ENERGY ANALYSIS AND OPTIMIZATION OF PUBLIC BUILDING USING BUILDING INFORMATION MODELING APPLICATION

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This prject report is dedicated to my family for their endless support and encouragement.

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ABSTRACT

Energy usage and its respective become a controversial issue in the modern world. Energy is considered as one of the indispensable factors for continuous development and economic growth. Among the wide range types of different buildings, Public buildings are considered as one of the biggest energy consuming sector in the world and major part of this amount is used by the air conditioning system especially in tropical climates. One of the public buildings that have the most occupied compared to the other public buildings are libraries. It has to be more consider with regard to energy consumption issues. The aim of this study is the analysis and optimization of energy usage in public buildings to reach the comfort level. It management of consuming the energy input by using BIM application. A selected case study modeled within the BIM application and simulated through suitable energy analysis software. The result of a questionnaire distributed among users showed that the air quality is uncomfortable. The current energy consumption patterns of this case are identified and shifted to the optimized level of energy usages by recommending some practical passive ways to change the materials, internal design and the comfort level of the building.

ABSTRAK

Penggunaan tenaga menjadi isu kontroversi dalam dunia moden hari ini. Tenaga dianggap sebagai salah satu faktor penting untuk pembangunan berterusan dan pertumbuhan ekonomi. Terdapat beberapa jenis bangunan yang berbeza dan, bangunan awam merupakan salah satu sektor yang menggunakan tenaga yang sangat banyak. Ia adalah hasil penggunaan sistem penghawa dingin terutamanya di kawasan iklim tropika. Salah satu daripada bangunan-bangunan awam yang mengguna tenaga yang paling banyak berbanding dengan bangunan-bangunan awam yang lain ialah perpustakaan. Ia seharusnya diberi pertimbangan yang lebih berkaitan dengan isu-isu penggunaan tenaga. Tujuan kajian ini, adalah untuk menganalisis dan mengoptimumkan penggunaan tenaga dalam bangunan awam untuk mencapai tahap keselesaan dan pengurusan input tenaga dengan menggunakan aplikasi BIM. Satu kajian kes dipilih untuk dimodelkan dalam aplikasi BIM dan simulasi perisian analisis tenaga. Hasil soal selidik yang diedarkan di kalangan pengguna menunjukkan bahawa kualiti udara adalah tidak selesa. Corak penggunaan semasa tenaga dalam kes ini dikenalpasti dan beralih kepada tahap dioptimumkan kajian ini mencadangkan beberapa cara yang praktikal untuk menukar bahan, reka bentuk dalaman dan tahap keselesaan bangunan.

TABLE OF CONTENT

2 LITERATURE REVIEW

LIST OF TABLE

LIST OF FIGURE

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Introduction

At present, the construction industry time encounters a range of daunting challenges that requires our sustained effort to change and adjust our activities in a more environment-friendly manner. Sustainable construction, in other words, green building is a universal understanding in the developed world. However, it holds less true throughout developing countries, facing key and acute problems in the arena of their development. Hence, the built environment demand for green innovations and mechanisms, which are regarded far more pressing than the past. Sustainable building is the employment of much healthier as well as resource-efficient models of construction operation, maintenance, renovation and demolition as well.

1.2 An Introduction to Sustainability

In order to address green and maintainable construction, maintainable style (also called environmental style, ecologically maintainable style, environmentally conscious style, etc.) is the viewpoint of designing actual things, the built environment and services to adhere to the principles of social, economic and environmental durability. The intention of maintainable style is to eliminate the negative environmental effect completely through skillful, sensitive design.

Symptoms of maintainable designs require no non-renewable sources, effect on the surroundings minimally, and relate people with the ecosystem. Applications of this viewpoint range from the microcosm small things for everyday use, through to the macrocosm buildings, cities, and the planet's actual surface. It is a viewpoint that can be applied in the fields of the structure, landscape structure, city style, city planning, technological innovation, graphics, industrial style, style, and fashion style. Sustainable style is mostly a general reaction to the global environmental downturn, the rapid growth of business activities and people, destruction of organic sources, damage to environments and loss of bio-diversity.

1.3 Sustainable Design

Sustainable design is the concept of designing physical objects, the built environment and services to comply with the principles of economic, social, and ecological sustainability. The purpose of sustainable design is to deduct negative environmental impact completely through skillful, sensitive design.

