the problem before it occurs (Giama, 2006).

3.2.4 Hardware configuration

Detailed performance models can very accurately predict the behavior of proposed hardware upgrades, using performance counters and simulating transactions against the virtual hardware. The upgrades can be set according to the required simulation parameters and data input, so the simulations will be more dependable by improving the calculating system. (Giama 2006)

3.2.5 Architectural assessment

One way to assess the performance quality of two radically different architectural structures is to build both and examine the actual results. This is hardly feasible in the real world of software engineering or multi-client services, however. Both cost and time would be prohibitive. TCA can be used to produce estimates regarding overall system performance based on hardware and network architecture, but it still requires verification.

3.3 Performance Modeling Methods

There are three basic performance modeling methods; analytical modeling, statistical modeling and simulation.

3.3.1 Analytical modeling

The process of analytical modeling involves the use of mathematical expressions to represent the interactions that take place on a system. In some cases mathematical notations such as queuing networks and Petri networks are employed to represent the architecture of a system.

Typically, each component in the model, whether it represents a hardware device, network transaction, section of software code, or user activity, is represented in the underlying system in mathematical terms. Complex equations, representing the relationships between these components, are developed and then solved to determine the projected value of a given variable in the model.

3.3.2 Statistical modeling

Statistical modeling in performance engineering relies on known performance metrics for existing systems. This data can be used as a basis to predict the behavior of a new, not yet built system. This is achieved by analyzing the measured data with techniques such as regression analysis. Then the resulting statistical models can be used to extrapolate the performance of the system in new configurations. (Giama, 2006)

3.3.3 Simulation

Simulation involves building a proposed system and subjecting it to simulated load patterns to assess its performance. The accuracy of simulation modeling in this manner is rivaled only by real-world experience, because the hardware and software in place are the real tools used to provide the service being tested. (Giama, 2006)

3.3.4 Performance Model In Buildings

Building users are the ultimate beneficiaries of the building design. Therefore, it is essential for the designer to articulate the needs of the users to improve the quality of the design. Articulating the needs of users however, is not an easy task,

particularly for buildings where the users are unknown. The designer often has to make predictions on quality by checking the design for its conformity with general requirements set by applicable codes/standards or rules of thumb.

Computer-based performance model:

- formulating the model concept
- constructing the model structure for evaluating performance of a building
- selecting the computer modeling technique
- carrying out the modeling experiments

In this case study the goal was to find out the evidence of the extent of environmental tools synergy. EPE (Environmental Performance Evaluation) is a new term used to describe a formal process of measuring, analyzing, reporting, and communicating an organization's environmental performance with respect to criteria set by its management. The process involves collecting information and measuring how effectively an organization manages its environmental aspects on an ongoing basis. (Giama, 2006).

3.4 Simulation Tool Of Performance Model In Energy Efficient Intelligent Buildings

Building energy performance simulation is a powerful tool that architects, engineers, and developers use to analyze how the form, size, orientation, and type of building systems affect overall building energy consumption. This information is vital for making informed design decisions about building systems that impact energy use, including envelope, glazing, lighting, and HVAC. It is often the case that a few building simulation runs in the early phases of a project can lead to design solutions that, though they appear simple, significantly improve building energy performance. (Huang, 2007)

There are many building energy simulation software available nowadays. Some are simplified energy analysis tools that only provide a quick analysis of annual energy use of buildings, but some use more detailed models and run on hourly basis that provide detailed hour-by-hour energy analysis of buildings. Optimize Energy Performance specified three compliance path options to evaluate the achievement of increasing levels of energy performance above the baseline in the prerequisite standard. One option is whole building energy simulation, which is to calculate a

percentage improvement in the proposed building performance rating compared to the baseline building performance rating per ASHRAE Standard 90.1-2004 by a whole building energy simulation using the Building Performance Rating Method in the Standard. The Standard has many requirements for the simulation programs. DOE-2 and Energy Plus are programs that meet the requirements.(Huang, 2007)

It is hard to estimate the annual energy costs associated with operating a building while it is still under design. The answer depends on numerous factors, including the construction details and orientation of walls and windows, occupancy patterns, local climate, operating schedules, the efficiency of lighting and HVAC systems, and the characteristics of other equipment loads within the building. Accounting for all these variables, as well as their interactions, is a daunting task, especially because some change by the hour. Given this complexity, rigorous calculations of annual building energy costs were rarely performed before personal computers became common place. (Huang, 2007)

3.4.1 Strategies for simulation tool to have greatest dependable results

First of all start early, by incorporating building simulation into the earliest design phases. Then keep it simple, by adding no more detail to a simulation model than is necessary to answer the design questions you are considering. Finally, refine as you go, so that the simulation model evolves with the design; and maintain vigilance, to avoid mistakes. (www.energydesignresources.com)

3.4.1.1 Early start of simulation

A simple energy model can be used to effectively guide major decisions early in the design process. Such decisions may include envelope construction and orientation, glazing type, and the form of exterior shading. (www.energydesignresources.com)

3.4.1.2 Keeping the simulation simple

It will be better to ignore details that won't have a significant impact on the design questions at hand. (www.energydesignresources.com)

3.4.1.3 Refining detailed simulations

As the simulation developed and the building design is refined, then the energy model must be updated to match so that it can be used to answer more detailed

design questions. For example, late in the design process the design team may want to know the energy impact of reducing ductwork sizes to accommodate a smaller ceiling cavity space. (www.energydesignresources.com)

3.4.1.4 Maintaining the importance

Given the vast amount of data that goes into creating a building simulation as well as the detailed and voluminous output reports that most programs generate there are abundant opportunities for making mistakes, from input errors to misinterpretation of results

3.4.2 Calibration

This means a simulation model of the test component and the test environment by simulating with using the measured climatic data, and then comparing predicted performance with measured performance. If the results are dependable, it will be helpful to show the component characteristics. Then used process can be improved by using simulation to get the optimum performance of the experimental design.

3.4.3 Scaling

This step requires the modeling of selected full scale buildings for deployment of the building component under test. Simulations are undertaken of a base case of the building without the component, and then with the component included. Comparisons are made over a range of appropriate performance metrics such as energy consumption, thermal comfort and visual comfort.

The technique allows a more realistic estimate of how the component will perform when it is fully integrated into a building, taking account of, for example, the utilization of passive solar heating.

3.4.4 Replication

This step is about the simulation with different climate datasets and different local operational regimes to determine performance in different locations.

3.4.5 Validation

The main elements of empirical validation are:

- i. Use of modeling to help design the experiment-the accuracy required for the different measurements, the likely range of heat fluxes and temperatures, etc.
- ii. Use of laboratory measurements for important thermo physical and optical properties.
- iii. Create a model of the base case building (as built, or as designed, without the new building component that is being studied).
- iv. Establish representative boundary conditions (e.g. climate).
- v. Undertake integrated simulations using suitable simulation programs.
- vi. Express multi-variety performance in terms of suitable design criteria.
- vii. Identify potential configurations of the technology under study as a function of building type and location.
- viii. Making use of the models tuned in the calibration study, create a series of models of the identified design cases. Care must be exercised to ensure that the component models are not used outside the range for which they have been calibrated.
- ix. Compare the base case and design cases against the selected criteria.
- x. Consider further design cases to improve performance.
- xi. Repeat the procedure for other climate zones to determine the sensitivity of a design to its location (this is termed replication).

3.5 Analyses Of Intelligent Buildings Performance Modeling Methods

In this part some of the performance models of intelligent buildings will be analysed and the advantages and disadvantages of these models will be demonstrated in order to provide input of parameters from performance models for conceptual energy efficient intelligent building business model that will also be defined by its components and relationships between all the disciplines.

3.5.1 Orbit 1-2 Method

The aim is to show the performance of the buildings based on user's requirements in order to take precautions for future buildings (Francis, 1983).

Basic organization subjects are:

- Change in the number of total person in organization
- The improvement in work capacity

- Hierarchy, situation and power of communication
- Organization of staff
- To take the informal interaction to the highest level
- Human factors
- Image
- Outside & inside security (Francis, 1983)

Basic technology subjects are:

- Interrelation between equipment
- The change of cable settlement
- Hierarchy, situation and power of communication
- Required environmental equipment
- Protection of equipment process
- Energy demand
- Re-settlement of equipments that produce heat
- Human factor: work stations
- Communication (Francis, 1983)

Advantages of this model are:

- Useful in design feedback mechanism
- Evaluations are chosen according to their aims
- User's requirements and demand are important for this model (Oğuz, 2007)

Disadvantages of this model are:

- System integration is not included to evaluation
- There is no subtitle about passive systems which provides the evaluation of building sustainability
- No integration between design, planning, operation and the duration.
- Cost analyzing cannot be evaluated, only energy demand is taken into consideration (Oğuz, 2007).

3.5.2 LCC (Life cycle cost) method

In this method “cost” is taken into consideration as basic subject:

- capital cost
- maintenance cost
- management cost

- demolition cost

Optimization of costs are based on:

- Optimum locality evaluation
- Reduction of executive cost
- Engineering and developing cost reduction
- Optimization of energy cost (both production and use)
- Reduction of maintenance cost
- Optimization of building management systems
- Automation management
- Facility data management

Process of LCC:

- Choosing the alternative design for cost analyzing
- To define the cost of investment and life-cycle-cost
- Choosing the exact design with taking into account the function, quality and other components (Fuller, 2003)

Advantages of this model are:

- Helps to analyze the design parameters
- Fundamental for cost efficient and optimum design decision making
- It can be applied to all components or only a component of buildings

Disadvantages of this model are:

- A comprehensive evaluation can only applied to analyze cost
- No parameters belonging to environmental analyses
- User's requirements are not included to cost analyses

3.5.3 Intelligent buildings evaluation method

ABSIC performance criterions: Space quality, Thermal quality, Air quality, Acoustical quality, Visual quality and Construction Quality.

ABSIC Integration Criterions: Structure, Environment, HVAC, PLEC, Interior systems.

User's requirements are defined as:

- Air Quality
- Acoustical Quality
- Thermal Comfort

- Privacy
- Lighting Control
- Control of Space
- Noise Control
- Health
- Motivation

Organizational requirements are defined as:

- Change in Number of Staff
- Hierarchy of Communication
- Staff Organization
- Human Factor
- High Prestige Image
- Outside Security
- Inside Security
- Equipment Connection
- Efficiency

Local environmental requirements are defined as:

- Wind effect in residential area
- Noise effect in residential area
- Daylight effect in residential area
- Shading effect in residential area
- Residential plan convenience
- Re-use of existing areas

Global environmental requirements are defined as:

- Greenhouse gas emission:
- Design based low energy consumption
- Reduction of air conditioner
- Use of energy resources with low emission
- Optimum control
- CFC emission
- Energy consumption of the whole building
- Climate factor

Organization requirements can be evaluated but project management system criteria are not included. Since there is no analytical approach in the system, compared results are not dependable.

3.5.4 Matrix tool

A method that aims to demonstrate energy performance of intelligence buildings in order to identify the requirements of building developers and operators and hence facilitate the acceleration of the market penetration of SMART building technologies. A matrix tool, “Matool”, has been developed in order to fill the gap by presenting a practical and feasible manner for assessing the intelligence of buildings.

The matrix tool takes into account the following three elements:

- The built environment should provide for the safety, health, and productivity of the occupants by meeting the requirements for thermal, visual and acoustic comfort and indoor air quality.
- The building should have the potential to serve future generations through sustainability, or adaptability over the life cycle of the building, and the safeguarding of environment resources.
- The building can be constructed and operated within some financial constraints whilst retaining market value.

The Matool has been developed for assessing the intelligence of buildings during design, procurement and operation. The objective was to develop a tool that would assist in the identification of the weak points of the building project remit, design or operation and indicate where intelligence may be improved.

The basis of the Matrix Tool is the definition of the Intelligent Building as a building that:

- Provides a productive and cost-effective built environment through optimization of its four basic components - structure, systems, services and management – and the interrelationships between them (focusing on the benefit of the owners, i.e. creating the desired indoor environment)
- Maximizes the quality of the indoor environment (focusing on the benefit of the occupants, i.e. impact of meeting desired indoor environmental conditions on occupants)

- Allows effective management of resource with minimum life cycle costs (focusing on the benefit of the environment, i.e. through minimum environmental impact whilst maximising economic impact)

Over the years relevant technologies for use in designing, constructing and operating intelligent buildings have significantly progressed and are still being rapidly developed.

Plenty of intelligent buildings have been built. However, how intelligent these buildings actually are compared with conventional buildings is often a question. Due to the lack of a commonly accepted method and pertinent supporting data, assessing the overall performance of intelligent buildings can't be carried out on a solid ground. It is difficult if not impossible, to carry out like-to-like comparison between different buildings in term of intelligence. As a result, the industry still goes without adequate knowledge about the best practice of intelligent building. (Bassi, 2005)

This matrix tool should be used by facility managers and construction professionals to allow the assessment of the following performance indicators of the building:

- Built environment
- Responsiveness
- Functionality
- Economic Issues
- Suitability

Each of the five Intelligent Building Performance Indicators is influenced by all five fields of Impact. Their interactions are considered in the Matrix Tool.

Each of the performance indicators has a value ranging from 0 to 5, with 5 indicating the best and 0 indicating the worst. Once these individual performance indicators are assessed against the relevant building features, the overall performance is computed as below:

P are the value of individual performance indicators: Built Environment, Responsiveness, Functionality, Economic and Suitability respectively are respectively the weighting factors for individual performance indicators.

The building is assessed using the developed questionnaire. A PI may be affected by all or some of building features described below. Building features and their

interaction with each other, with the user and with the environment determine the performance of a building. The building features are identified in “Matool” as below:

Site, locations

- The building location
- Utility services
- Accessibility
- Facilities nearby
- Convenience of site and location for building users, visitors and business clients.

Building envelope, core and space layout

- The building form
- Internal space layout, depth, floor to floor height, grid, form, internal partition
- Maximum distance to fire escape
- Occupancy density
- Atria, etc.

Amenities

- External access
- Circulation
- Toilets and common rooms, public areas,
- Servicing facilities

Structure

- Safety and protection against earthquake, subsidence, flooding
- Future extension
- Span, load
- Embedded monitoring

Materials

- Energy performance
- Internal environment quality (IAQ)
- Sustainability (embedded energy, recycling, waste treatment)

Façade and cladding

- Glazing
- Cladding

- Shading
- Natural ventilation and lighting features
- Use of solar energy (heat collect or PV)

Environmental system

- HVAC
- Passive and active solar system
- Natural ventilation

Mechanical system

- Vertical transportation
- Plumbing, water storage, cleaning system, waste disposal
- Recycling system

Electrical system

- Power supply
- Lighting
- Lightning protection

IT and communication system

- Telephone, fax, computing
- LAN, WAN
- TV & Radio

Fire safety system

- Fire prediction/detection system
- Fire alarm system
- Fire protection system
- Fire fighting system

Building management system

- Security system
- HVAC control
- Lighting control
- Vertical transportation control

All these building features directly influence each individual performance indicator and the overall performance, or the “Intelligence” under “Matool”, of a building. (Bassi, 2005)

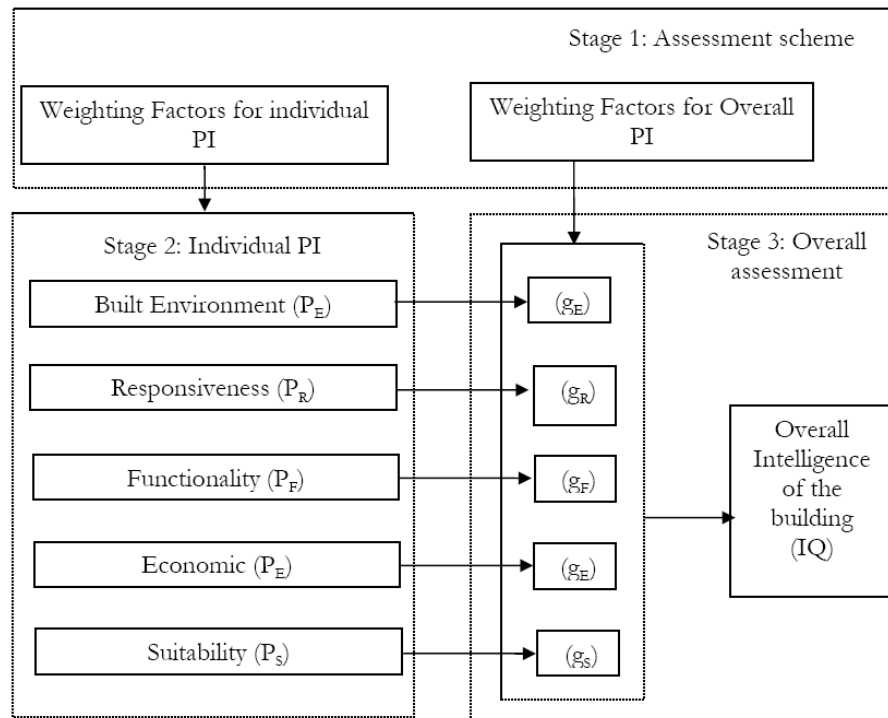


Figure 3.1 : The relation of components of MATOOL and the the system

This figure shows the system of matrix tool to figure out how the mechanism works:

According to this diagram IQ is equal to the sum of all weighting factors for individual times wieghning factors for overall. P is the value of individual performance indicators: Built Environment, Responsiveness, Functionality, Economic and Suitability respectively. The g is respectively the weighting factors for individual performance indicators.

The value of IQ specifies the “intelligence” of a building under the “Matool”. The maximum value of IQ is 125. The rating of the intelligent building is accordingly specified as follows:

- Bad: <50
- Good: 50 ~80
- Very Good: 80 ~100
- Excellent: 100~125

3.5.5 Analytical Network Process Model

Developed analytical methods and techniques over the past few years of research efforts have facilitated and enabled the decision-making and evaluation for intelligent building designs.

The major gap is to develop an integrated systematic methodology and techniques in addressing the system intelligence of the intelligent building systems and components (Wong, 2007).

The tried intelligent building system configuration in one project does not necessarily mean the most suitable option in another project as the project nature and building design varied from one to another. As a result, inadequate understanding of system intelligence might lead to incorrect selection of building systems or components.

The multi-criteria decision-making (MCDM) technique is proposed as a solution to solve the complexities involved in the building system intelligence justification. The multiple dimensions of system intelligence (i.e. the intelligent attributes) of the key intelligent building systems are to be evaluated through an analytic hierarchy-network process (i.e., a combination of AHP and ANP approaches). The analytic network process (ANP) approach is utilized in the current research for two reasons. ANP allows a more comprehensive analytic framework which is not restrictive with a hierarchically structural model alone (i.e. analytic hierarchy process, AHP). This method can be used to integrate qualitative information and quantitative analysis, and to capture interdependencies among the decision attributes (Wong, 2005).

The first conception of the intelligent system relates to the abilities on performing self-operative functions ('autonomy'). An intelligent system should be designed in a manner that allows minimum human intervention as much as possible during execution of task (Wong, 2007).

Self-calibration, self-diagnostics, fault tolerance and self-tuning are considered to be the key autonomous features of intelligent systems. Second, a system is considered to be 'intelligent' when it possesses the ability to perform interactive operative functions, and is able to make a very complicated dynamic system well-controlled ('controllability for complicated dynamic systems').

A review of literature suggested that the main operational benefits of installing intelligent building components include:

- improved operational effectiveness and energy efficiency
- enhanced cost effectiveness
- increased user comfort and productivity
- improved safety and reliability
- integrated building management system (IBMS) for overall monitoring and building management function
- heating, ventilation and air-conditioning (HVAC) control system for indoor air quality (IAQ) and comfort control;
- addressable fire detection and alarm (AFA) system for fire prevention and annunciation;
- telecom and data system (ITS) for communication network backbone;
- security monitoring and access (SEC) system for surveillance and access control;
- smart/energy efficient lift system (LS) for multi-floors transportation service;
- digital addressable lighting control (DALI) system for light design and control; and,
- computerized maintenance management system (CMMS) for inventory control and service works (Wong, 2007).

3.5.5.1 Integrated Building Management Systems

The main function of IBMS is to integrate all essential building services systems to provide an overall strategic management in all aspects with the capacity to systematically analyze and report the building performance and connect with multiple site/location to give corporation a portfolio view of the situation.

The hierarchy of IBMS system is figured below to define the relations and between the components.

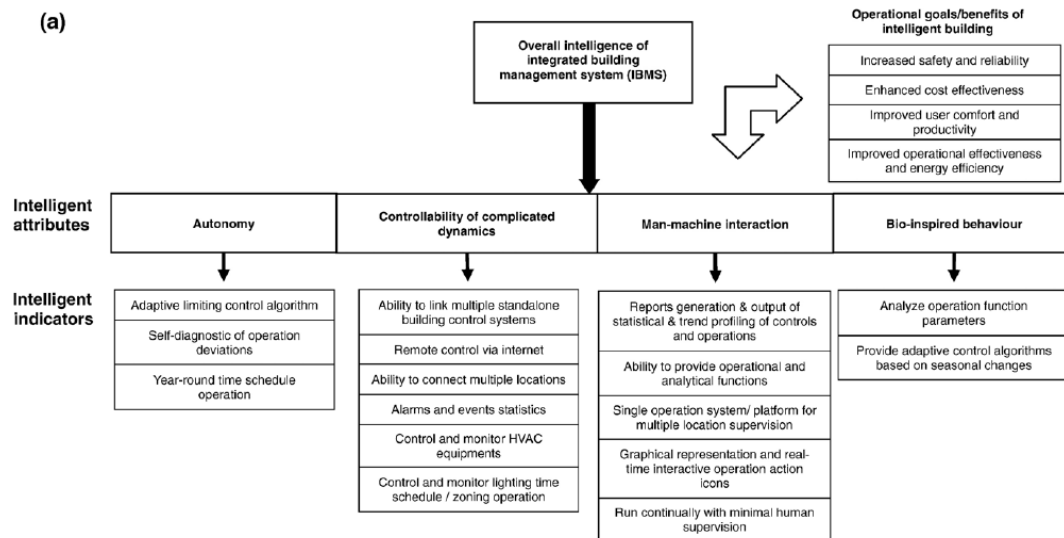


Figure 3.2 : Intelligent attributes and indicators of IBMS (Wong, 2007)

As it is figured out above in Figure 3.2 at the top of the control hierarchy, it is the ultimate objective that is wanted to be achieved. The ultimate objective is to determine the overall intelligence of the integrated building management system (IBMS). The relationship between the intelligent attributes and the identified operational benefits is explored based on the fact that if system designers look for the best operational goals/benefits from implementing intelligent building components, which intelligent attribute(s) is/ are relatively important in leading to such benefits. In contrast, each intelligent attribute might have varied degree of importance in promoting these operational goals/benefits. Thus, the four operational goals/benefits (operational goals/benefits of intelligent building) act as external variables and form network relationships with the intelligent attributes in the analytical decision model. It is noteworthy that the list of operational goals/ benefits is not exhaustive, but they are considered as prominent goals or benefits promoted by the intelligent technologies in the available intelligent building literature (Wong,2007).

The remainder of the decision network hierarchy is more conventional in that the elements have a hierarchical relationship (i.e., the relationship between the intelligent attributes and their corresponding indicators). The proposed analytical models for the rest of the intelligent building control systems were illustrated in Figure 3.3 and the relations between the components are defined according to its system process (Wong, 2007).

3.5.5.2 Telecom and data system (ITS)

The telecom and data system is a communication network backbone in intelligent building designed to provide effective and efficient information transmission or exchange inside and outside building. Four intelligent indicators including the ‘ability of integrating multiple network or service providers’; ‘transmission capacity control and diversion’; ‘the installation of fixed hub/terminal port’ and ‘system life and turn-round complexity’, were identified as the most suitable indicator by the stakeholders.

The relation and the process of ITS system is shown below in Figure 3.3:

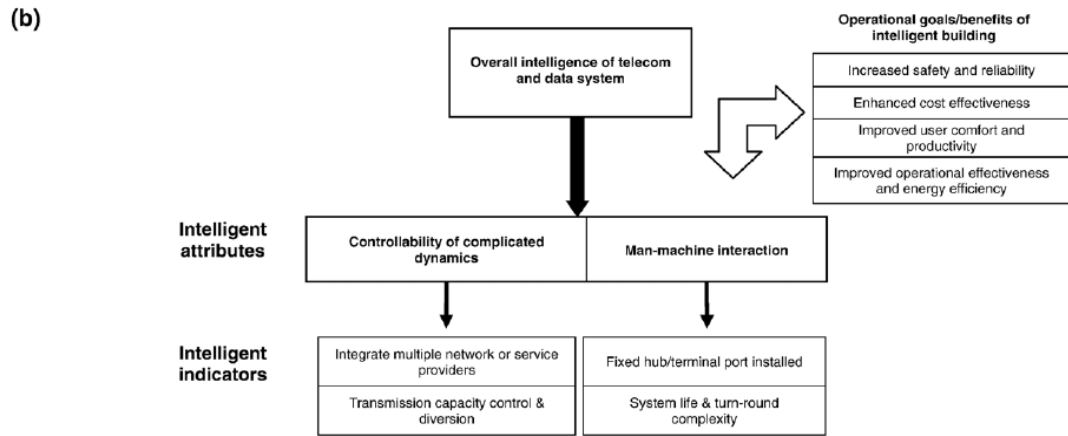


Figure 3.3 : ANP decision model for the system intelligence appraisal of the telecom and data system (Wong, 2007).

Operational goals and benefits are defined in figure 3.4, also the intelligent attributes and the intelligent indicators are defined in the diagram.

3.5.5.3 HVAC control system

The primary objective of HVAC control system is to enhance thermal comfort, humidity control, and adequate ventilation inside the buildings. To determine the intelligence performance of a HVAC system, design consultants placed greater emphasis on the ability to ‘sense the internal temperature and humidity, and auto-adjustment’, and the ‘interface with EMS, BAS, or IBMS’ of HVAC control system. A comfortable and healthy visual environment is critical to support the activities of the occupants. In HVAC control system, the PID (Proportional-Integral-Derivative) controls are employed to control the supply air temperature, supply static pressure,

and return air flow rate. The intelligent attributes and the intelligent indicators of HVAC systems are defined below in Figure 3.4.

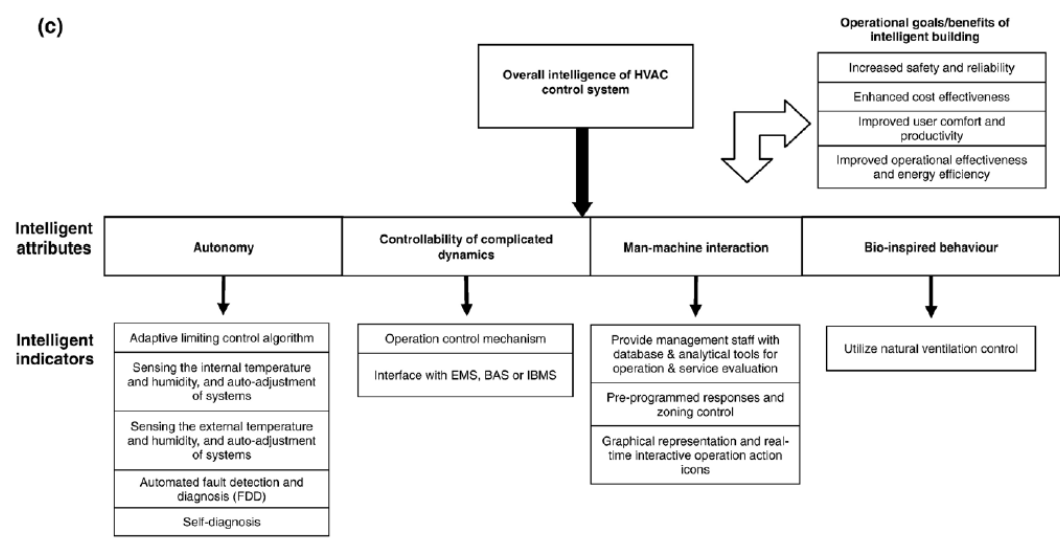


Figure 3.4 : ANP decision model for the system intelligence appraisal of the HVAC control system (Wong, 2007).

3.5.5.4 Addressable fire detection and alarm (AFA) system

The key function of the AFA system is to provide effective fire detection, control and fighting in the building. Other than the statutory requirements of the fire detection systems, a total of ten indicators were determined by stakeholders as important in justifying the system intelligence of fire detection system. The top two indicators include the ‘alarm deployment algorithm within the building and notification to Fire Department’, and ‘self-diagnostic analysis for false alarm reduction’. Facility managers emphasized three other intelligent properties of AFA system as 1st ranking: ‘interface with security systems’, ‘Run continually with minimal human supervision’, and ‘interface with HVAC systems’.

The control strategy for each subsystem of the HVAC plant should set up the control action to be taken in the event of receiving a fire alarm signal.

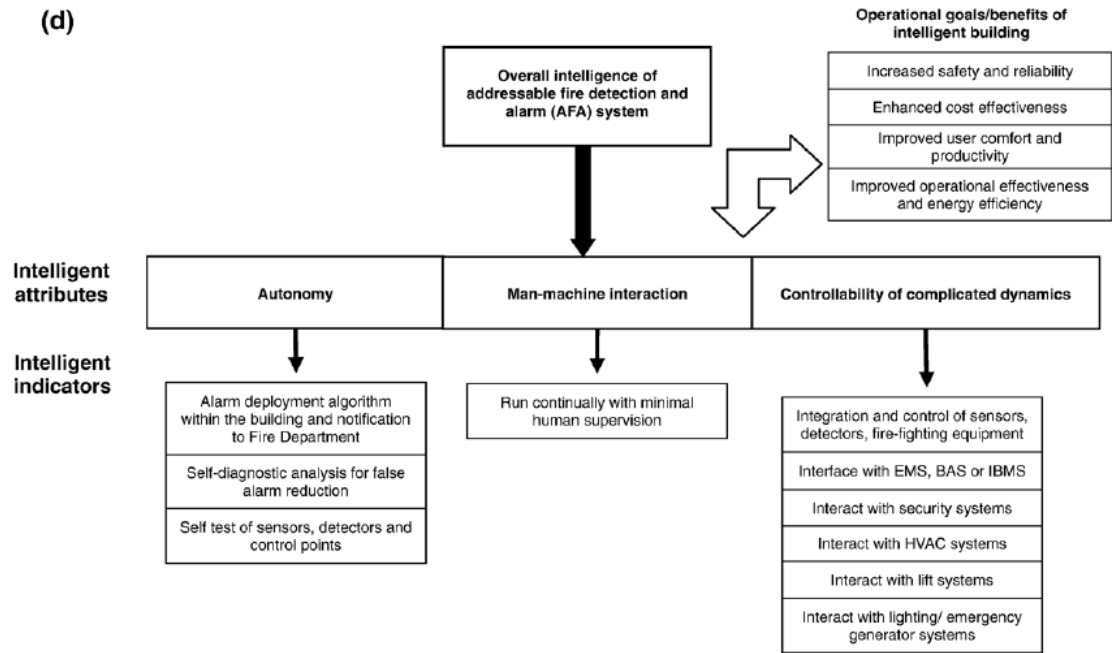


Figure 3.5 : ANP decision model for the system intelligence appraisal of the fire detection and alarm (AFA) system.

The intelligent attributes and the intelligent indicators of AFA systems are defined above in Figure 3.5.

3.5.5.5 Security monitoring and access control (SEC) system

The SEC system is developed to provide surveillance and access control to detect unauthorized entry and enhance security and safety inside the building. Eight intelligent indicators were determined. Three indicators that were quite consistently in rankings among developers, design consultants and facility managers include ‘configurable to accurately implementation of the security policies for the premises’, ‘interfacing with other systems’, and ‘continual operation with minimal human supervision’.

The intelligent attributes and the intelligent indicators of SEC systems are defined in Figure 3.6. according to this figure operational goals and benefits are:

- Increased safety and reliability
- Enhanced cost effectiveness
- Improved user comfort and productivity
- Improved operational effectiveness and energy efficiency

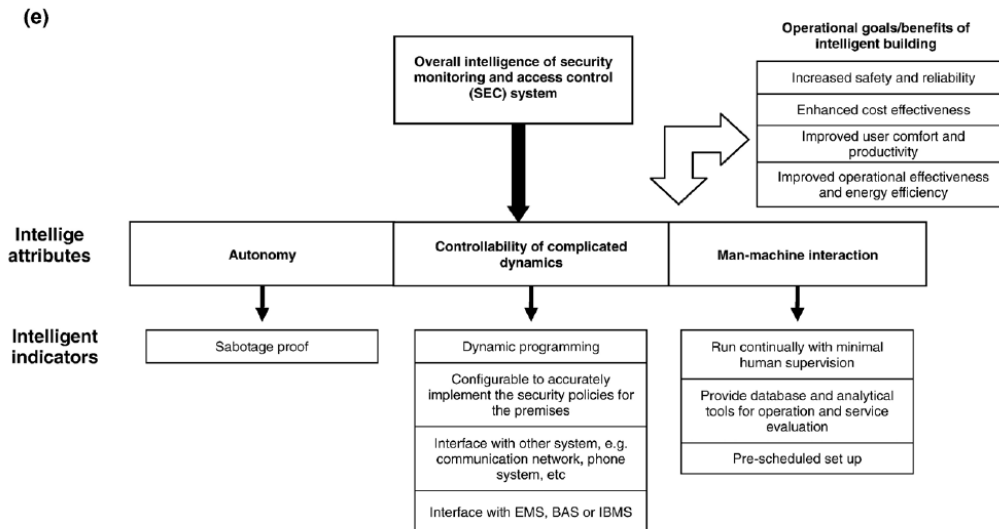


Figure 3.6 : The components of SEC system

As it is listed above the basic part of these network is “the controllability of complicated dynamics” that are also related with autonomy and man machine interaction.

3.5.5.6 Smart/energy efficient lift system (LS)

The smart/energy efficient lift system aims to transport passengers to the desired floor quickly, safely, and comfortably. A total of 8 key intelligent indicators were determined by the respondents. The four highest rank of intelligent indicators included ‘auto-controlled navigation at emergency’; ‘human engineering design’; ‘accommodate changes of passenger traffic pattern’; and, ‘interface with EMS, BAS, or IBMS’.

As it is demonstrated below in Figure 3.7 the man-machine interaction are specified as:

- Human engineering design to facilitate convenience of passengers,
- Provide management staff with database and analytical tools for operation and service evaluation,
- Pre-scheduled of special events and normal routines

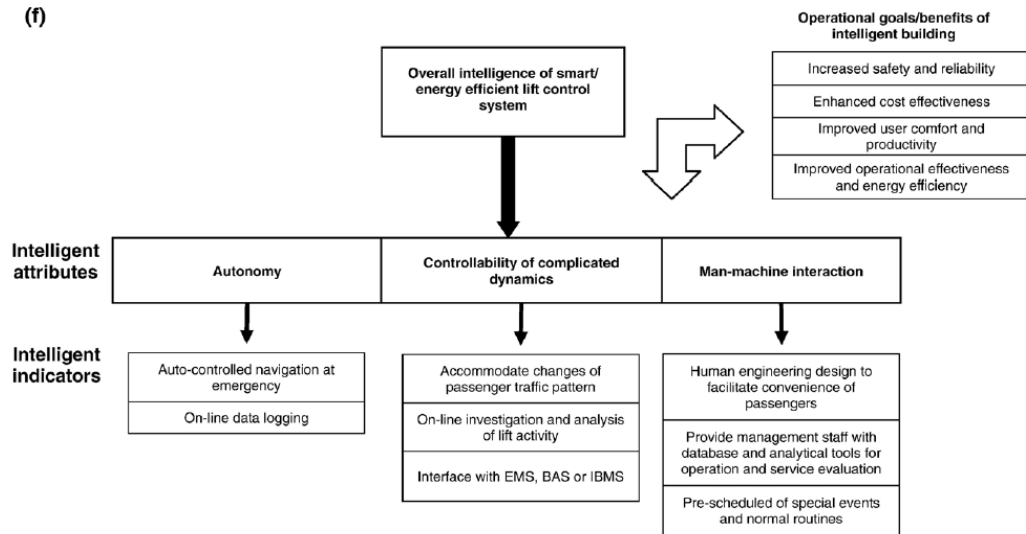


Figure 3.7 : ANP decision model for the system intelligence appraisal of the smart/energy efficient lift control system (Wong,2007)

3.5.5.7 Digital addressable lighting control (DALI) system

The digital addressable lighting control system is expected to provide acceptable levels of illumination for all aspects of occupations, and to enhance efficient lighting usage and energy conservation in the intelligent building. Seven key indicators were identified by the stakeholders in the survey. Both design consultants and developers ranked the ability of system control of individual luminaries, groups of luminaries, and, lighting zones' and the 'system interface with EMS, BAS, or IBMS' as the prime intelligent indicators. The controllability of complicated dynamics are shown in figure 3.8 as:

- Presence detection including dimmable occupancy sensor, access triggered control,
- Control of individual luminaries, groups of luminaries or lighting zone,
- Interface with EMS, BAS or IBMS

The man-machine interaction and the bio-inspired behaviour are also defined in the network diagram below (Wong,2007).