The boundaries of Sustainable design are optimizing whole world effects are going to be considered because of growth in products or solutions is continually out pacing profits in performance. Consequently, the pure effect of Sustainable design nowadays has been to simply improve the performance of quickly improving effects. The present strategy, which concentrates on the performance of providing individual products and solutions, does not fix this problem. The basic challenges include: the improving complexity of performance upgrades, the problems of applying new systems in are physical effects of providing products or solutions are not nearby but allocated throughout the economies systems, and that the range of source uses is growing and not backing.. In architecture, sustainable design is not the connection or complement of architectural design, but a stylistic process. This needs close collaboration of the styling team, the designers, the technical engineers and the consumer at all venture levels, from the site choice, program development, material choice and purchase and venture execution.

1.4 Energy Role in the Construction Industry

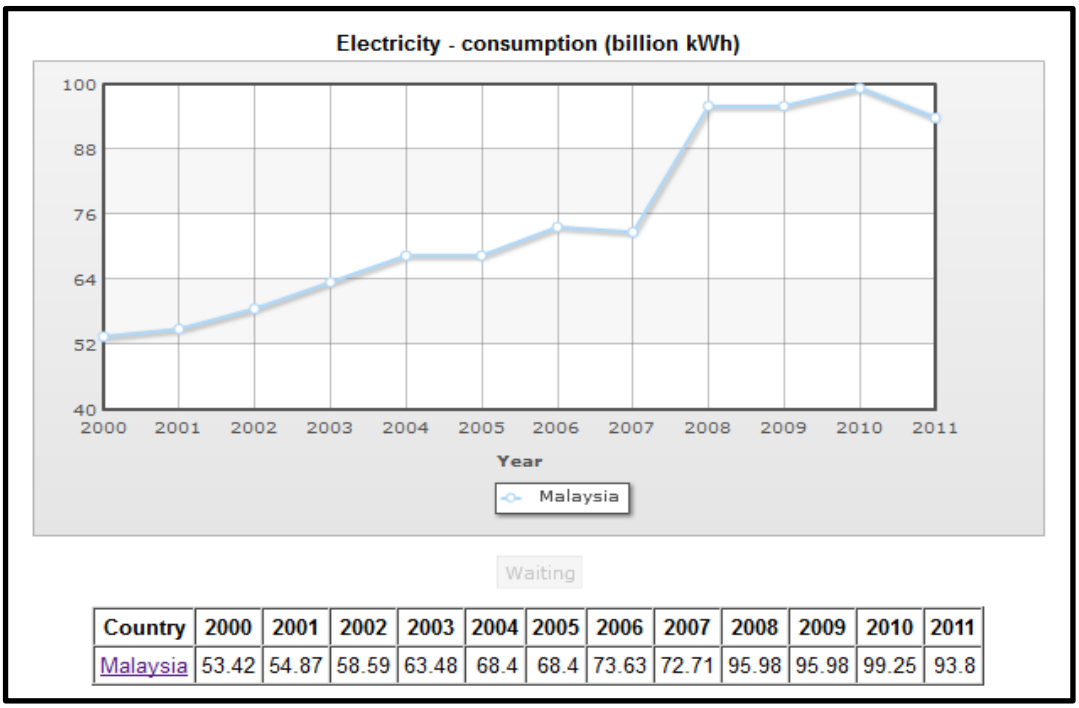
Energy usage and its related issues have proved to be a disputable case in the contemporary world. Energy is regarded as a crucial factor for unremitting development and economic development. Indisputably, competent usage of the energy would create massive privileges to create a mitigated economic and ecological status of the countries. It is axiomatic that management of the energy usage paves the way for obtaining a useful tool to sensibly make use of our energy resources. This is done targeting at prioritizing the improvement of energy efficiency policies in many countries. In the present investigation, efforts are taken to solidly determine comfort temperature and the aggregation of its related data. It strives to recommend efficient strategies to cut down on energy usage in non-residential buildings.

Energy management and energy usage have turned to be significant issues; consequently, numerous full-scale researches have been conducted in these arenas by various researches. In the final years of the 19th century and beginning years of the 20th century, several Asian countries have enjoyed great economic growth, which inevitably, gave rise to a major soar in the energy demand. This movement, however, requires great consideration for sustainability. It is merely, the single way to protect the earth against global warming. It is evident that excessive energy consumption and CO2 emissions are largely held responsible for global warming.