(g)

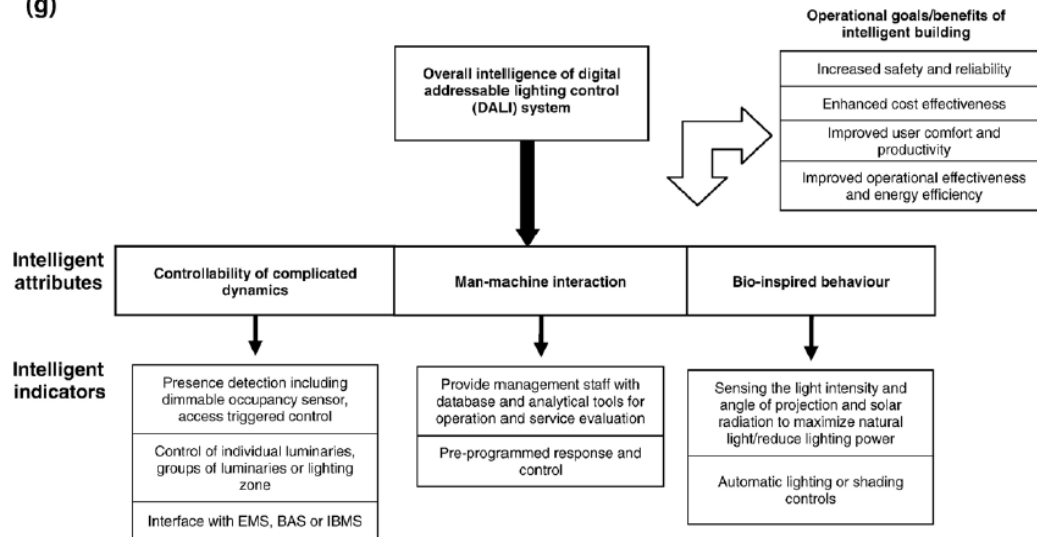


Figure 3.8 : ANP decision model for the system intelligence appraisal of the digital addressable lighting control (DALI) system. (Wong, 2007)

3.5.5.8 Computerized Maintenance Management System (CMMS)

The CMMS is designed to provide efficient and effective inventory control and service works management of the building. Seven indicators were suggested by the stakeholders to determine the system intelligence. The result implies that the availability, reliability and maintainability of the CMMS are very common and important in any facilities management operation systems strategy. This is a key to effective serviceability and maintenance management of the building.

(h)

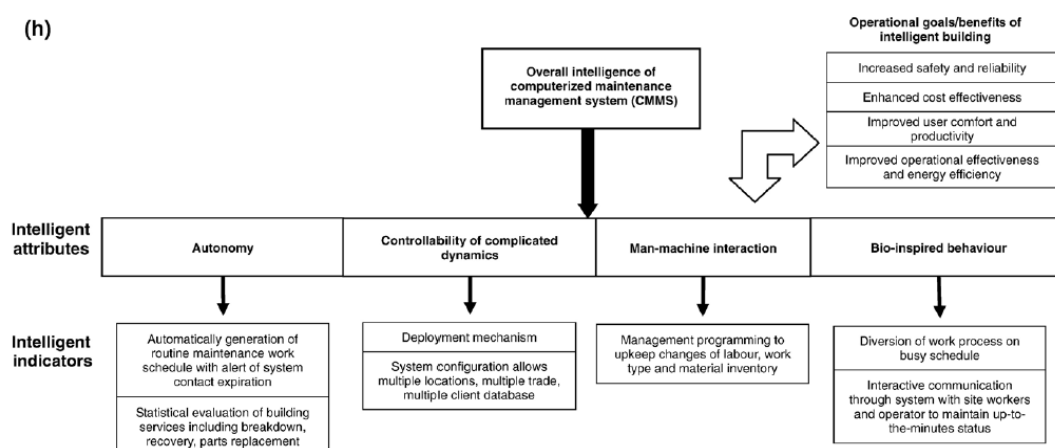


Figure 3.9 : ANP decision model for the system intelligence appraisal of the computerized maintenance management system (CMMS). (Wong, 2007)

The remainder of the decision network hierarchy is more conventional in that the elements have a hierarchical relationship (i.e., the relationship between the intelligent attributes and their corresponding indicators). The proposed analytical models for the rest of the intelligent building control systems were illustrated in the figures from 3.2 to 3.9.

3.6 Synthesis of Performance Model Analysis

- Feedback mechanism is needed
- User's requirements and demand should be taken into consideration
- System integration is required:
 - Coordination between the energy consuming systems
 - Passive design strategies should be taken as basic strategy
 - Sustainable design parameter should be integrated
 - Cost analysing should be integrated:
 - execution cost
 - cost efficiency
 - user's requirements should be included to cost analyses
- It is required that there should be a data processing and condition evaluation
- Environmental criterions should be included
- There should be a mechanism that measures the pleasure of user's like a survey or any other thing to analyze user's comfort.

3.7 Inputs of Performance Model Analysis For Conceptual Business Models

To design a performance based business model, all of these performance models are analysed. There should be an integration between the performance models since they have some missing points that mentioned as disadvantages above and so they are not sufficient for a comprehensive model. There could be an integrated dependable performance model to demonstrate the value proposition of an intelligent building and also they can show the reduction in energy consumption, so this is also a revenue generation for stakeholders. In matrix tool, all the building systems are defined and these systems will be used as a guide for conceptual performance based energy efficient Intelligent building business model.

On the other hand, the analytic network process model defines the network between systems efficiently and comprehensively, for a detailed business model, this performance model can be recommended for future studies on performance based business models.

4. PERFORMANCE BASED BUSINESS MODELS IN ENERGY EFFICIENT INTELLIGENT BUILDINGS

There is not so many existing comprehensive model for intelligent buildings as an economic and business activity. It is an innovation to improve an efficient business model for intelligent buildings. This section will emphasize the importance of business models for energy efficient intelligent buildings.

Furthermore, a conceptual performance based business model for energy efficient intelligent buildings will be designed diagrammatically depending on the main functions and components of business models and also the stakeholders that are specified for intelligent building industry. The conceptual business model will be defined beginning from the intelligent building request by target customers then coming to an end at the demolition period of the building since the business model should be designed for every stages for a building with its feedback mechanisms. The business model is a living concept for buildings that provides the control of value and the revenue at any period of an energy efficient intelligent buildings.

In addition to these expressions a case study will be analysed in this section in order to demonstrate its performance of energy efficiency and will be checked with the conceptual business model to show their business strategy and business model recommendations as an output of case study for future projects.

4.1 Business Models In Construction Sector

Construction is a project-based industry and so an effective and successful industry is the result of effective and successful projects. To model construction activities, it is needed something between a model of the firm and a model of the Project, with a particular focus on interpersonal and inter-organizational relationships (Hillebrant, 2003).

According to researches, “demand” can be mentioned that the focus of private investors on reduction of direct cost. In addition, an efficient business model helps to define and understand the construction industry. Moreover, models would enable

industry and society to run different scenarios and test their consequences, and also they would assist in clarifying the concept of value and where this emerges, or is added, in the supply chain (both physically and intellectual) and in the lifetime of construction. At least two distinct models would be required:

- One for the part of the industry that produces new building
- Another for the part that modifies buildings already produced.

Models of construction have focused on the actions that need to be accomplished in order to achieve the completed building or structure. A model that illuminates the way the industry operates will need to pay more attention to the actors. Dr PM Hillebrandt mentions in his search of a business model for UK that the problem in creating a model for the construction industry is very complex and diverse. Unless the model were detailed it would not be sensitive enough to predict effects of change. He adds that to create detailed model of the whole industry would take years and much research resource, so that its use to predict the effects of change would be long delayed. As a result a business model does not have to comprise the whole industry, it would be more efficient if a part of it is taken by as a business area in order to define network of the process, the project and the interrelation between them. In the next chapter, it is aimed to take a part from construction sector that is called “intelligent buildings” in order to define a business model for them (Hillebrandt, 2003).

4.2 Business Model For Energy Efficient Intelligent Buildings

Since there is not sufficient research for defining business model for intelligent buildings, it is difficult to show an exact model and to test their performance in order to analyze their efficiency. In this study business model for smart buildings will be taken as a source and will be adapted to “energy efficient design based intelligent buildings business model”. The “building Smart Building” platform focuses on the following services area will be supported by the platform:

- services for comfort
- services for safety and security
- services for sustainable performance
- services for human/building interaction
- services for health and well-being

In this aspect it can be mentioned that the services above are also needed for energy efficient design based intelligent buildings. According to Michael Brambley making buildings smarter means developing the technology for buildings that collects data, process it in the traditional sense of performing numerical analyses, then interpreting the results of those analyses to reach conclusions about the status of the building or the system. However, according to many definition that has shown in this study it is clear that if a building intended to be intelligent building, it should also be designed basically energy efficient besides the technologic systems.

4.3 Functions Of Energy Efficient Intelligent Building Business Models

According to the search by Chesbrough and Rosenbloom, mostly a business model focuses on the mechanisms for generation of revenue in the value chain and there can be defined six functions of a business model:

- to articulate the value proposition of energy efficient intelligent buildings
- to identify a market segment for construction sector of intelligent buildings
- to define the structure of the firm's value chain
- to specify the revenue generation of mechanisms
- to describe the position of the firm within the value network
- to formulate the competitive strategy (Chesbrough, 2002)

4.4 Six Components Of A Basic Business Model Of Intelligent Buildings

First component is “value proposition” that is a description of the customer problem, the solution that addresses the problem, and the value of this solution from the customer's perspective. Value proposition of energy efficient intelligent buildings can be described as the benefits that are delivered by the firm (the firm that is proposed to build an energy efficient intelligent building) to its external constituencies (Bagchi and Tulske, 2000). It can be described as the definition of how items of value, such as products and services are packaged and offered to fulfill user requirements of the energy efficient intelligent building.

Second component is “market segment” that the group to target, recognizing that different market segments have different needs. Sometimes the potential of an innovation is unlocked only when a different market segment is targeted. In other words, market segments are group of high-potential prospective customer with

common characteristics and need that distinguish them from other high potential market segments.

Third component is “value chain structure” that is the firm's position and activities in the value chain and how the firm will capture part of the value that it creates in the chain. Value chain analysis views the organization as a sequential process of value-creating activities. In competitive terms, value is the amount that buyers are willing to pay for what a firm provides for them. The Value chain approach is very useful for understanding the building blocks of competitive advantage. A firm is profitable to the extent that the value that it receives exceeds the total costs involved in creating the product or service.

Fourth component is “revenue generation and margins” that is about how revenue is generated (sales, leasing, subscription, support, etc.), the cost structure, and target profit margins.

Another component is position in the value network that is an identification of competitors, complementors, and any network effects that can be utilized to deliver more value to the customer.

Last component is “competitive strategy” that is about how the company will attempt to develop a sustainable competitive advantage and use it to improve the enterprise's competitive position in the market.

4.5 Possible Seeds Of Business Model Of Energy Efficient Intelligent Buildings

There are two main possible seeds that are; leasing of energy efficient building components and open building approach.

4.5.1 Leasing of energy efficient building components

Leasing and/or rental of off-site building components are typical service providing business models. Users can enjoy benefits because suppliers assure the quality of service embodied with functions and performance of components for duration of contract. Though there is a risk on future expense for maintenance and repair, it could be beneficial for supplier because of potential to increase business opportunities. The leasing model gives incentive to fabricate exchangeable and durable components, which contributes to better resource productivity (Habraken, 1998).

4.5.2 Open building approach

Works to existing buildings are seeds of various service providing business models. Owners and users of building have explicit/tacit need of tailor-made of building over its life cycle, respecting on ever changing requirements in turbulent socio-economical and technological environment. Open building approach is the methodology of continual customization where, organizationally and physically, built environments are subdivided into several independent levels; urban tissue, support and infil (Habraken, 1998).

4.6 Designing A Conceptual Energy Efficient Intelligent Business Model

Designing an efficient business model for intelligent buildings is not an easy issue because there can not be a unique model for buildings, since each building has different design conditions, user's requirements, etc. If a constant business model will be defined for construction sector, this can be something like a diet program that is planned for all people although they all have different metabolic problems and different life styles. However, a basic business model may be defined with all the basic components and it can be improved by project developers by adapting their own project.

4.6.1 Identification of stakeholders for energy efficient intelligent buildings

As the term of stakeholder is defined in part two, stakeholders are an integral part of a project. They are the end-users or clients, the people from whom requirements will be drawn, the people who will influence the design and, ultimately, the people who will reap the benefits of a completed project. The intelligent building technologies industry involves a wide range of stakeholders, which bring with them a great variety of interests, concerns, requirements and potential opportunities. To provide structure in considering these stakeholders, they have been grouped in four categories, based on somewhat common interests and needs. These seven main categories are; developer/owner/operators, occupants/tenants, suppliers, design engineers, contractors, equipment and system manufacturers, authorities having jurisdiction.

4.6.1.1 Developers/ Owners/ Operators

This includes all who have an ownership and ownership-type interest and role in construction projects and in the ownership and operation of commercial and large residential buildings, which use or could use intelligent building technologies.

For the building developer, intelligent building technologies provide advanced functionality at modest cost, and integration provides more usable (and revenue earning) space.

Traditionally, developers create and construct a building complex and subsequently seek occupants/tenants, or the developers undertake customized construction to meet the established requirements of an identified customer. The developer generally seeks to meet the market's requirements, with minimum investment. Intelligent building technologies reduce the infrastructure space needs, e.g., fewer conduits, control systems and control locations, increasing the usable office space.

There are also the current trends clearly indicate that occupants/tenants value the improved services and environment in the building. This produces a tangible and saleable improvement to the building, which is clearly attractive to any developer.

Besides intelligent building technologies reduce operating and maintenance costs, and allow for more effective and responsive building management, these technologies can also provide a single interface for the integrated building services. The inherent intelligence also allows the owner/operator to transfer some building control to the occupant/tenant, improve telephone services and accessibility for the end user and facilitate security management. All of these changes provide operational efficiencies and the opportunity for increased revenue. These systems also provide owners/operators with greater operational flexibility, e.g., the ability to operate several buildings from one control centre, improving effectiveness while reducing cost.

4.6.1.2 Occupants/ Tenants

This includes all who occupy space in the building, whether as tenants or as employees of the building owner, e.g., building occupants, tenants and end users of all kinds, including retailers and restaurants as well as those who occupy office space.

Building occupants/tenants clearly prefer the up-to-date bells and whistles that differentiate premium office accommodation from commodity space. What they want and what are they seeking is what intelligent building technologies can provide and they clearly perceive that these features bring enhanced value, although, like consumers the world over, they look for the best value at the lowest price. These Premium features focus on two areas. One addresses a more comfortable environment (HVAC, lighting, access and security) and the other relates to services and features that will improve efficiency and effectiveness.

4.6.1.3 Suppliers

This includes all who supply anything within the intelligent buildings industry, both in new construction and in the ongoing operation of existing intelligent buildings, and including suppliers of both goods and services, e.g., the construction industry in all its aspects, architects, design engineers, all specialties, building products suppliers, building equipment and system manufacturers, researchers and developers within supplier organizations, support and maintenance organizations, educators.

4.6.1.4 Design Engineers

For the design engineer, intelligent building technologies provide enhanced functionality, facilitate commissioning and reduce dependency on proprietary vendors. Furthermore, intelligent building technologies provide design engineers with better control of site construction, because of fewer subcontractors and ensure consistent infrastructure options and implementation. If the infrastructure for intelligent building technologies is covered by a single contract, it is normally undertaken by a single contractor who is responsible for both the integration and the infrastructure.

4.6.1.5 Contractors

For the construction industry, intelligent building technologies allow interchange of vendors and manufacturers, ensure control of construction costs and make testing and commissioning easier. Intelligent building technologies can allow for building completion in stages, i.e., it becomes possible for occupation of those floors of the building that are complete rather than awaiting full completion of the building project before occupancy may occur.

4.6.1.6 Equipment and System Manufacturers

The intelligent buildings market provides promising new business opportunities for technology developers. The development of standards is also promoting co-operation among vendors. Many technologies initially developed for other markets are now finding applications in the construction sector.

For building equipment and system manufacturers, intelligent building technologies offer good marketing opportunities through vendor interoperability. Intelligent building Technologies decrease costs and increase reliability through the sharing of a common communications infrastructure.

4.6.1.7 Authorities Having Jurisdiction

This includes all who regulate, legislate or make rules that affect the intelligent buildings industry, including building codes, health and safety regulations, municipal by-laws that relate to land use and construction and buildings, and the requirements of fire officials and waste disposal officials, e.g., regulatory authorities; building code regulators, health and safety policy developers, all levels of government, and other industry agencies. These groups will sometimes overlap, and they may often represent conflicting interests. Broader issues will often affect the stakeholders in intelligent building technologies, e.g., policies related to energy efficiency, social policies (e.g., low income housing) and sustainable development policies.

4.6.2 Value proposition part of intelligent building business model

The element “Value Proposition” is an overall view of one of the firm's bundles of products and services that together represent value for a specific customer segment for energy efficient intelligent buildings. Customer segmentation is the practice of dividing a customer base into groups of individuals that are similar in specific ways relevant to marketing, such as age, gender, interests, spending habits, and so on. Using segmentation allows companies to target groups effectively, and allocate marketing resources to best effect. To summarize value proposition describes the way that the firm who is proposed to built the energy efficient intelligent building, differentiates itself from its competitors and is the reason why customers buy from a certain firm and not from another.

Project general information

- Project Name
- Project Type
- Project Location
- Project Duration
- Project Mission
- Project Firm & Partners

Project Master Plan

- Approach to concept of design & Problem Description
- Approach to site (Analysis of facilities nearby, transportation, . . . etc.
- Business plan of project
- Resource balancing

4.6.3 Market segment part of intelligent building business model

Market segmentation is the identification of portions of the market that are different from one another. Segmentation allows the firm to better satisfy the needs of its potential customers.

Project Concept Design

- User's requirement definition based on market research
- Project advertisements supported by 3D models and videos
- Innovative design improvement according to targeted customers

4.6.4 Value chain & design part of intelligent building business model

Value chain analysis views the organization as a sequential process of value-creating activities. In competitive terms, value is the amount that buyers are willing to pay for what a firm provides for them. The Value chain approach is very useful for understanding the building blocks of competitive advantage. A firm is profitable to the extent that the value that it receives exceeds the total costs involved in creating the product or service.