1.5 Energy Consumption Situation in Malaysia

Malaysia, along with the other Asian countries, has undergone a rapid economic and technological growth; hence, the energy usage has experienced a rapid increase during these years.

Figure1 demonstrates the trend of electrical energy consumption. As it can be observed, the level of energy consumption has increased from 52 kWh in 2000 to 100 kWh in 2010.



Country	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Malaysia	53.42	54.87	58.59	63.48	68.4	68.4	73.63	72.71	95.98	95.98	99.25	93.8

Figure 1.1 Trends of Electricity Energy Consumption in Malaysia

A study conducted in the year 2006 in house energy usage by the CETDEM_ Center for environment, Technology and Development, Malaysia (Figures 2 and 3), point to the fact that air conditioning and refrigerator account for roughly 70% of the average family electricity use. Air conditioning has shown to be the largest consumer of electricity in homes. Global warming forces people to use more energy for cooling and it will become increasingly important in the future .

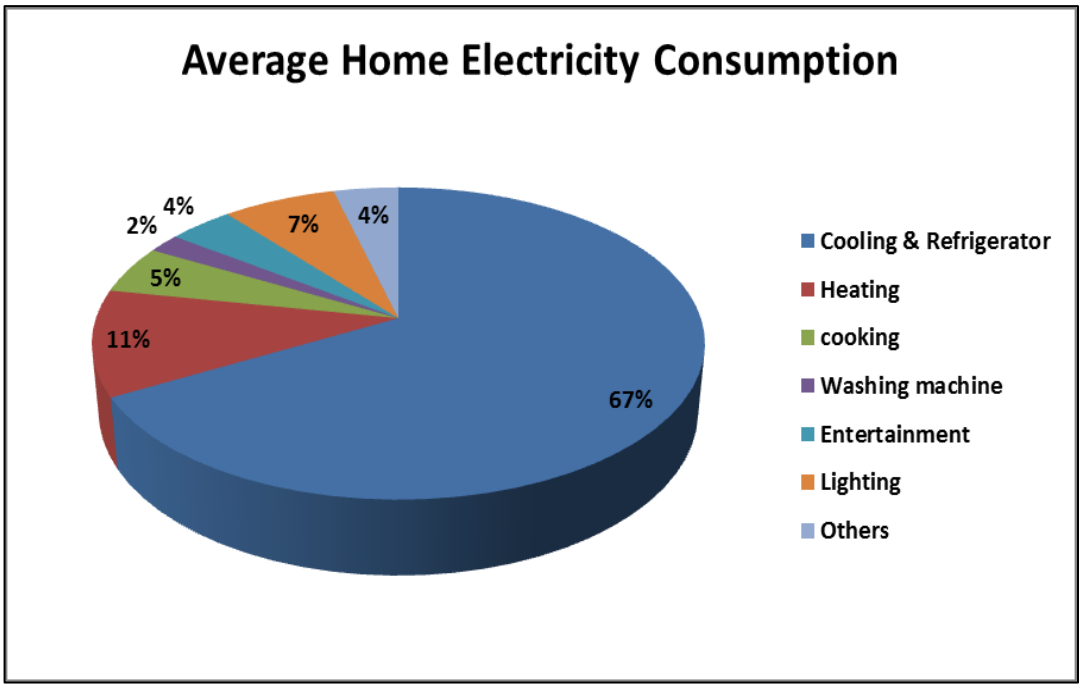


Figure 1.2 Home Electricity Consumption by CETDM, 2006

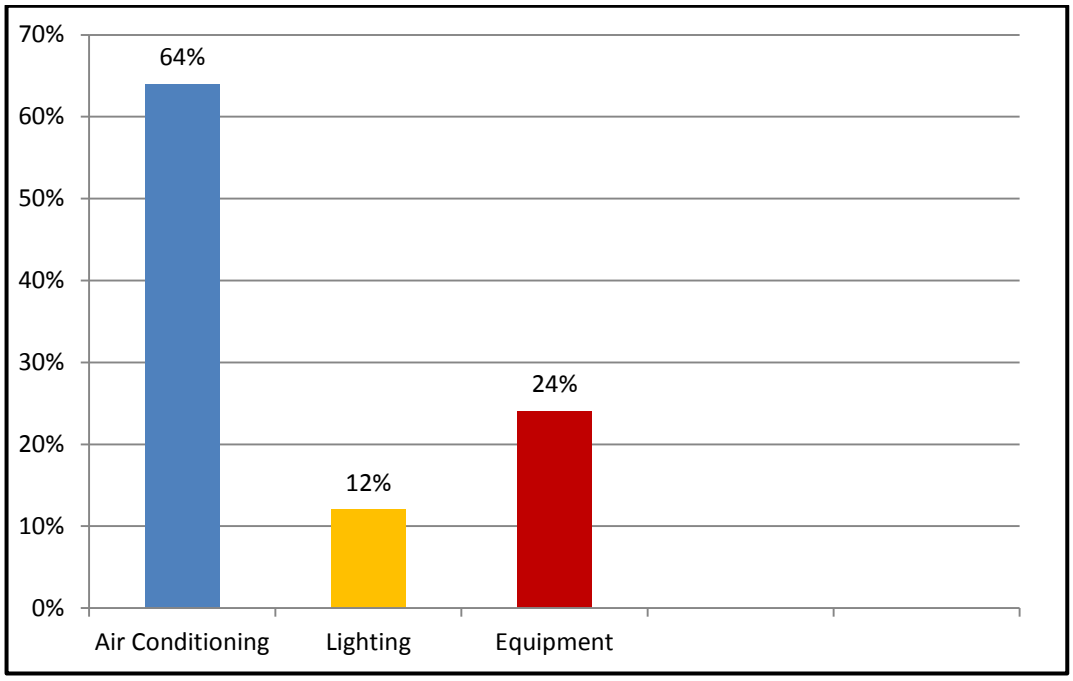


Figure 1.3 Office buildings electricity consumption by CETDM, 2006

1.6 An Introduction to BIM

To materialize sustainable design, efficient energy analysis and optimization, many new methods have been recruited in the previous decade. Building information modeling solutions would facilitate sustainable design practices by empowering architects as well as engineers to more precisely visualize, simulate, and analyze building performance before the design stage . The smart abilities in the building information model would enable us to increase the usage of the desktop tools.

The American Institute of Architects has defined BIM as “a model- based technology linked with a database of project information”. This definition reflects the broad dependence on database technology as the foundation. At some point in the future, structured text documents like specifications may be possible to be explored and connected to regional, national, and international standards.

1.7 Relation Between Sustainable and BIM

An example of BIM software is Autodesk Ecotect, an inclusive environmental design means which envelop a broad variety of simulation as well as analysis functions needed for full understanding of how a building design would function. Environmental design principles, including solar, thermal, shading, and lighting, as well as airflow, are most successfully addressed in the initial phases of the design process. Through Ecotect tools, architects and engineers are capable of measuring how primary criteria will influence building performance in the conceptual and comprehensive stages of design. Architects and designers can easily work in 3 dimensional environments and implement a rich range of apparatus that are important for consumers to fuel and support a sustainable future.

1.8 Background

In the recent years, some studies have been conducted by scholars to analyze BIM applications potential in the energy analysis and optimization fields.

The design optimization of energy consumption in residential buildings through building information modeling in 2012. The case study is a double storey bungalow located in Johor Bahru. It was modeled in Revit Architecture and exported to Autodesk Ecotect Analysis, which both of them are the epitome of BIM tools, for energy analysis (Mahmoud Shakouri, 2012).

A Study of Application of BIM in Sustainability Analysis (Hamed Golzarpoor, 2010) for a one story building in the area of Universiti Teknologi Malaysia was modeled as the case study for building energy, cost and carbon analyses that based on modeling of the case study in Autodesk Ecotect Analysis software and uploading exported gbXML model to the Autodesk Green Building Studio.

A survey was administered in five cities (Harris and Ogbonna, 2006) each of which represented a specific climate area. The research focused on the use of building and clothing control of the occupants. The results indicated that that there is an explicit relationship between indoor comfort and outdoor conditions compatible with an adaptive strategy to gain thermal comfort. They did a recent thermal study in 2006 at Jos, Nigeria, in the sub Saharan a city in the tropical savanna region. Additionally, there have been numerous studies investigating diverse ways of the management of energy usage worldwide.

1.9 Problem Statement

Public buildings as the main energy consumer sectors among residential buildings are using a huge amount of energy. The major part of this energy consumption used for the air conditioning system especially in tropical climates. One of the public buildings that has mostly used to compare with other public buildings are libraries. Consideration to energy consumption in this building is important and the unavailability of analysis the energy especially in public buildings such as libraries using an application of BIM in tropical climate are less available.