- Climate of Located Site
- Building Form
- Integrating concept of energy efficiency based on passive solar
- strategies

- Additional concept of sustainability
- Internal space layout, dept, floor to floor height, grid, form, internal
- partition
- Maximum distance to fire escape
- Occupancy Density
- Facade and Cladding
 - Glazing
 - Cladding
 - Shading
 - Natural ventilation and lighting features
 - Use of solar energy (heat collector or PV)
- Materials
 - Energy performance
 - Internal environment quality
 - Sustainability (embodied energy, recycling, waste treatment
- Amenities:
 - External Access
 - Circulation
 - Toilets and common rooms, public areas
 - Servicing facilities
- Environmental system
 - - HVAC
 - - Passive and active solar system
 - - Natural ventilation
- Mechanical system
 - - Vertical transportation
 - - Plumbing, water storage, cleaning system, waste disposal
 - - Recycling system
- Electrical system
 - - Power supply

- - Lighting
- - Lightning protection
- IT and communication system
 - - Telephone, fax, computing
 - - LAN, WAN
 - - TV & Radio
- Fire safety system
 - -Fire prediction/detection system
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 - -Fire protection system
 - -Fire fighting system
- Building management system
 - -Security system
 - -HVAC control
 - -Lighting control
 - -Vertical transportation control

4.6.5 Revenue generation

This section is about how revenue is generated, the cost structure and target profit margins. This term is used in intelligent building business model instead of “sales” or “marketing” because the discipline of generating revenue should penetrate every corner of the organization by the view of all the energy efficiency aspect. Since business model is considered based on intelligent buildings the revenue generation can be also taken as cost reduction in energy consumption. If the building is constructed to sell, cost reduction demonstration can be a marketing strategy. If the building is constructed to use by investor, revenue generation in life-long cost reduction by passive solar strategies and active solar strategies will be one of the prior important cautions.

Revenue Generation in Energy Efficient Intelligent Building Business Model is about:

- A lifetime of reliable and profitable growth of benefit of the all stakeholders
- Structure in place to efficiently and consistently execute that aligned strategy
- Best practice tools to guide the implementation of revenue tactics
- Documented learning for continuous improvement and predictable revenue growth.
- Sales & marketing model of energy efficient intelligent design recommendations
- Market & customer segmentation (both experiential-based and quantitative)
- Profile, grade & classify accounts into tiers
- Objective sales manager productivity assessment
- Manager role definition & shifts to focus on high-value activities
- Sales process design, support tools & service integration
- Performance measurement & incentive programs

4.6.6 Position in the Value Network

A value network for intelligent buildings is a complex set of architectural and technical resources. Value networks work together via relationships to create innovative energy efficient intelligent buildings.

Fjeldstad and Stabell present a framework for "value configurations" in which a "Value network" is one of two alternatives to Michael Porter's Value Chains (the other being the Value shop configuration).

F&S's value network consists of these components:

- A set of customers.
- Some service the customers all use, and enables interaction between the customers.
- Some organization that provides the service.
- A set of contracts that enables access to the service.

Value network analysis is a superior method for understanding, visualizing, optimizing and leading complex organizations and businesses. It applies to both internal and operational value networks as well as industry value networks and business webs. Value networks fundamentally expand and redefine the scope, value and importance of networks to business, economies and civil society.

Value network tools are redefining operations, tactics and strategies in the smartest organizations. They provide a powerful road map to the network-centric future. Value networks and value network analysis are becoming commonplace in top global firms. Value networks drive improvements in resource utilization, productivity, innovation and bring sharp business results overall.

Defining an exact value network for intelligent buildings requires a comprehensive research but it can be said that the position depends on the certificates (LEED, BREAM... etc) and building qualities belonging to sustainability and intelligence based on passive solar design strategies.

4.6.7 Competitive Strategy

This is the strategy to improve the enterprise's competitive position in the market. Since there is a growing interest on intelligent buildings, the concept chosen with taking into consideration sustainability, energy efficiency and intelligence will make the difference from other projects, and also will demonstrate the innovation in the market.

4.7 Diagrammatic Conceptual Performance Based Energy Efficient Intelligent Building Business Model

In Figure 3.10, a conceptual business model is designed for design and construction period of an intelligent building. First of all there should be a requirement to get started with a business model to build an energy efficient intelligent business model. Then suppliers and developer/owner become a part of the business model. Suppliers for this business model are: architects, design engineers, all specialties, building products suppliers, building equipment and system manufacturers, researchers and developers within supplier organizations, support and maintenance organizations and coordinators. Developer/Owner uses the resources and manages the capital cost at every stage of the business model. To view and manage the business model provides a control mechanism for developer/owner. This stakeholder has the opportunity to perform the value of the project.

SWOT analysis should be performed since these analysis are suggested as a starting point. It is not enough to have a number of "strengths". But, rather it is the

integration among the value creating activities in the firm to create value that is important.

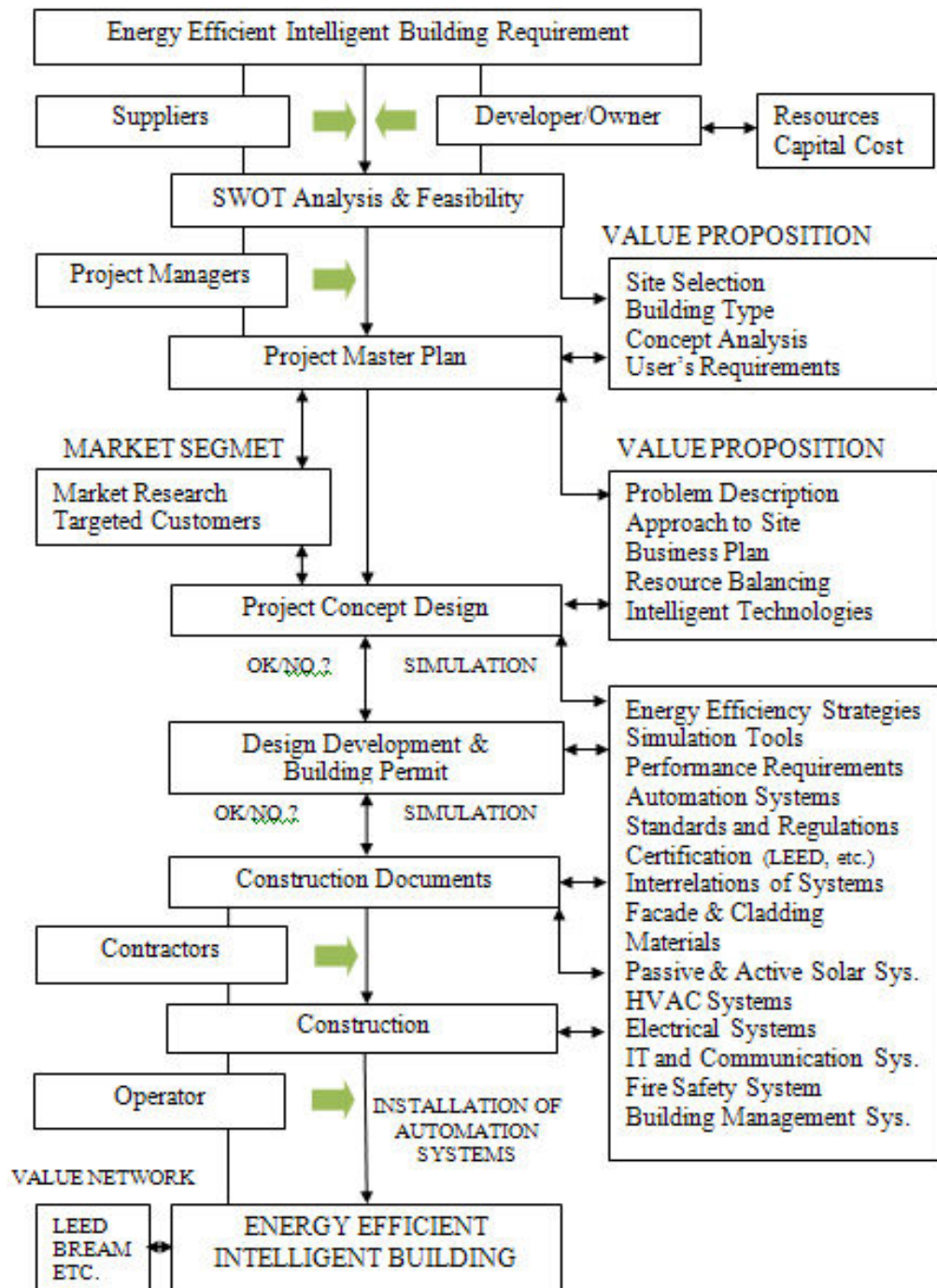


Figure 3.10 : Diagrammatic conceptual business model for design and construction period

In this conceptual model yellow rows sign the stakeholders and their integration to the business model. Twice side rows are defined for feedback mechanism. As it is

shown in figure there should be a feedback mechanism in specified parts of the business model to control it and upgrade the value proposition at any stage of design.

Feasibility researches are also a milestone for a project since they draw a roadmap of the whole process. If the project is feasible then other stakeholders take a part in the business model.

In first “value proposition” part of this conceptual business model;

- Site will be selected,
- Building type will be defined belonging to SWOT analysis and feasibility research,
- Concept analysis will get started at this stage,
- User’s requirements will be defined

Then project master plan will start with always a feedback mechanism in order to check the availability and the value proposition. The target customers should be defined and also the market research should be performed efficiently since the outputs of this researches will be an input for conceptual design.

In the second section of “Value Proposition” , problem will be defined, approach to site will be checked, business plan should be presented to regulate the resource balancing. Besides, the intelligent technologies should be chosen as energy efficient and have the optimum solution from the cost efficiency and energy efficiency aspect. In addition, building simulations should be performed to view the energy consumption simply and to prevent very high energy consumption. While setting the simulation values, all of the systems that will be installed to the building should be defined and the results should be checked stage by stage continuously if any change will be made in the components of the systems.

It is important to control the cost efficiency and energy efficiency during the construction period, since there can be some missings that are not taken into consideration during design period. So, the business model gives the opportunity to control all the systems and take an overview of value proposition and revenue generation.

Since the building will be designed as energy efficient and the intelligent strategies will be installed sustainably, this will improve the value of the building in value network.

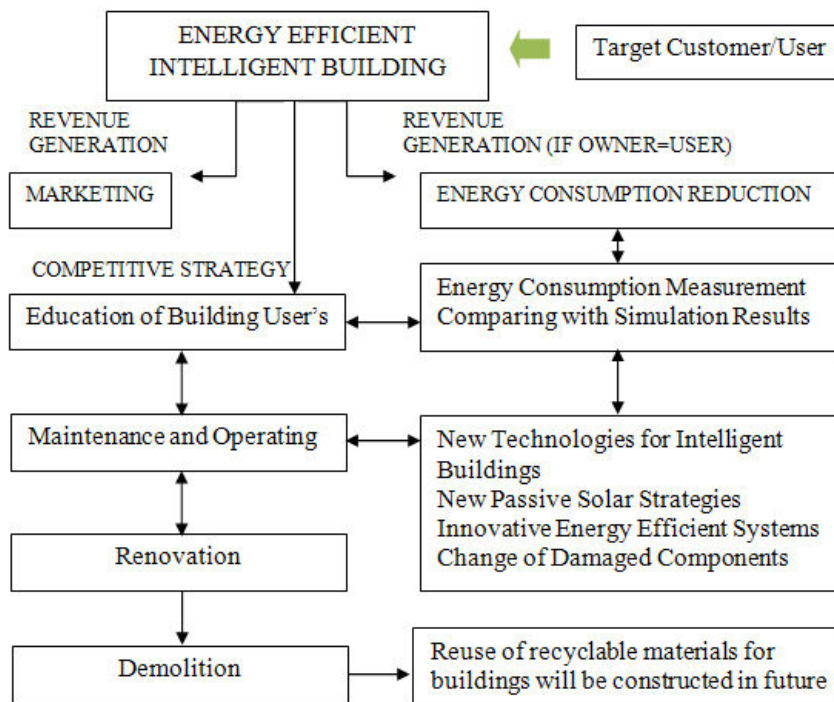


Figure 3.11 : Diagrammatic conceptual business model for operating

In Figure 3.11 a conceptual business model for operating is designed. After the building will be constructed, the revenue can be generated belonging to the cases; if the user is the owner of the project, then the revenue is the reduction of the energy consumption during the operating period. If the owner/developer will sell the building revenue will be generated via an efficient marketing strategies. Since the intelligent building will be a new life-style, the users of the projects should be educated in order to get expected efficiency from the systems.

The energy efficient intelligent building should be adaptable to further technologies, so during the operating period there can be a renovation to integrate innovative energy efficient systems. There can be adaptable new technologies for intelligent buildings, then the feedback mechanism of the business model will show the availability of the installation.

Many years later, like every building existing in the world, the intelligent building may be not sufficient for future conditions and the owner may want to develop other projects at building site. In this case, the building life will come to an end, as the components are chosen recyclable or reusable, the materials will be able to be used for other projects.

4.8 Case Study: Analysing An Energy Efficient Building By The Conceptual Business Model In Order To Demonstrate The Role Of Business Model

In this case study, the building will be analysed according to the business model components to view the value proposition and the revenue generation from the building.

4.8.1 Value Proposition Part of Intelligent Building Business Model

The value proposition part starts from the beginning of the building demand, for an energy efficient building, the concept should be defined exactly.

4.8.1.1 Project General Information

Project Name: Southampton Educational Center

Project Type: Reception and Offices of an educational center

Project Location: Southampton UK (HfT Applied Science, SARA Project)

4.8.1.2 Project Description

With 2500 m² Gross Area the Administration & Student Services Building, Southampton University, is a new department building located on the existing campus site. The building comprises of two separate 3 storey high blocks (A and B) and an atrium. (Sara, D3, Final Report)

4.8.1.3 Project Mission

It is aimed to construct sustainable, cost effective, high energy performance, public-access eco-buildings that are immediately replicable at large scale in many locations. The eco buildings will be equipped with advanced sustainable energy technologies integrated by an innovative architectural approach and combined monitoring and building management systems, BMS. (Sara, D3, Final Report)

4.8.1.4 Project Firm and Partners

SARA (Sustainable Architecture Applied to Replicable Public Access Buildings) aimed to construct six sustainable, cost effective, high energy performance, public-access eco-buildings that are immediately replicable at large scale in many locations

and demonstrate the cost-effective potential for improving the energy performance of Europe's buildings. The project officially started in June 2004 and finished successfully in May 2008. (Sara, D5, Final Report)

4.8.1.5 Project Master Plan

Approach to concept of design & Problem description : The key aspects of the project are public-access, innovative yet cost effective and replicable results, consideration of end users and an interdisciplinary team working on various RTD activities. These aspects, applied across various climatic regions will produce large scale social, urban and environmental benefits. The project will therefore contribute to future development of European energy policy and legislation that will accelerate market penetration of innovative sustainable technologies. The demonstration sites include integrated project planning, active and passive solar design, low energy construction, including sustainable materials and components and including renewable energy technology and building energy management systems. (Sara, D3, Final Report)

4.8.1.6 Approach to site (Analysis of facilities nearby, transportation, .etc.)

The building is situated in the centre of the University's Campus. It extends from and old Office building through an atrium, at its northern side, and finishes near a main Campus road a possible source of noise and pollution.

As in all universities campus, the area has plenty of gardens and very few high building. The PV system, on top of the atrium will not be shaded. The only source of noise and pollution is the main campus road that limits the building in its southern side, but that it is not a very busy road although the bus stop is next to the main atrium entrance. The atrium will be used as the main reception for the students. (Sara, D3, Final Report)

4.8.2 Market Segment Part of Intelligent Building Business Model Energy

Performance Aspect of Project Concept Design

The building will surpass the energy performance requirements demanded by the recent European Directive on Energy Consumption in Buildings and the Project is committed to achieving energy savings of %30 with an over cost of no more than 5 % compared to conventional public buildings in the country. The over costs will be

due to the use of more environmentally sustainable architectural practices and techniques, energy systems. All of these innovations are market ready and replicable in other buildings. The simple payback period for the investment, based on the financial savings due to reduced energy costs in use, is about 7.5 years.

The design was driven by two main objectives, i. e. minimizing energy loss & maximizing passive gains; these to be achieved by means of extensive use of the daylight; passive cooling and heating wherever/whenever it is possible. (Sara, D11, Final Report)

4.8.2.1 Project Advertisements Supported by 3D Models, Website

The figure that is shown below is the advertisement that has been taken from the website of SARA projects.

Educational Office building



Southampton
United Kingdom





John Brightwell
Project Coordinator,
Estates & Facilities,
University of
Southampton

*"The typical standards required by investors in UK property have been consistently excessive and much wasted energy was inherent in the designs and specifications that were led by a largely ill-informed group of letting agents; a few large developers, and still fewer investors were aware of this, and things are now improving, but **the Southampton project gave a real opportunity to demonstrate that a good office building could be produced without air conditioning.***

The ability to get back to basics, while at the same time using modern materials and advanced timber engineering, was a challenge to all members of the design team

The best result was a building completed on programme, to a high standard of finish, and to a tight budget, while at the same time producing a useful model for widely applicable sustainable construction."

Figure 3.12 : The advertisement of the building on web site

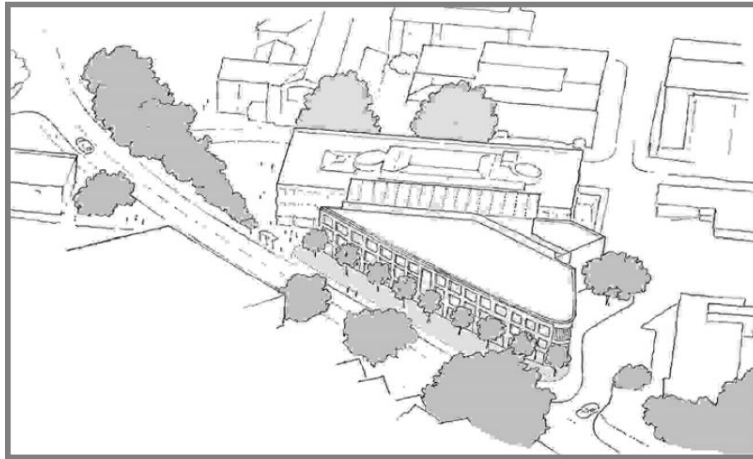


Figure 3.13 : General view perspective drawing of the building

4.8.3 Value Chain & Design & Design Evaluation Part of Energy Efficient Intelligent Buildings Business Model

The value chain part , the design and the design evaluation part of energy efficient intelligent building business model includes some analysis and datas in order to demonstrate the comparison between expected value and the value in reality.

4.8.3.1 Climate of Located Site

Southampton Climate:

British weather is rarely extreme, monthly rainfall is between two and four inches (50 and 100 millimeters), snow is infrequent and the temperature seldom dips below freezing. Southampton has a temperate climate with only slight temperature variations between day and night, summer and winter. The average for January is 5 degrees Celsius (40 degrees Fahrenheit) and 18 degrees Celsius (68 degrees Fahrenheit) for July. The best time to visit is between April and September, when the days are longer, staying light until after 10:00 pm in late June.