The major purpose of any air conditioning system is the provision of acceptable and comfortable cool indoor conditions. The tropical climate in Malaysia tends to be hot and humid; consequently, enormous amounts of energy are consumed by the cooling system in the public buildings. The most tangible challenge in these buildings is a waste of energy, pertinent to the cooling system. Most of times, however, the users of these buildings are not content and comfortable with the level of the building's indoor temperature. It seems utterly evident that adopting proper choices in design in general, and material selection in particular plays a pivotal role in energy consumption issues.

The sustainable buildings and the application of BIM tools are a new concept in Malaysia that have been mainly overlooked by clients, consultants and contractors due to lack of the necessary familiarity. It can be observed that few construction projects recruit the guidelines provided by BIM tools in their development.

1.10 Aim and Objectives

The aim of this study is the analysis and optimization of energy usage in public buildings for the comfort level. It is also a management of energy refinement by using BIM application by the following objectives:

- To identify and evaluate the occupant satisfaction with regard to internal thermal comfort.
- To model and simulate the selected case through BIM application.
- To analyze and assess the current pattern of energy usage in the selected case.
- To recommend a practical ways to optimize energy consumption with respect to occupants' requirements.

1.11 Research Questions

- What are the main criteria of occupant satisfaction with regard to internal thermal condition?
- How can the selected case be modeled and simulated through BIM application?
- What is the current pattern of energy usage in the selected case?
- Which practical ways can we apply to improve the energy optimization pattern in this case?

1.12 Scope of Study

In this research several parameters of air quality a measured and use as input to BIM softwares for analysis and optimization the energy usage.

By using Autodesk Revit Architecture 2011, the library plan is modeled and exported to Autodesk Ecotect for simulation and energy analysis.

In order to achieve the objectives of this study, the case study only focused on the public buildings in Malaysia. The scopes of data collection are:

1. The selected library building is located on UTM Johor campus.
2. It focused on the cooling load analysis as one of the wide range of energy analysis concepts.

1.13 Significance of Study

This research analyzes the energy consumption in the library building by application of BIM situated at tropical climate. The process of improving the energy efficiency of these buildings can be a sample for designers. This study highlights the importance of evaluation of public building performance and its impact on the energy consumption in the design stage.

REFERENCES

Adams, W. M. And Jeanrenaud, S. J. (2008). Transition to Sustainability: Towards a Humane and Diverse World. Switzerland: Gland.

Alshawi, M; Faraji, I. (2002). "Construction Innovation: Information, Process, Managemen". 2 (1).

Anuj Kumar1, I. P. S., and S. K. Sud (2009). "Thermal Comfort Feelings Assessment Based on Digital Signal Processor". International Journal of Recent Trends in Engineering 2 (1).

Ar Chan Seong Aun.Green .(2009). Building Index-MS1525. Code of practice on Energy Efficiency And uses renewable energy for Nonresidential Building.

ASHRAE (2004). ANSI/ASHRAE Standard 55.Thermal Environmental Conditions for Human Occupancy". Atlanta: American Society of Heating Refrigerating and Air-conditioning Engineers Inc.

ASHRAE (2004). ASHRAE Standard 90.1. Energy Standard for Buildings Except Low-Rise Residential Buildings. Atlanta: ASHRAE.

Autodesk, (2009). Sustainable design analysis and building information modeling‖, Autodesk white paper.

Autodesk, (2009), Using Autodesk Ecotect Analysis and Building Information Modeling , Autodesk Ecotect Analysis user guide.

Autodesk Green Building Studio Help, https://gbs.autodesk.com.

Autodesk, (2008), Using Green Building Studio with Revit Architecture and Revit MEP, Green Building Studio user guide.

Autodesk, (2008), BIM and the Autodesk Green Building Studio‖, Autodesk.

Azhar, S.; Hein, M; and Sketo, B. (2008)."Building Information Modeling: Benefits, Risks and challenges".Proceeding of the 44th ASC National Conference. Alabama, USA: Auburn.

Azhar, S. (2011). Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry, Leadership and Management in Engineering. Whitepaper: 241-252.

Blewitt, J. (2008) Understanding Sustainable Development. London: Earthscan.

Bosselaar, L. (1997). "The Netherlands policy for stimulating the use of passive solar energy". 7th International Conference on Solar Energy at High Latitude. Espoo-Otaniemi, Finland: 27-30.

Brager, G. S. a. R. J. d. D. (1998)."Thermal Adaptation in the Built Environment, A Literature Review". Elsevier Science: 84-95.

CETDAM (2004). Working with the Community on Energy Efficiency at Household Level in Petaling Jaya. A CETDAM Study on Energy Efficiency 200.

Holness, G. V. R. (2006). "Building Information Modeling Gaining Momentum." ASHRAE Journal: 28-40.

Church, J. M. (1994). "A market solution of Green Marketing: some lessons from the economics of information." Minnesota Law Review: 245-278.

CIOB, "Sustainability and Construction", The Chartered Institute of Building.

Crawley D., Hand J., Kummert M., Griffith B., (2005), Contrasting the capabilities of building energy performance simulation programs‖, Joint Report, Version 1.0.

D.A. Coley, S. S. (2002). "Low-energy design: combining computer-based optimization and human judgment." Building and Environment 37 (12): 35-40.

Davis, M.P., Nor din, N. A. (2003) "Thermal Comfort Housing in Malaysia, China and Arab Countries". Buletin Ingenieur. pp. 35-40.

De Dear, R. J., Brager, G. S. (2002). Thermal comfort in naturally ventilated buildings: revisions to ASHRAE Standard 55. Energy and Buildings, 34: pp. 549-561.

Dennis, K. (2006). "The compatibility of economic theory and proactive energy efficiency policy." Electricity Journal 19 (7): 58-73.

B, E., Ed. (2003). Green Buildings pay. 2nd Ed. London: New york: Spon press.

Ezzeldin, S., Rees, S., Cook, M (2008). Energy and Carbon Emission Savings due to Hybrid Ventilation of Office Buildings in Arid Climates. PLEA 2008 conference. Dublin, Ireland.

Fanger, P. O. (1970) Thermal Comfort. Analysis and applications in Environmental Engineering. McGraw Hill.

Fanger, (1982). “Thermal Comfort Analysis and Applications in Environmental Engineering”, Rebert E Krienger Publishing Company, Malabar, Florida.

Fisher, A. C., Rothkopf, M.H (1989). "Market failure and energy policy: a rationale for selecting conservation." Energy Policy 17 (4): 397-406.

Giles Atkinson, Simon Dietz, Eric Neumayer.(2007). Handbook of Sustainable Development.

Givoni, B. (1969). "Man, Climate & Architecture." Elsevier London.

Givoni, B. (1994).” Passive and Low energy cooling of buildings”. New York, Van Nostrand Reinhold.

Hamed, Golzarpoor. (2010).” Application of BIM In Sustainability Analysis”

Holness, G. V. R. (2006). "Building Information Modeling Gaining Momentum." ASHRAE Journal: 28-40.

HSE,(2009):Information on http://www.hse.gov.uk/temperature/thermal/factors.htm.

Ibrahim, Hussein. (2009).”Field study on thermal Comfort in Malaysia”.

IECC, (2000). International Energy Conservation Code, International Code Congress, Falls Church, VA, Second printing, January 2001.

ISO, (1994). “International Standard 7730, Moderate Thermal Environment: Determination of PMV and PPD Indices and Specification of Conditions for Thermal Environment”. International Organization for Standardization, Geneva.

EN7730, I. (1994). “Moderate thermal environments – Determination of the PMV and PPD indices and specification of the conditions for thermal comfort”. Geneva, International Standards Organization.

J.A. Clarke, J. C., S. Conner, J.W.Hand, N.J.Kelly, R.Moore, T. O’Brien, P.Strachan (2002). ", Simulation-assisted control in building energy management systems." Energy and Buildings 34 (9): 933-940.

J. Fergus Nicol and Micheal A Humphreys (1996). “Adaptive Thermal Comfort and Sustainable Thermal Standards for Buildings”.

J. F. Nicol(2004). “Adaptive Thermal Comfort Standards in the Hot Humid Tropics”, Energy Buildings.

Kats G(2003).” The cost and financial benefits of green buildings: a report to California’s sustainable building task force”. Sacramento, CA: Sustainable Building Task Force.

K. Peippo, P. D. L., E. Vartiainen (1999). " Multivariate optimization of design trade-offs for solar ; low energy buildings. Energy and Buildings." Energy and Buildings 29 (2): 189-205.

Lee G., Sacks R., Eastman C. M., (2006), "Specifying parametric building object behavior (BOB) for a building information modeling system", Automation in Construction, 15 (6), 758-776.