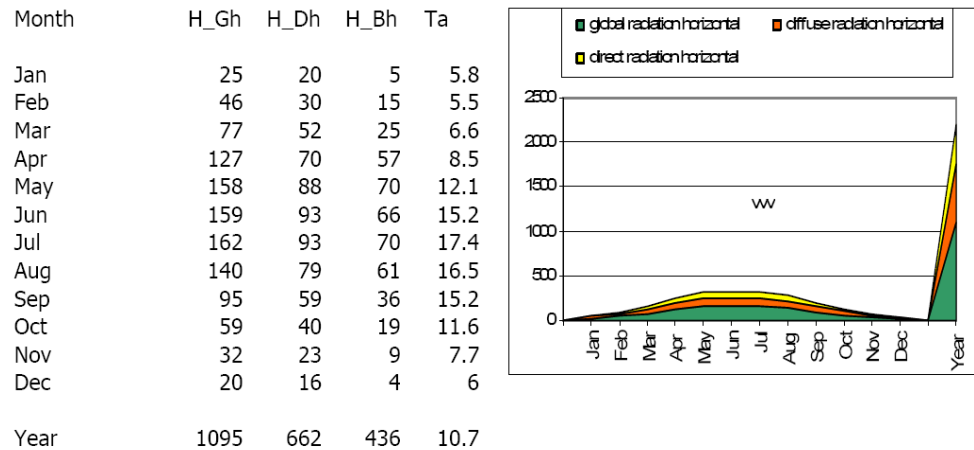


Figure 3.14 : Annual radiation graph of Southampton

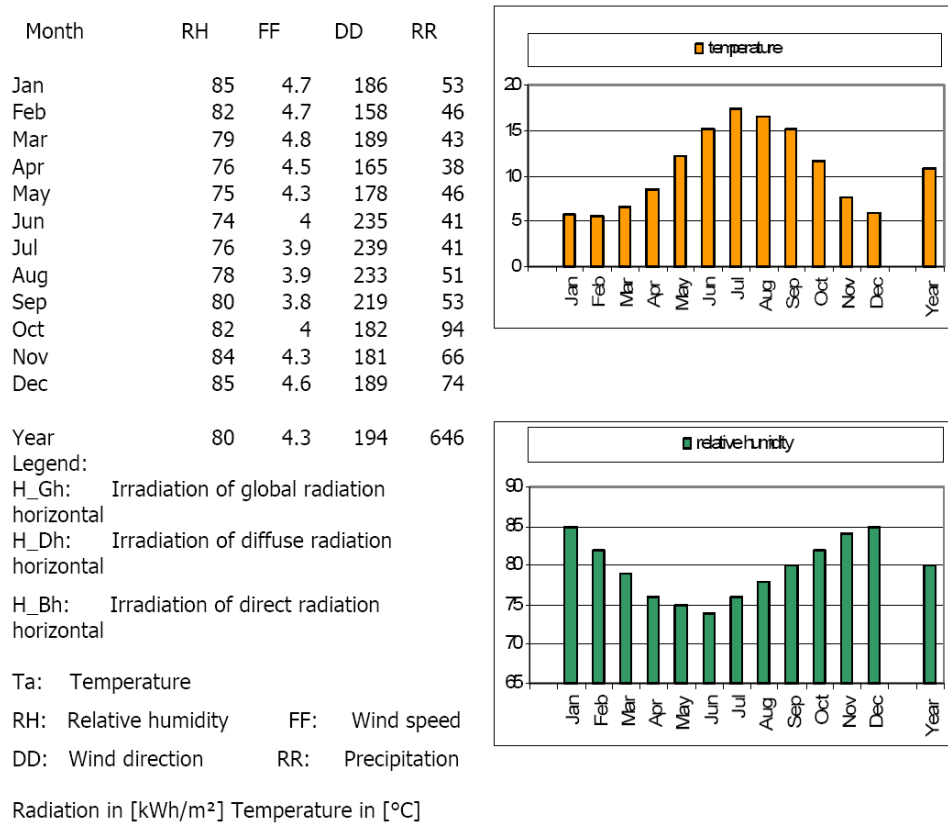


Figure 3.15 : Annual Temperature and Relative Humidity graph of Southampton

The graphics are taken from the report of Sara Sothampton Project, because all the climate data has been set by the developer of the simulation program that is used in this thesis to evaluate the heating consumption of case study building.

4.8.3.2 Building Form

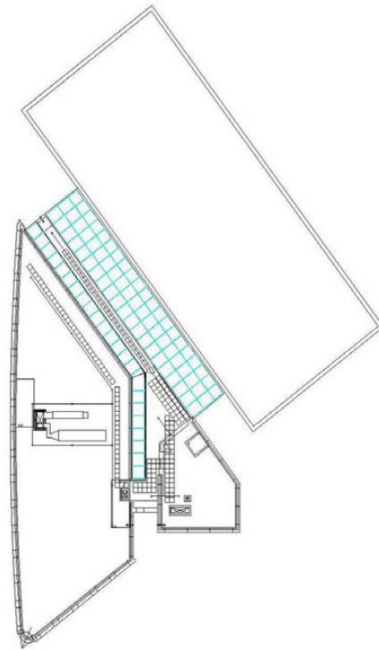


Figure 3.16 : The triangular plan scheme of new building

The figure shows the geometrical form of the building, the form is also a parameter of energy efficient design.

4.8.3.3 Integrating Concept of Energy Efficiency Based on Passive Solar Design Strategies

The design included: maximising the use of daylight through atrium and specially specified windows; shading devices to stop overheating; heavy mass structure protected by thick insulation and low overall u-values for the stabilisation of internal temperatures; ceilings with exposed thermal mass and passive night time ventilation for free cooling; pre-cooled air for the atrium through earth coupling system; natural ventilation and stack effect ventilation to minimise mechanical inputs; an overall strategy for lighting, internal temperature control and heat recovery in order to maximise energy conservation. Natural lighting is available from the glass roof and the windows. In order to stop overheating the building has solar shading devices. The glazed photovoltaic array has been designed to provide an optimum compromise between shading and daylight. (Sara, D11, Final Report)

Design Strategies-Technical Considerations

The atrium was conceived as a buffer zone between the old and the new office buildings. It is a source of daylight and solar gains, and it works together with the specially designed windows. Structural thermal mass and a well insulated envelope complete the system for energy conservation and passive gains. Southampton's climate, with enough difference between day and night temperatures during the warm season, allows for the free cooling of the exposed thermal mass by night time cooling using the building's ventilation system. During the day those ceilings will perform as heat sink for excess heating from computers and staff. (Sara, D11, Final Report)

Technical Considerations-Architectural Considerations

The design of this building has taken account the user's requirements, through an extensive consultation process. The elevations are designed to create a strong link with adjacent University buildings sharing a common language of materials and expressed in a contemporary and innovative way. Much use is made of natural light and natural ventilation, and in order to establish its credentials as an environmentally sustainable building, a bare minimum of mechanical ventilation is provided, where otherwise comfort levels might drop.

Air conditioning is not provided, but free cooling by means of exposed structural mass and ground cooling from low-level air displacement units in the atrium will combine with opening ventilation panels alongside each double-glazed fixed window, to provide occupiers with a comfortable environment, over which they can directly influence a degree of control.

Novel advanced engineering, in the shape of photovoltaic panels in the atrium glazing, is intended to generate up to a third of the power consumed in the new office floor area, and provide solar shading.

The pitch and orientation of the larger glazed roof is governed by photovoltaic considerations, and the vertical atrium roofing elements will include mechanically controlled natural ventilation systems, which, like all services and environmental readings will be continuously monitored by a Building Management System.

The function of the building requires a clearly legible identity, so that first-time visitor to the campus will be able to easily recognise the ready and open access to information on all manner of things which will be provided by the staff (Student

Advisors) at the atrium counter. The atrium is a fundamental element in providing both an external statement and an internal service and communication area, and it links at all three above-ground levels into the existing Administration building. The opportunity has been taken to significantly upgrade the vertical circulation to levels 2, 3 & 4 in the old building by providing a large new lift, centrally positioned in the overall complex. (Sara, D11, Final Report)

Additional Concept of Sustainability

- The use of renewable resources (such as timber)
- Minimizing the amount of materials required
- Materials of minimal embedded energy
- Recyclable materials and components
- Materials which contribute to high energy efficiency
- Internal space layout, dept, floor to floor height, grid, form, internal partition
- Maximum distance to fire escape
- Occupancy Density
- Facade and Cladding

Glazing Strategies of the Project

- decrease of transmission heating losses, low U value
- reduce solar income in summer, low G value
- positive affect to inside surface glazing temperatures

Cladding Strategies of the Project

- decrease of transmission heating losses
- positive affect to inside surface wall and ceiling temperatures

Shading Strategies of the Project

- reduce solar income by glazing in summer
- reduce glare
- uniform daylight distribution

Natural Ventilation and Lighting Features

The building form has been developed to be accommodated within the site boundary; the internal layouts address the client's requirements and ultimately the needs of the buildings occupants. In addition it has previously been established that in order to

maximise the energy saving opportunities available the preferred solution is to have a naturally ventilated scheme.

Unlike a mechanically ventilated scheme there are inherent limitations on the operating parameters of a naturally ventilated scheme, foremost there is the restriction in floor plate depth at which a naturally ventilated system operates effectively.

The buildings architectural form offers some opportunity for natural ventilation particularly cross ventilation or a single sided scheme. The building has openable windows on opposing facades which allow the natural differences in external wind pressure between inlet and outlet openings to provide air movement across the floor plate. However one of the facades is not exposed, neighbouring the atrium condition, and in addition the building has a floor plate of approximately 15m wide with both of these factors severely limiting the effectiveness of a natural ventilation solution. It is important to note that the figures stated in the table are hypothetical and in order to determine the actual effective areas dynamic modelling of the building would need to be undertaken.

Therefore on the basis of a 15m facade to facade floor plate there is a deep plan area, which does not receive adequate ventilation. Obstructions such as secondary partitions, stair cores, and fixed facade areas impose restrictions on the ability to naturally ventilate. They obstruct that airflow across the deep plan Office space and present difficulties in implementing a cross ventilation scheme. Given the extent of restrictions, a cross vent proposal is rendered ineffective for a large portion of the deep plan areas and in addition it causes inherent problems relating to the flexibility of the office space.

With all of the natural ventilation systems discussed there is the problem relating to control of the airflow through the office space, in a typical installation there is always the issue of local occupant control. An example of this would be where an occupant in a perimeter zone is experiencing discomfort and wishes to close the window; as a result occupants in an adjacent deep plan area will have restricted airflow and will subsequently have no control over their surrounding conditions.

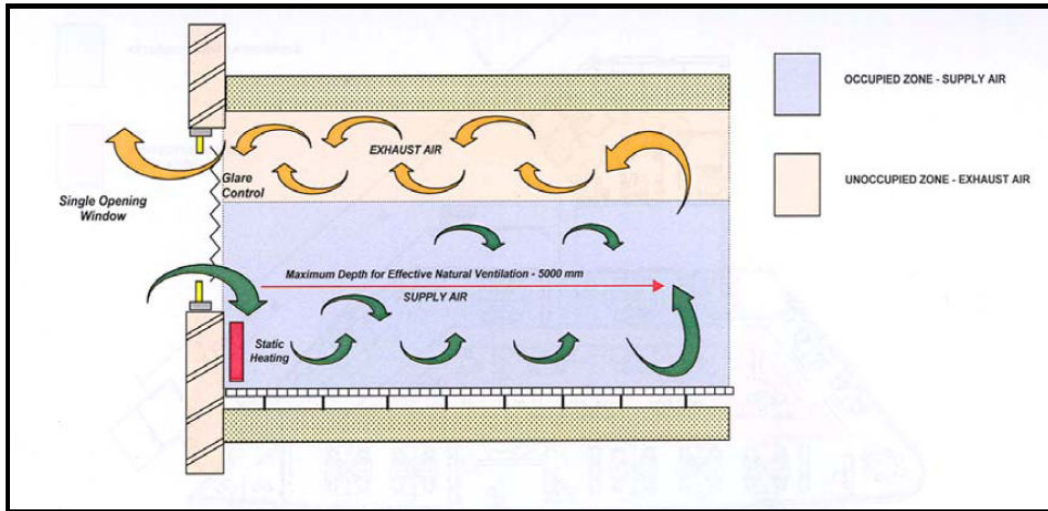


Figure 3.17 : Single-sided natural ventilation (Sara, D7)

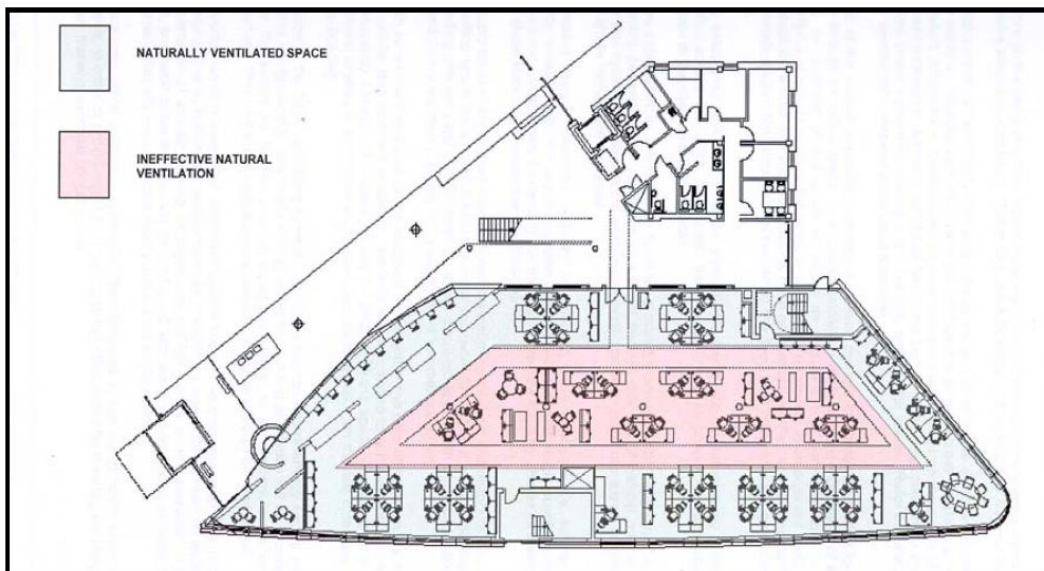


Figure 3.18 : Single-sided natural ventilation scheme (Sara, D7)

Having established that a pure natural ventilation scheme does not satisfactorily maintain adequate ventilation across the office floor plate, there was the need to provide an alternative method of ventilation to the deep plan office spaces. In these circumstances it is common to adopt a mixed mode ventilation solution, this comprises of maintaining perimeter area ventilation conditions through the use of natural means, and using a mechanical system to maintain the ventilation conditions deep plan core areas

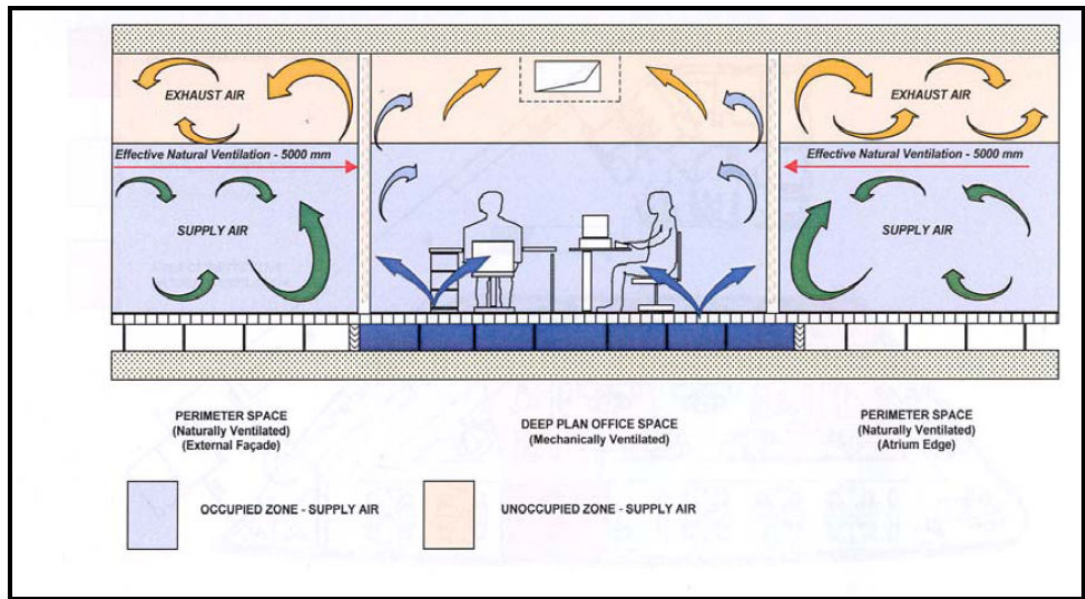


Figure 3.19 : Mixed mode ventilation zone (Sara, D7)

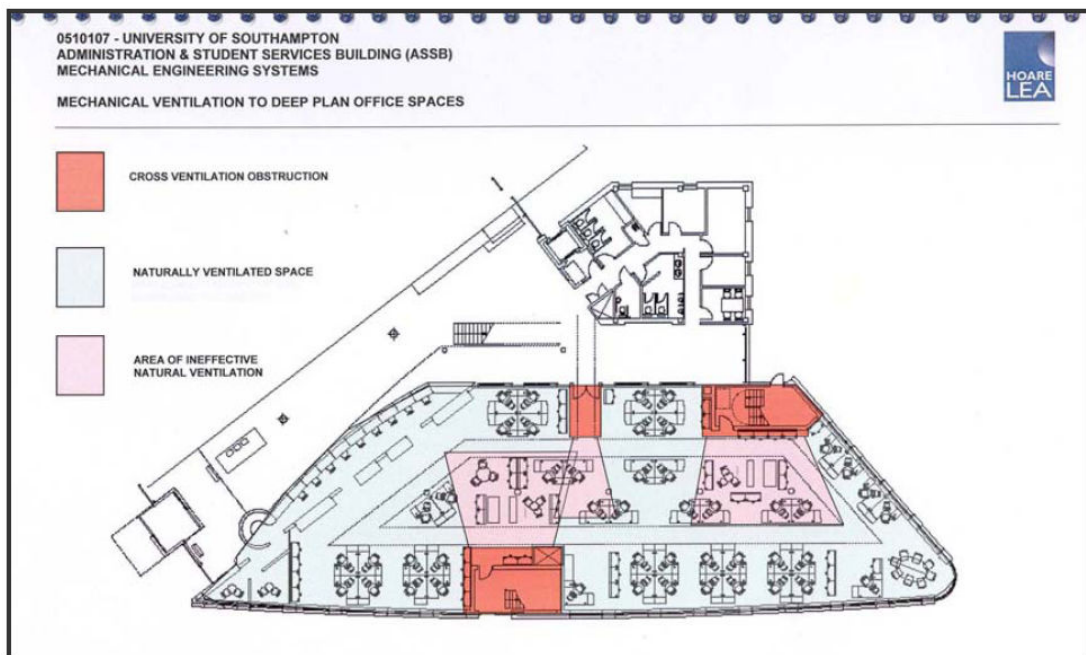


Figure 3.20 : Cross ventilation- natural ventilation scheme (Sara, D7)