Lee, S.E., Rajagopalan, P (2008)." Building energy efficiency labeling program in Singapore". Energy Policy.36 (10): 3982-3992.

Lee, W.l., Yik, F.W.H.(2004). "Regulatory and voluntary approaches for enhancing building energy efficiency". Progress in energy and Combustion Science.30: 77-499.

Manning, R., & Messner, J.I. (2008)." case studies in implementation for programming of health care facilities". ITcon.13:446-457.

Mao, X., Lu, H., & Li, Q.(2009). International Conference on Management and Service Science, 2009. MASS '09., 1-5 doi: 10.1109/ICMASS.2009.5303546.

Matthiessen L.F., Morris P. (2007). "The cost of green revisited: reexamining the feasibility and cost impact of sustainable design in the light of increased market adoption". Retrieved on February &, 2008, from www.davislangdon.com.

Mahmoud, Shakouri (2012)."Design Optimization for Energy Consumption In Residential Buildings Through Building Information Modeling".

M. Deru, B. Griffith, P. Torcellini (2006)." Establishing Benchmarks for DEO Commercial Building R&D and Program Evaluation". National Renewable Energ Laboratory.Available from: http://www.nrel.gov/docs/fy06osti/39834.pdf, 2006.

Moeck M., Yoon J.Y. Green (2004)." Buildings and potential electric light energy savings". Journal of architectural Engineering.10 (4): 143-59.

Ofori, G., Ho, L.K. (2004)." Environmental awareness into decision making". Building Research & Information.32 (1): 27-37.

PLEA Passive and Low Energy Architecture (2003). Retrieved from: http://www.plea-arch.org . 10 February 2003.

Proceedings of World Engineering Congress (1999):" Industrialized Building Systems and Structural Engineering". 19-22 July. Kuala Lumpur, 37-42.

Qian, Q.K., Wu, J., Chan, E.H.W. (2006)." Policy deficiencies in promoting building energy efficiency in Mainland Chaina". The CRIOCM20 06 International

Symposium on Advancement of Construction Management and Real Estate. Beijing, China.

Raftery, J. , Ans on, M. , Chaing , Y.H., Sharma, S. Regional overview.(2004). In: Chiang, Y.H., et al. (Eds.). The Construction Sector in Asian Economics. Spon Press, London.

Robert E. Middlebrooks, (2005).”Realizing the Future of Sustainable Design through BIM and Analysis”, Autodesk document.

Ruben A., Greg B., (2009), “The intersection of BIM and sustainable design”‖, Structure Magazine.

R. Yokoyama, T. Wakui, R. Stake (2009).” Prediction of energy demands using neural networks with model identification by global optimization”. Energy Conversion and Management. 50:319-327.

Santamouris M. (2007). “Advances in passive Cooling”. Earthscan, London.

Sherwin D.(2006).” Reducing the cost of green”. Journal of Green Building. 1(1):46-54.

S. Kumar, S. Sinha, T. Kojima, H. Yoshida (2001).” Development of parameter based fault detection and diagnosis technique for energy efficient building management system”. Energy Conversion and Management.42 (7): 833-854.

Stein R G(1997). “Conserving Energy through Rational Design”. Architecture & Energy., Garden City, New York. Anchor Press / Doubleday.

Taylor, J.E., & Bernstein, P.G. (2008).”Paradigm trajectories of building information modeling practice in project networks”. ASCE Journal of Management in Engineering.

Thormark C.(2006).”The effect of material choice on the total energy need and recycling potential of a building”. Building and Environment.41 (8): 1019-26.

Trikha, D.N. (1999). Industrialized Building System- Prospects in Malaysia.

Vine, E., Rhee, C.H., Lee, K.D.(2006).” Measurement and evaluation of energy efficiency programs: California and South Korea”. Energy. 31: 1100-1113.

Warszawski, A. (1999).” Industrialized and Automated Building Systems”. Technion-Israel Institute of Technology. E & FN Spon.

Yannas, S. (2003).” Towards environmentally-responsive architecture. Keynote”. 20th International Conference. November 9-12 2003. Santiago de Chile. 2003.

Yudelson J. (2008).” The green building revolution”. Washington, D.C.: Island Press.

Y. Zhu (2006).” Applying computer-based simulation to energy auditing: a case study”. Energy and Buildings.38: 421-428.