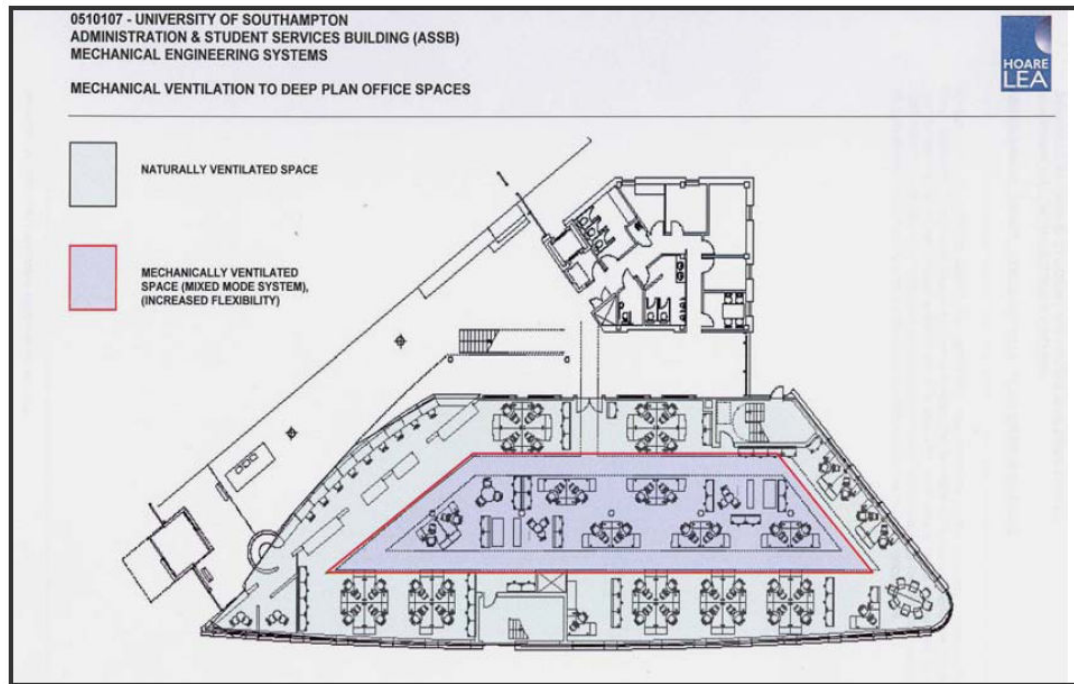


Figure 3.21 : Mixed mode ventilation scheme (Sara, D7)

Description of Passive Strategy

The design strategy adopted is based on the mixed mode ventilation principals, i.e. natural ventilation in perimeter areas through the use of openable windows with a central single supply air-handling unit is proposed and will be located externally, on the roof of the new building (See Figure 6.1). In order to satisfy the ventilation requirements of the building a combined system has been selected. The mixed mode system provides the benefits of a natural ventilation system where a comfortable level of ventilation performance is assured, and where there is the risk of not achieving satisfactory ventilation to deep plan occupants we have incorporated a mechanical ventilation system to guarantee an air supply and satisfactory conditions for the building occupants.

Design Strategies Technical Considerations

The introduction of a deep plan ventilation system overcomes the issue relating to occupant control and ensures that all occupants receive fresh air in accordance with their needs. In addition to this the implementation of any partitioning arrangements will not impact on the operation of the ventilation system, perimeter areas will naturally be configured with access to openable windows and deep plan partitioned areas will have a ducted supply and extract configurations.

The supply air handling unit will filter and heat the incoming fresh air and distribute it to the core areas of the office space via a network of sheet metal ductwork run within a vertical distribution riser. The air-handling unit will supply 100% fresh air to the occupied space with no re-circulation of return air proposed. There will be no cooling of the supply air in summer conditions.

Fresh air will be introduced to the occupied space within the core office areas via the raised floor where circular displacement ventilation terminals will be installed to suit the proposed furniture layout and occupancy density. All exhaust air will be taken from the space via high level ductwork spigot connections located in each core and routed back to an extract fan located externally on the roof of the new building. In addition to the base ventilation system, in order to provide further energy saving measures when conditions are favourable, any useful energy within the exhaust air stream will be recovered and given over to the supply air system prior to being discharged to atmosphere via a run around coil arrangement.

i. CFD model

A series of CFD models were carried out to ensure the concept was a feasible solution. After discussions with the University it was felt opening the windows was not acceptable. Therefore additional CFD and Acoustic Auralisations were carried out by SARA Southampton Project

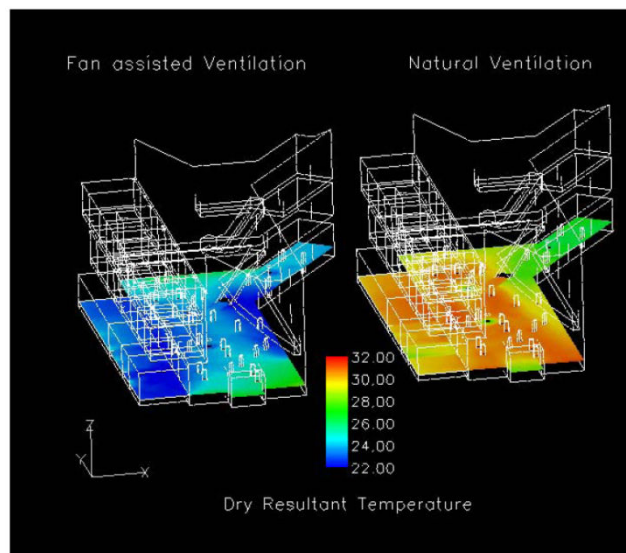


Figure 3.22 : Comparing Fan Assisted/ Natural Ventilation (Ground Floor) (Sara, D7)

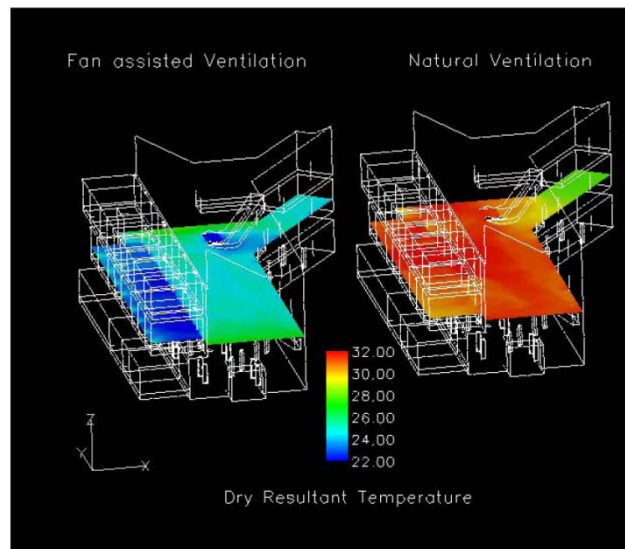


Figure 3.23 : Comparing Fan Assisted/ Natural Ventilation (First Floor)

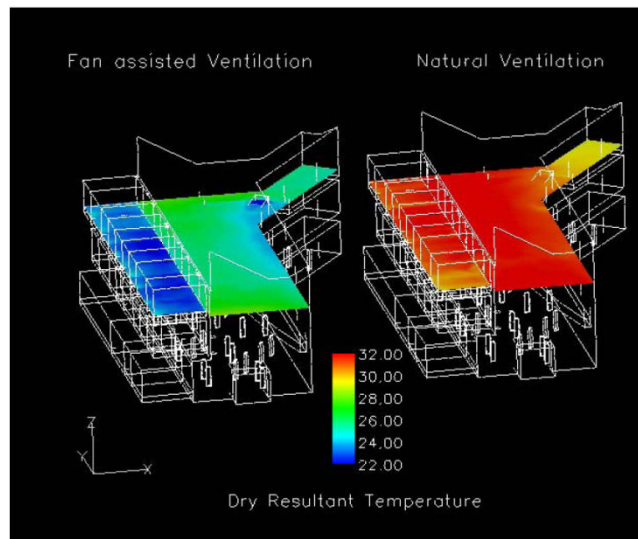


Figure 3.24 : Comparing Fan Assisted/ Natural Ventilation (Second Floor) (Sara, D7)

According to this results it can be reported that the serious differences between fan assisted and natural ventilated is on second floor. So, there can be taken extra cautions by mechanical ventilation to prevent over heating.

Use of solar energy (heat collector or PV)

A new triangular footprint building links to the existing administration building via multi level walkways enclosed within a glass atrium. Such an atrium represents an opportunity to use a BIPV system in the Southampton University.

The linking, semi-transparent atrium performs 3 functions:

- 1) Solar shading

2) Electrical power generation

3) Thermally insulated link between existing administration building and new building.

Photovoltaic panels were installed in the atrium glazing. It is estimated that they will generate up to a third of the power consumed in the new office floor area, and provide solar shading.

The pitch and orientation of the larger glazed roof is governed by photovoltaic considerations, and the vertical atrium roofing elements includes mechanically controlled natural ventilation systems, which, like all services and environmental readings will be continuously monitored by a Building Management System.

The roof of the atrium is orientated South-South-West (25 degrees offset from South to the West) at a roof pitch of 30 degrees. The estimated in-plane irradiance for the site is 1172 kWh per annum. The PV installation can be seen in figure 3.25 below.

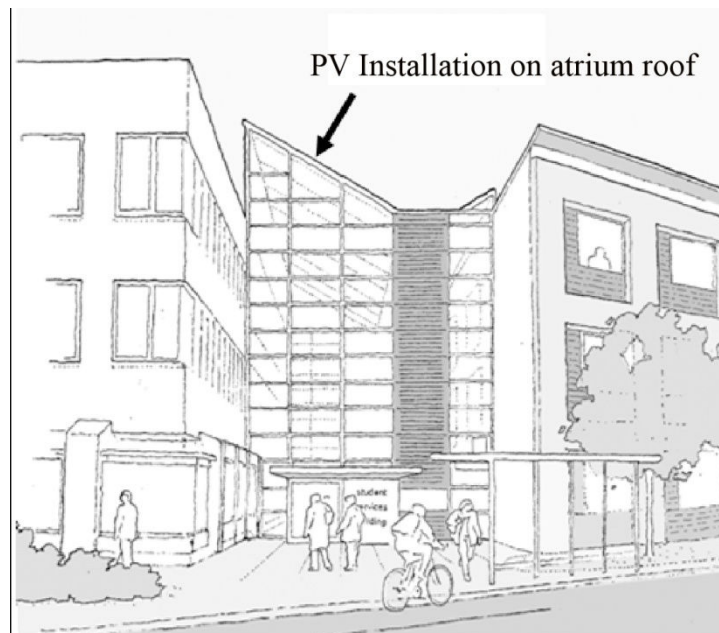


Figure 3.25 : PV Installation on Atrium Roof

Architectural considerations:

Analysis of the possibilities of integration

In order to connect the old office building with the new one and, at the same time, create an spacious reception for the students, an atrium was designed. Its glazed roof gave the architects the opportunity to add the PV system.

The function of the building requires a clearly legible identity, so that first-time visitors to the campus will be able to easily recognize the ready and open access to information on all manner of things which will be provided by the staff (Student Advisors) at the atrium counter. The atrium is a fundamental element in providing both an external statement and an internal service and communication area, and it links at all three above-ground levels into the existing Administration building. The opportunity has been taken to significantly upgrade the vertical circulation to levels 2, 3 & 4 in the old building by providing a large new lift, centrally positioned in the overall complex.

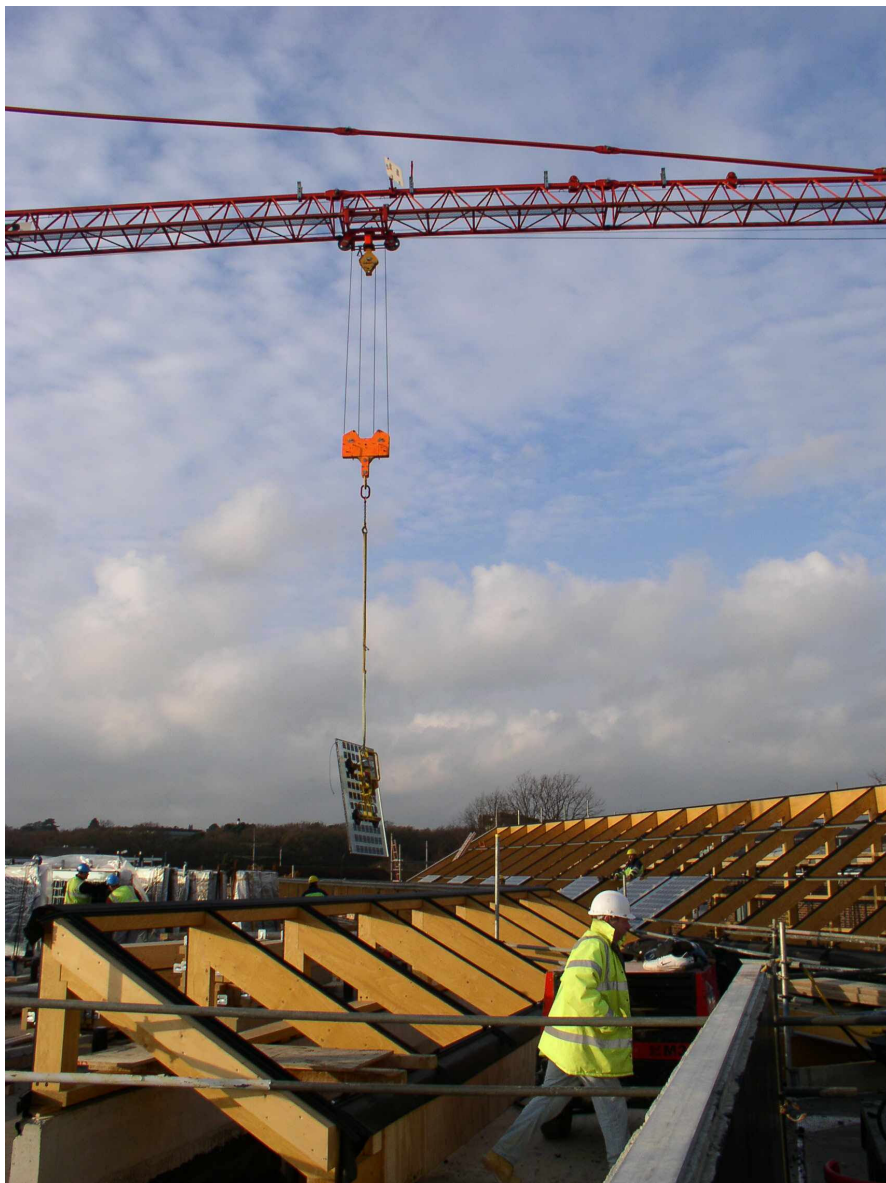


Figure 3.26 : The installation of Photovoltaic Panels

Technical considerations

Characteristic (type of cells/module)

Novel advanced engineering, in the shape of photovoltaic panels in the atrium glazing, is intended to generate up to a third of the power consumed in the new office floor area, and provide solar shading.

The requirement for the atrium to provide a thermally insulated link between the two buildings required a double glazed PV laminate to be used. The upper pane of the glazing consists of the PV laminate (glass-glass produced by Romag) which is combined with a second glazing to produce the double glazed unit.

A low-e coating is applied to the inner pane of the PV laminate. The PV laminate utilises high efficiency BP Solar monocrystalline solar cells (Saturn) which are spaced to provide an overall transparency of 50 % for the laminate. The glazed PV element has a u-value of 1.4 W/m²/K which is superior to standard triple glazing (1.5 W/m²/K) or double glazed argon filled units (1.8 W/m²/K).

Some Pictures from applied PV panels are demonstrated below:

Constructive conditions (structure)

The main structure of the atrium is reinforced concrete which will incorporate largely exposed soffit slabs to provide free cooling in combination with natural crossflow and mechanical ventilation. This will be encouraged by a limited stack effect within the atrium which will be promoted by controlled opening vents placed in the vertical roof elements.

System specification

The total glazed roof area of the atrium is 253m². The 177 m² sloped atrium component is covered with 63 semi-transparent PV laminates configured as four separate sub-arrays, each of which will feed a string inverter. The laminates will have the following ratings: 21 X 193 Wp, 21 x 228 Wp, and 21 x 245 Wp. As a result, the total is 13,986 Wp.

Calculations and simulation

The 14 kWp PV array has a predicted output of 12,525 kWh per annum, using PVSYS and based on a normal cell operating temperature of 56 °C. This yield will

have a value of £564 per annum at the University's purchase price of 4.5 p/kWh. The baseload demand of the ASSB building is such that there is no possibility of electricity export. (Sara D7, Final Report)

Economical Considerations

Capital cost of installation

The estimated total system cost including glazing is, according to the architectural project, £ 130,000. PV Cost analysis can be seen in figure 3.27 below:

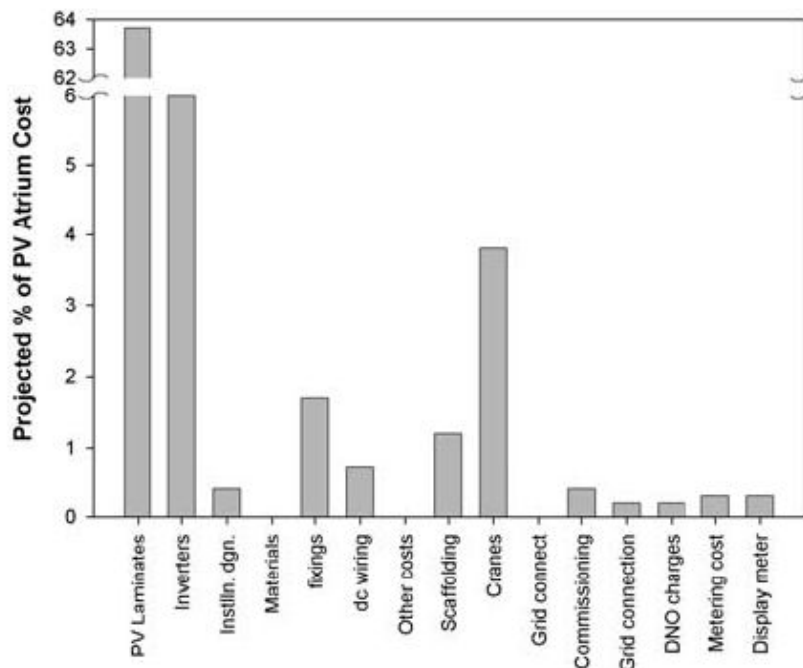


Figure 3.27 : PV Cost Analysis (Sara, D7)

Subsidies

The roof, glazing and the photovoltaic system, is costing approximately £130,000. Just the glazing would cost around £ 65,000. With a DTI grant that covers 50% of their installation the University has a very favorable position in terms of savings and pay back time. (Sara D7, Final Report)

Payback and energy savings

- Expected annual energy production: 12,525 kWh/yr
- Expected system lifetime: 25 years
- Expected lifetime electricity generation : 313,125 kWh

In economic terms:

- Investment cost: £65,000
- Annual income: £564
- Simple payback period: 115 years

However, as it was said in 3.1.6.2, £65,000 was what the atrium glazing would have cost anyway. With the DTI subsidy, the whole of the PV system cost was £65,000. Hence, this simple payback period is meaningless. (Sara D7, Final Report)

4.8.3.4 Material specifications

Substructure

- .Mass concrete foundations, ground beams, blockwork sleeper walls
- .Ground floor slab: suspended precast concrete with insulation
- Service tunnel/undercroft (formed as Enabling Works, see above) adjacent B37 at level
- to accommodate realigned cables, cooling from B37 Main Distribution Frame Room (telecoms for a substantial part of Highfield Campus), space for new ventilation plant for atrium, and fire escape from level 1 B37.

Superstructure

- Frame: in situ reinforced concrete columns, shear walls, lift shaft and upper floor and roof slabs.
- Roof: “upside down” asphalt, insulation and ballast; siphonic and gravity drainage systems; Mansafe or similar approved fall arrest system.
- Atrium roof structure: Kerto or similar approved laminated timber beams; timber and aluminium framed curtain walling to glazed areas; photovoltaic arrays to northern half; opening vents to vertical glazing upstands; timber and ply framed valley gutter, upgraded locally to provide pedestrian access, with enhanced guarding for authorised visitors to inspect (part of) the photovoltaic array.
- Atrium balcony at level 3: in-situ concrete upstand balustrade.
- Stairs: emergency escape stairs (2 and 3) of in situ concrete; atrium accommodation stair, in situ concrete; mild steel balustrades and handrails (stainless steel in atrium).
- Roof access: 70 degree steel ladder (fixed) in Block B and roof hatch; emergency (drop down) ladder in stair 3 concealed below roof hatch.

- External wall: brick/block to Block B; one brick thick wall to most of Block A, in lime mortar; mineral fibre insulation; prefabricated modular window panels to remainder of external wall, see 2.9. Small areas of insulated render on north & south returns of Block A and entrance lobby.
- Entrance lobby pod: in situ concrete walls; glazed automatic sliding doors; steel framed roof with integral gutter and metal covering.
- External windows (Block A): prefabricated panels comprising fixed, timber framed, double glazed unit with integral venetian blind, opening side panel vent. (Sara, D11, Final Report)

4.8.3.5 Amenities

- External Access
- External access is from atrium
- Toilets and common rooms, public areas & servicing facilities

Block B accommodates the main toilet / kitchen facilities, with individual interview rooms located on ground floor (level 2). The Atrium is a triple height, glazed communal space and acts as a link for both Block A & B as well as an extension to an existing building.

4.8.3.6 Energy performance

Thermaplan Transit simulation program is chosen to demonstrate heating and cooling demands of this building, then the measured data is compared with this results in order to know how the program is dependable for other projects at the beginning of the design. The basic steps of the program will be shown below.

Project general information

This part of the simulation tool is to define the building in general view. Date of Simulation is very important to demonstrate submittal of date of the inputs. There could be a difference between Conceptual design project inputs and permit design inputs. In this case, design developers will offer to see the changes of energy consumption step by step.

Account No is also important to emphasize the version of simulation, there can be two or more alternative for design inputs and design developer could want to see the differences of energy consumption.

Building definition of simulation tool

General Inputs should be submitted, if any remarks required they could be also written. Climate Data should be uploaded, otherwise the simulation results will be completely different. In this thesis, the case study takes place in Southampton so the climate data is fixed as Southampton Climate Data.

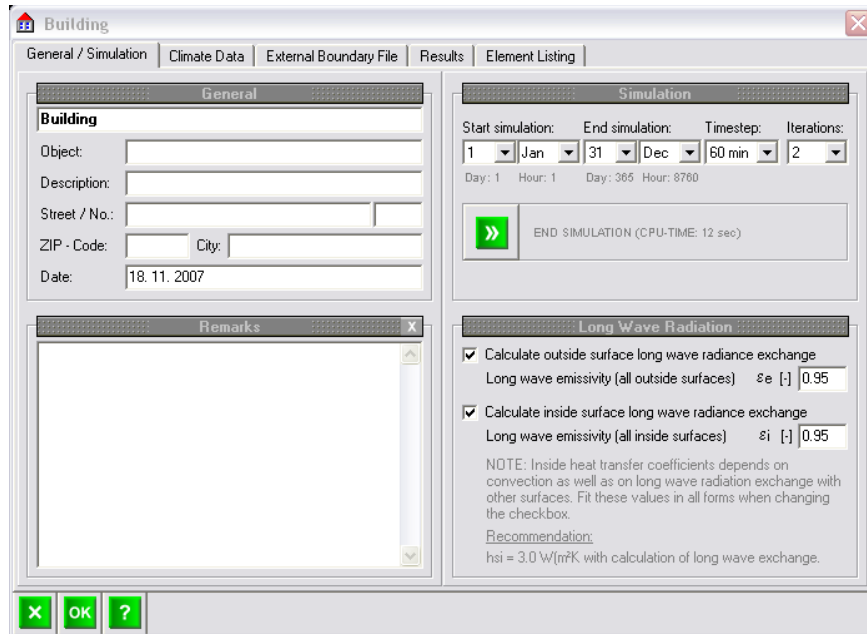


Figure 3.28 : Building Definition of Simulation Tool

- The simulation of this building has 3 zones:
- Block A (The office part can be seen on the figure above)
- Block B (Amenities and technical spaces)
- ATRIUM (This space is a buffer zone between the old existing building and new office part)

Then the period of simulation should be set as date and month, for instance the mechanical engineer may want to analyse only the winter season of the year in order to calculate the heating loads while the cooling loads are not taken into the consideration since the passive cooling strategies are efficiently integrated with the building.



Figure 3.29 : Three zones are shown in plan scheme of ground floor
Block A is the main block and it is connected with an atrium to old existing building.

Heating system definition of simulation tool

Activate Heating box is chosen, and timetable is also scheduled. Since the building is an office building, the schedule should be set as the system is on during week from 9 am in the morning to 7 pm in the evening and it is off during the weekend.

External components of simulation tool

	external wall	external wall h	external wall area	window area gl	window area th	win. number	total area floor m2	total window area	total thermal mass
BLOK A									
Ground Floor							600		
West	52.2	3	156.6	3.25	2.75	15		48.75	41.25
South-East	16.6	3	49.8			5			
East	23	3	69			3			
North-East	24.30	3	72.9			2			
South-West				7.5					
level 46.375							600		
West	52.2	3	156.6	3.25	2.75	15		48.75	41.25
South-East	16.6	3	49.8			5			
East	23	3	69			3			
North-East	24.3	3	72.9			4			
South-West				7.5					
level 49.975							600		
West	52.2	3.5	182.7	3.25	2.75	15		48.75	41.25
South-East	16.6	3.5	58.1			5			
East	23	3.5	80.5			2			
North-East	24.3	3.5	85.05			4			
South-West				7.5					
Total West			495.9					146.25	123.75
Total South-West								22.5	
Total South-East			157.7					48.75	41.25
Total East			218.5						
Total North-East			230.85					32.5	27.5

Figure 3.30 : Block A is analyzed to find the exact areas and volumes.

The simulation tool requires to define all the external components layer by layer, and every glazing area should be analysed side by side with an acceptable U-value and acceptable shading coefficient value in order to get an energy efficient simulation results.

	external wall	external wall h	external wall area	window area gl	window area th	win. number	total area floor m2	total window area
BLOK B								
Ground Floor							120	
West	11	3	33					
South	11	3	33	1.6		4		6.4
East	6	3	18	1		1		1
North-East	10.63	3	31.89	1		1		1
North-West	5.5	3	16.5					
level 46.375							120	
West	11	3	33	1.6		1		1.6
South	11	3	33	1.6		2		3.2
East	6	3	18	2.6		1		2.6
North-East	10.63	3	31.89	1		1		1
North-West	5.5	3	16.5					
level 49.975							120	
West	11	3.5	38.5	1.6		1		1.6
South	11	3.5	38.5	1.6		2		3.2
East	6	3.5	21	2.6		1		2.6
North-East	10.63	3.5	37.205	1		1		1
North-West	5.5	3.5	19.25					
Total West			104.5					6.4
Total South			104.5					7.4
Total East			57					6.2
Total North-East			100.98					2
Total North-West			52.25					

Figure 3.31 : Block B is analyzed as shown in figure

An example for external components of a building is shown above. According to this program, the area should be calculated, the slope should be defined, orientation of the component should be defined. U value can be fixed as a number, however is it always helpful to define the layers, details and find the real U value of that component.

- Roof: 0.25 W/m2K
- Wall: 0.35 W/m2K

- Ground Floor: 1.50 W/m²K

Wall North (Building)

General Settings | Construction | Results | Moisture Calculation

Element Specification

Wall North

Area: 12.04 [m²]

4.3 * 2.8

Orientation: North Slope: 90 °

Heat Transfer

☒ Calculate U-Value -> further settings in <Construction>

☐ R-Value (Direct Input)

Inside heat transfer coefficient: hsi [W/m²K] 3

Outside heat transfer coefficient: hse [W/m²K] 25.0

Overall heat transfer coefficient: U [W/m²K] 0.274

Thermal resistance: R [m²K/W] 3.276

Solar Absorption

Inside solar absorption coefficient: a(i) [-] 0.80

Outside solar absorption coefficient: a(e) [-] 0.95

Integrated Windows

Window	Area [m²]	U-Value [W/m²K]	g-Value [-]
Window North	7.00	1.24	0.642

(Informative, no input required)

Complete facade area (wall + windows): 19.0 [m²]

Complete window area (present facade part): 7.00 [m²]

Window area rate (present facade part): 36.8 [%]

OK ?

Figure 3.32 : Example definition of external part

Simulation results of case study building



Figure 3.33 : (Thermplan Transit) Simulation Results of Case Study Building

In figure 3.33 “Annual Heating Consumption” can be seen month by month. When it is compared with measured data, it was incredibly different with simulation results. Then SARA informed the project partners about the units; all the data was measured as megajoule, however the simulation program (Thermplan Transit) gives the results as kWh, so all the measured data results are divided by 3.6 in order to get the correct comparison results.

However, there were still some problems with heating consumption data of April 2007, then SARA informed the partners about the data of April, and corrected the data that gives the nearest results with simulation results. The data comparison before correction is shown below in figure 3.34.

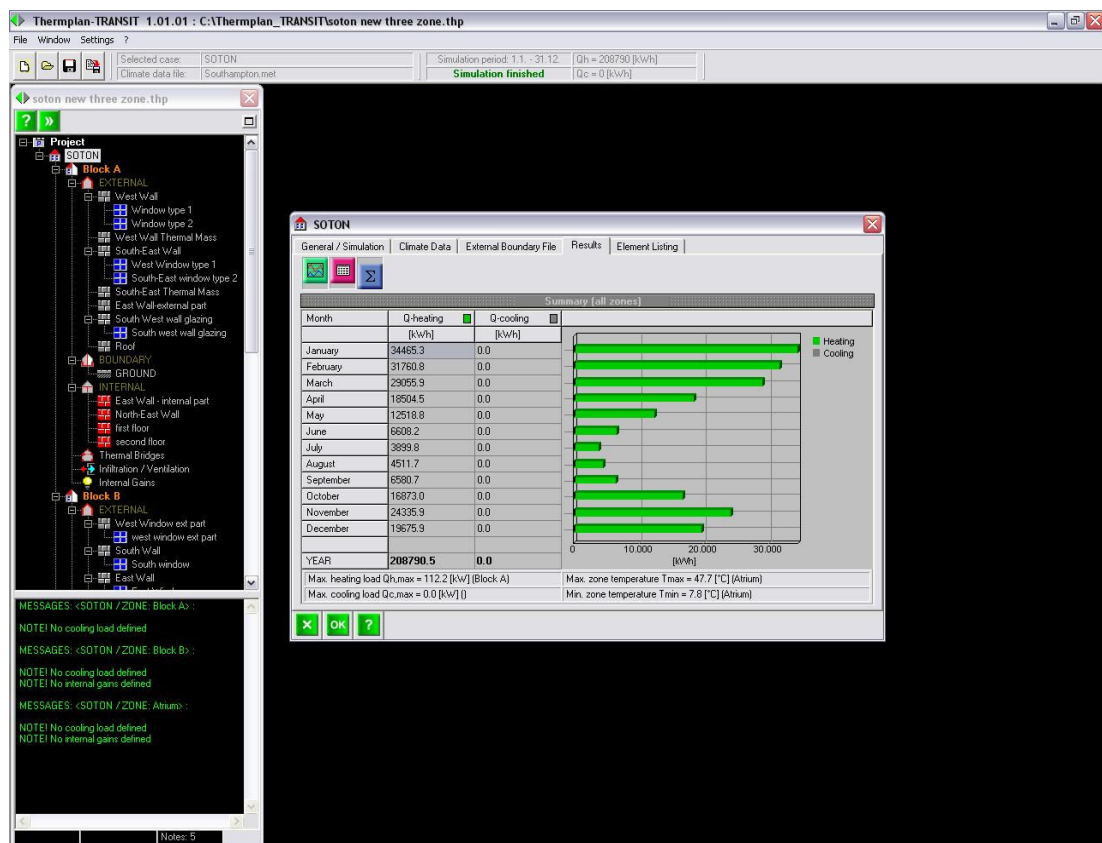


Figure 3.34 : Simulation Results of Case Building by Thermplan Transit

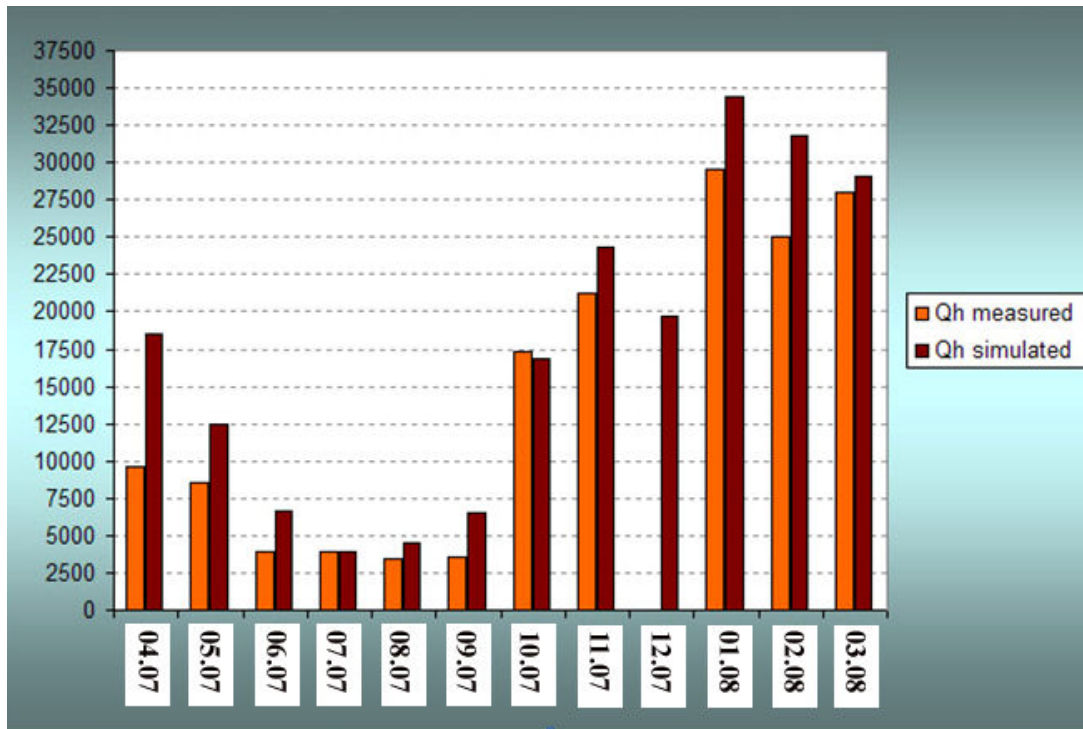


Figure 3.35 : The comparison between simulation results and measured data

As it can be seen in figure there is no measured data from December since there was a problem in the control system.

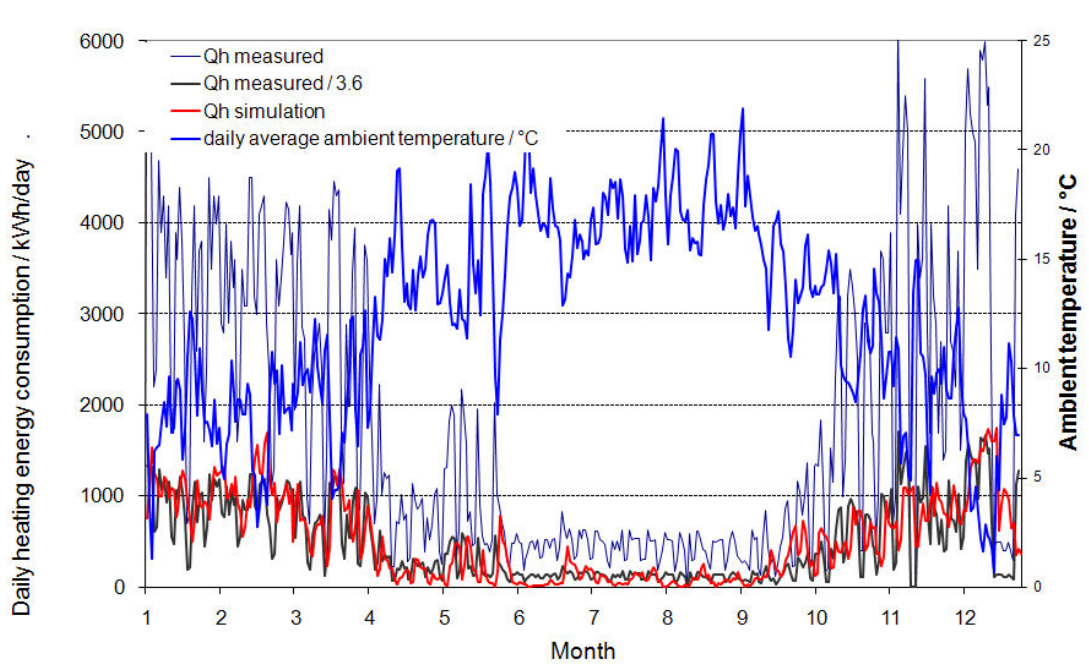


Figure 3.36 : The comparison between simulation results and measured data integrated with ambient temperature

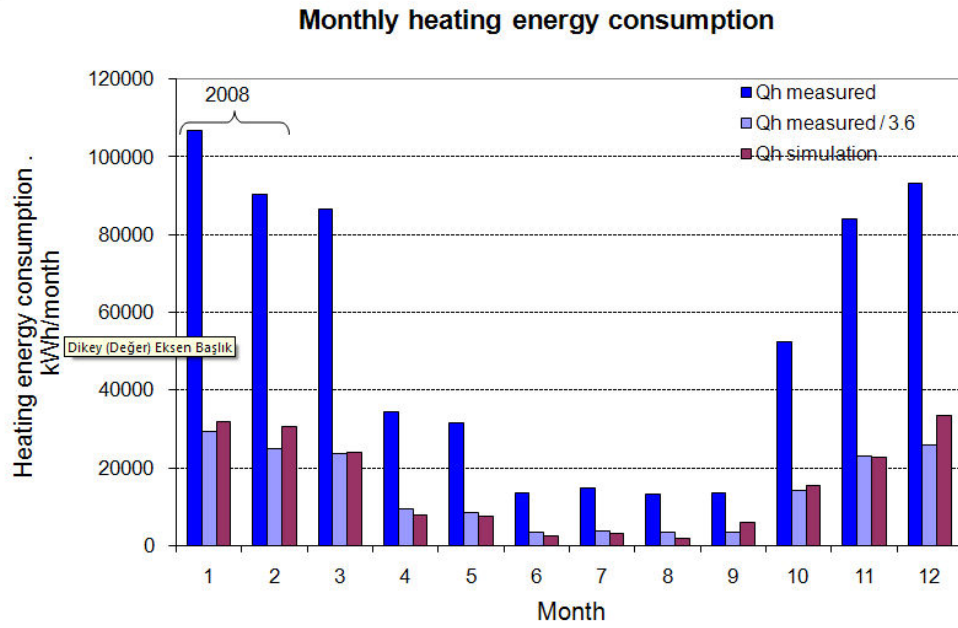


Figure 3.37 : Last comparison between simulation results and measured data

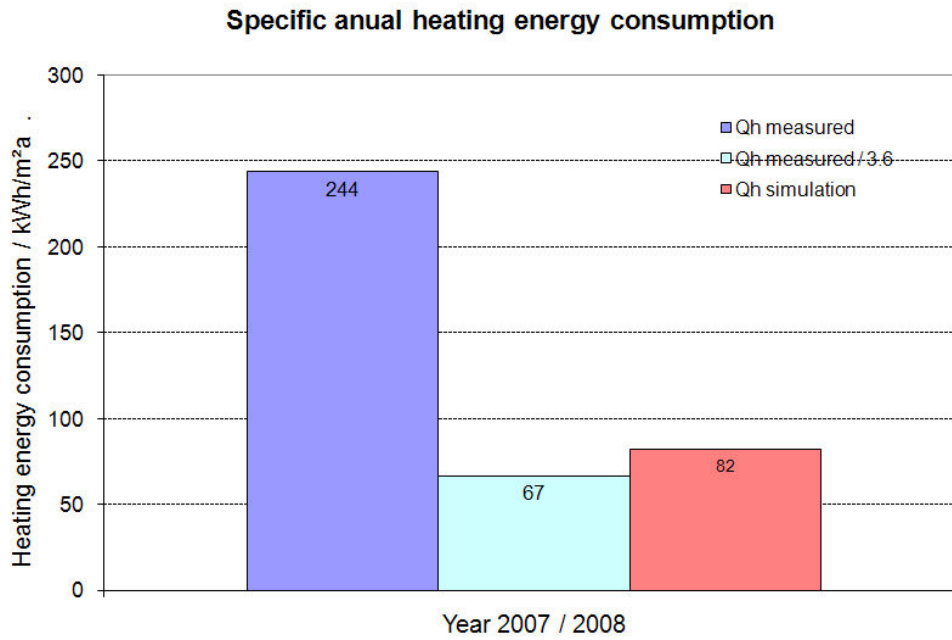


Figure 3.38 : Last annual comparison between simulation results and measured data

The first simulation results showed that there was a problem for April caused by simulation tool or by measured data, since there was a big difference between the while other months have dependable results. Then the data system has checked again

for any missings caused by Building Management System, after being realised the problem, BMS manager informed and they have sent new data. Then the problem seemed as fixed

4.8.3.7 BMS System of case study building

Systems and components

Building management systems generally consist of a various number of different components like sensors, actors and smaller decentralized controller units single component control which are all connected via communication lines to one whole system with one main controller unit responsible for the whole system control. Normally, the systems include also one or more user or management terminals for system observation and configuration. (Sara, D4, Final Report)

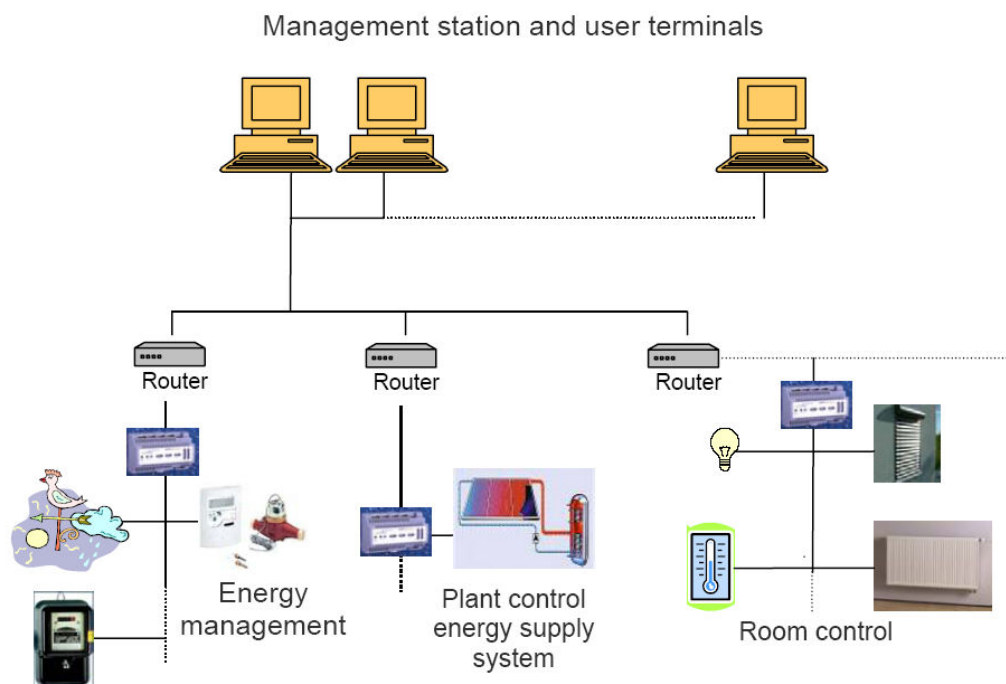


Figure 3.39 : Simplified structure of BMS

As it can be seen in figure above; the data from energy management system, from plant control energy supply system and from room control are taken to routers then they are transferred to the computers by managers of the systems. Then datas are controlled by manager in order to show that the systems are working effinciently

with any problem, or if there is any problem they will be able to see and realise then required cautions will be taken.

Sensors and energy meters

The types and number of required sensors strongly depend on the implemented control strategies within the installed BMS. A general description of available sensor types and their typical functions within building management systems are described in tables below. (Sara, D4, Final Report)

Integrated control functions of building management system

The installed building management system components are shown below. Their control function and description are also added to the table to demonstrate the whole system together. In table 3.1 the integrated control functions can be seen.

Table 3.1: Integrated Control Functions

System	Control Function	Description
Heating/ ventilation/ air conditioning (HVAC)	Night time energy saving	Control of the HVAC systems according to a schedule for night time and weekend energy saving periods with reduced set points.
	Self adapting thermal comfort control	Implementation of innovative thermal comfort control functions for air temperature set point evaluation which take into consideration the season and the actual ambient conditions.
	Optimised heating up/ cooling down period	Optimisation of the heating up/ cooling down period after night time and weekend energy saving periods. Often innovative self learning and adapting controllers with fuzzy- logic or simulation based control systems are used.
HVAC and lighting systems	Presence control	Control of the HVAC and lighting system according to the presence of people.
Ventilation system	Air quality control	Control of the ventilation system according to the air quality of rooms, e.g. CO ₂ -concentration.

Ventilation system	Air humidity control	Control of the supply air humidity in a certain range.
Illimination system	Illimination level control	Dimming function for the illimination system, which is controlled according to the daylight level in the rooms.
	Active daylight systems	Control of active daylight systems like the inclination of reflecting lamellas in the upper level of the shading system etc.
Sun shading devices	Sun protection	Control of sun shading systems according to the solar irradiation and wind speed
Measured Variable	Sensor Type	Control Function
Temperature	Resistance sensors PT 100/ PT 1000	-Ambient temperature -Room temperature control -Supply/return temperature control
Humidity	Capacitive sensors	-Ambient air humidity -Room air humidity control
Solar sensors	Photometry sensors	-Control of the sun shading systems
Wind speed sensors	Anemometers	-Control of sun shading systems automated window openings
Rain sensors	Rainfall/wetness sensors	-Control of automated window openings
Illimination	Photometry sensors	-Control of artificial lights and active daylight elements
Presence	PIR passive infared movement sensors	-Control of lights, heating cooling and ventilation system
Air quality	CO2- sensors	-Control of ventilation system

4.8.4 Revenue Generation

All the above passive strategies are incorporated in the building's construction cost by virtue of good design and early decisions about the building's philosophy, and a brief that would suit it. As UK's Building Regulations are getting more demanding about energy use and carbon emissions, it makes sense to design for as much passive gains as possible.

It is expected that energy efficient design and an intelligent control system will reduce running costs of lighting, ventilation and heating by 40% compared to reference building. High energy efficiency and use of passive design will enable low

primary energy usage. Energy performance will exceed current UK building regulations by at least 30%.

4.8.5 Position in the Value Network

Sara Project is part of the eco buildings network and also a Partner of Sustainable Energy Europe Campaign. So regarding to analysis of the project it can be said that the building can be one the eco buildings since it's design based on passive solar energy strategies behind the integration of active solar systems in order to provide a considerable reduction in energy consumption. If the sustainable ecological buildings compose a value network, Southampton Educational Center building may take an honorable place between them with its concept, installations, materials, components, systems and also cost reduction for life-cycle period of the building.

4.8.6 Competitive Strategy

SARA makes different projects in different countries as eco building projects, and demonstrates the strategy used in these projects in order to be a reference for other projects that will be constructed in the future. The partners prepare a good practice guide on their web site and also the detailed information that belongs to strategies

5. CONCLUSION AND RECOMMENDATIONS

In this study the technical background of performance based energy efficient intelligent building business models is defined and especially the importance of energy efficiency is emphasized. The business model components and the basic functions are defined based on the energy efficient intelligent buildings. The stakeholders are specified for this model.

Since a conceptual performance based business model of energy efficient intelligent building requires an exact definition of energy efficient intelligent buildings to specify the inputs for the business model, various studies are analysed in order to find a common dependable description for these terms and also to find an efficient performance model of intelligent buildings.

As it is mentioned in previous parts of this thesis, if a building is constructed as intelligent, it should use the energy sources efficiently by reducing the energy consumption, has sustainable structures and has reduced life-cycle cost, has a sense of environment, and has a relation between its systems. The concept of the intelligent building implies that it may be also useful to think of intelligent systems or intelligent networks beside the concept of intelligent buildings. From energy efficiency aspect, the intelligent buildings are not only the buildings that have well developed, efficiently installed automation systems, but also designed with the concept of energy efficiency. If a building does not reduce energy consumption, requires much more energy during the life-cycle period, how can it be called as intelligent. That building will be only a well automated building, but not an intelligent building. So, intelligent buildings should be designed based on passive solar energy strategies, then an efficient integration between the systems should be provided by automation systems.

Much research work has been focusing on the discussion of intelligent building technology development and performance evaluation methodologies. It is important to define an efficient performance model for intelligent buildings in order to show its performance and to evaluate its intelligence objectively. This model should include

all the stages from the beginning of design level to a specific life-cycle period, otherwise the term of intelligence will become a subjective nomination without any measurement or there will be some missing performance indicators. When there are all the stages of both design and construction period, comparisons will be available between simulation and measured data. Moreover, it is important that the design and construction team should agree early on as to the importance and priority of the intelligent attributes and works to keep them in scope, even when project budgets become a challenge.

However, all the system integrations need a business model to work efficiently, and also to define inputs, outputs clearly. It will also provide the management for the system integration. At this point of view, the term of “performance based business model” gains the priority to be defined for intelligent buildings. Since there is a requirement for a performance based business model, some performance models for intelligent buildings are analysed and their advantages-disadvantages are listed to get inputs for energy efficient intelligent building business model. So integrating the performance models to the business models will provide the availability to check the energy savings and to compare the results with real measured data.

According to the searches, a business model of performance based energy efficient intelligent buildings is a conceptual tool that directs to know the fundamentals of an efficient business by creating, marketing and delivering value with service and information flows. It is a whole complex of elements that composes the business and their relationships including business actors and the potential benefits for the various business. This study claims that a business model provides:

the value suggestion,

determines a market sector,

defines the structure of the firm's value chain,

designates the revenue generation mechanisms,

defines the situation of the firm

systematize the process in order to get a competitive strategy.

Finally, the case study building is analyzed according to designed conceptual business model. The simulation results are included and they are compared with the real data measured by the year 2007. The results have shown that a simulation tool should be integrated to indicate the performance of the building from the beginning

of design level. If simulations can be performed efficiently, the nearest values can be seen and the cautions can be taken at an early stage, so it can provide more energy savings and more intelligence.

Since there is not any information about business plan and resource balancing about case study, these subjects are only mentioned in conceptual business model. These components of the business model are also important for economic considerations. If a business plan can be regulated efficiently and the resource balancing can be performed intelligently, the problems will be minimized and this will provide cost savings. So, cost savings are also the initial subject for the intelligent buildings.

To summarize all, intelligent building is a mechanism that consists of:

- Energy Efficiency
- Performance Model Integrated With Simulation Tool
- Business Model

and this mechanism should provide an exact integration and relation between the systems of the building. The business models should be defined clearly before the design stage starts, the performance of the building should be checked at any stage to manage the energy consumption and also to take prior cautions. If simulations can be performed efficiently, it will give a nearest value to the measured value. It is also important to provide a comprehensive business plan integrated with resource balancing, then economic cautions can be taken and cost savings can be supported by this methods. The basic method for business models:

Future studies can be related with performance based business models for different type of the buildings according to the user's requirements. The results of this study is an output of the conceptual business model of an energy efficient intelligent buildings. So it can be an input for further models that will be developed for next projects which are intended to be energy efficient intelligent building projects.

REFERENCES

- Arkin, H. and Paciuk, M.**, 1997. Evaluating Intelligent Buildings According to Level of Service Systems Integration, National Building Research Institute, Technion, Haifa 32000 Israel
- Bassi, R.**, 2005. MATOOL: A Matrix Tool For Assessing The Performance Of Intelligent Buildings, Proceedings of the BRE Seminar On Intelligent Buildings, Building Research Establishment Ltd., UK
- Capeluto, E. O., and Ochoa, C. E.**, 2007: Strategic decision-making for intelligent buildings: Comparative impact of passive design strategies and active features in a hot climate. Climate and Energy Laboratory in Architecture, Faculty of Architecture and Town Planning, Technion-Israel Institute of Technology, Technion City Haifa 32000, Israel
- Chen, Z., T.D.J. Clements-Croome, Hong, J., Li., H. and Xu, Q.**, 2005. A Multicriteria Lifespan Energy Efficiency Approach to Intelligent Building Assessment, School of Construction Management and Engineering, The University of Reading, Reading, UK
- CIB Working Group W98**, 1995. Meeting Held at International Building Congress Proceedings, Tel Aviv, Israel, Edited A. Lustig
- Economic Commission for Europe**, 1991. Energy Efficient Design, United Nations.
- Francis, D.**, 1983, The Orbit Study, Information Technology and Office Design, Oxford Press, London.
- Fuller, S.**, 2003. Life Cycle Cost Analysis (LCCA), *National Institute of Standards and Technology*
- Giama, E and Papadopoulos, A. M.**, 2006, Environmental Performance Evaluation of Thermal Insulation Materials and Its Impact on Building, *Laboratory of Heat Transfer and Environmental Engineering, Department of Mechanical Engineering, Aristotle University Thessaloniki*, 54124 Thessaloniki, Greece
- Huang, Z., Pan, Y., Yin, R.**, 2007. Energy Modelling of Two Office Building with Data Center for Green Building Design, *Institute of Building Performance & Technology Sino-German College of Applied Science, Tongji University*, Shanghai 200092, China
- IBE.**, 1992. The Intelligent Building in Europe, DEGW (London) and Teknibank (Milan) with the European Intelligent Building Group
- Kroner, W. M.**, 1997. An Intelligent and Responsive Architecture, *Automation in Construction* 6, 381-393
- Markus, T. A.**, 1967, The role of Building Performance, Measurement and Appraisal in Design Method, *Architects Journal* 146

- Oğuz, O.** 2007 Akıllı Bina Kavramı ve Akıllı Bina Değerlendirme Metodları, İTÜ Fen Bilimleri Enstitüsü
- Osterwalder, A. and Y. Pigneur** 2003 Modeling Value Propositions in e-Business. Fifth International Conference on Electronic Commerce (ICEC), Pittsburgh, USA.
- Osterwalder, A., M. Rossi, et al.** 2002 The Business Model Handbook for Developing Countries. IRMA'2002, Seattle.
- Osterwalder, A.** 2004 The Business Model Ontology A Proposition In A Design Science Approach
- Roaf, S., Fuentes, M. and Thomas, S.,** 2003. Ecohouse 2A Design Guide, Oxford
- T. D. J. Clements-Croome,** 1997. What Do We Mean by Intelligent Buildings? Automation in Construction 6, 395-399
- T. D. J. Clements-Croome,** 2001: Building Environmental Engineering: The Invisible Architecture, *Department of Construction Management and Engineering University of Reading.*
- Watson, D.,** 1979: Energy Conservation Through Building Design, McGraw Hill Book Company, New York
- Wigginton, M. and Harris, J,** 2002. Intelligent Skin, Architectural Press, Oxford, UK
- Wong, J. K. W., Li, H. and Wang, S. W.,** 2005. Intelligent Building Research: A Review, Department of Building and Real Estate, The Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong, Department of Building Services Engineering, The Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong.
- Wong, J. K. W., Li, H. and Wang, S. W.,** 2007. Evaluating the System of Intelligence of the Intelligent Building Systems, construction and Validation of Analytical Models, *Department of Building and Real Estate, The Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong, Department of Building Services Engineering, The Hong Kong Polytechnic University, Hunghom, Kowloon, Hong Kong*
- Sara Project, Final Reports Supported by Hochschule für Technik Stuttgart**
- Url-1** <<http://www.arvetice.com>>. accessed at 05.02.2009
- Url-2** <<http://www.caba.org>>. accessed at 22.03.2009
- Url-3** <<http://www.energydesignresources.com>>. accessed at 17.5.2008
- Url-4** <[http:// http://www.sara-project.net/](http://http://www.sara-project.net/)> accessed at 21.04.2008

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