UNIVERSITI PUTRA MALAYSIA

INTEGRATION OF HUMAN COMPUTER INTERACTION IN ARCHITECTURAL PRACTICE ON BUILDING ENERGY DURING SCHEMATIC DESIGN

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By

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Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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January 2012

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A complex computational calculation is involved to predict the energy performance level of a building; therefore, an ideal practice is to adopt Building Energy Simulation (BES) as a prediction tool for architects to make sustainable design decisions during Schematic Design Phase (SDP). However, this application is still not prevalent amongst architects in Malaysia especially for Jabatan Kerja Raya (JKR - Public Works Department) architects. An acceptance of BES in the JKR Architects' Design Practice will lead to the improvement of many government's buildings energy performance and significant measurable impacts towards Malaysian Government's energy saving policy. While energy standards and policies deal with key planning, there is no guideline to those designing for energy performance buildings. The main objective of this research is to develop a flexible design workflow for JKR architects to use BES during SDP.

Consequently, this study has integrated literature review and presented a table of three categories of BES barriers; Functional Performance, Requirements in Architectural Design and Design Workflow Process**.** The categories have been broken down further to pose the proposition that **BES could be practised successfully by JKR architects when functional performance evaluation is made a prerequirement during design workflow process.** In order to test this theoretical proposition, this research has reviewed existing documents to analyse BES procedure and JKR architects' current design practices during SDP. An interview was carried out with several JKR architects to determine the barriers towards employing BES, while simulation was performed to identify the technical procedure in BES application.

The results and analyses of the BES procedure and JKR design practice found similarities in term of the process performed by the actor: objective, structure & tool and output. A workflow model using *HCI's ActionWorkflow Theory* found that both BES procedure and JKR design process can co-exist within a process loop during SDP. The research has addressed some of the unsolved problems in the architectural design process where there is a complex phenomenon that involves architect's experience, knowledge and background (qualitative/ artistic) and the effects of an intervention – building performance evaluation which is more quantitative and technical in nature.

The benefit of this study includes formalisation of a BES and JKR architects integrated workflow process which recommends practice guidelines for JKR architects to employ BES during SDP. These results are expected to lead towards the advancement of new knowledge by enhancing the design process using BES

Procedure – JKR Architects Workflow Process whereby BES is accepted by JKR architects to predict building performance in term of energy use and environmental and sustainable practices.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia bagi memenuhi keperluan untuk ijazah Sarjana Kedoktoran

PENYEPADUAN INTERAKSI MANUSIA-KOMPUTER DALAM PRAKTIS ARKITEK BERKAITAN TENAGA BANGUNAN SEMASA REKA BENTUK SKEMA

Oleh

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Pengiraan pengkomputeran yang kompleks terlibat dalam meramal tahap prestasi sesebuah bangunan, maka sesuatu praktis yang paling sesuai adalah untuk mengaplikasikan simulasi tenaga bangunan (BES) sebagai alat untuk arkitek membuat keputusan berkaitan rekabentuk mapan semasa fasa rekabentuk skema (SDP). Namun begitu, penggunaannya masih terhad di kalangan arkitek Malaysia terutama arkitek di Jabatan Kerja Raya (JKR). Penerimaan BES dalam amalan rekabentuk arkitek JKR akan membawa kepada kemajuan prestasi tenaga bagi bangunan kerajaan dan memberi impak yang boleh diukur terhadap polisi penjimatan tenaga oleh kerajaan Malaysia. Piawaian dan polisi tenaga adalah merupakan perancangan utama, namun tiada garis panduan tertentu untuk mereka yang merancang prestasi tenaga bangunan. Maka tujuan utama kajian ini adalah untuk

menyediakan satu garis panduan aliran kerja yang fleksibel untuk diguna oleh arkitek JKR dalam melaksanakan BES semasa SDP.

Oleh yang demikian, penyelidikan ini telah menggunakan kaedah kajian literatur dan mempersembahkan jadual untuk tiga kategori halangan penggunaan BES iaitu; Fungsi Prestasi, Syarat dalam Rekabentuk Senibina dan Proses Aliran Kerja Rekabentuk. Kategori ini telah dihuraikan lagi bagi mencadangkan suatu saranan di mana; **BES boleh dipraktiskan secara meluas dalam kalangan arkitek JKR sekiranya fungsi penilaian prestasi bangunan dijadikan prasyarat dalam proses aliran kerja rekabentuk.**

Sebagai usaha untuk menguji saranan teori ini, kajian ini telah meneliti dokumen-dokumen sedia ada bertujuan menganalisa prosedur BES dan praktis reka bentuk terkini arkitek JKR semasa SDP. Seterusnya, satu sesi temuduga bersama arkitek JKR telah diadakan bagi menentukan halangan terhadap penggunaan BES, ketika simulasi bangunan dilaksanakan untuk mengenal pasti rangka kerja teknikal BES.

Hasil dari analisa prosedur BES dan reka bentuk yang dipraktiskan oleh arkitek JKR menemukan persamaan proses yang dilaksanakan oleh seorang aktor; objektif, struktur & alatan dan output. Satu model aliran keja yang telah dipilih menggunakan Teori *HCI ActionWorkflow* mendapati bahawa kedua-dua proses reka bentuk JKR dan prosedur BES boleh wujud dalam satu proses gelung atur semasa SDP. Kajian ini telah menyelesaikan beberapa masalah reka bentuk senibina di mana terdapat fenomenon kompleks melibatkan pengalaman, pengetahuan dan latar belakang arkitek (kualitatif/ artistik) dan kesan dari penilaian prestasi bangunan yang lebih bersifat kuantitatif dan teknikal.

Manfaat kajian ini adalah termasuk memformalisasikan penyatupaduan proses aliran kerja yang mencadangkan satu garis panduan yang praktikal untuk arkitek JKR dalam menggunakan BES semasa SDP. Keputusan ujian akan membawa kepada kemajuan dalam bidang ilmu pengetahuan dengan mempertingkatkan proses rekabentuk dengan penggunaan Prosedur BES - Proses Aliran Kerja Arkitek JKR di mana BES bakal diterimapakai oleh arkitek JKR bagi meramal prestasi bangunan berkaitan penggunaan tenaga dan persekitaran serta mempraktis usaha ke arah pembangunan mapan.

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The thesis was submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the supervisory committee were as follows:

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DECLARATION

I declare that this thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree in Universiti Putra Malaysia or at any other institutions.

NOR SHAHRENE MOHD. IBRAHIM

Date: 30 January 2012

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ABBREVIATION:

5S	:	*seiri, seiton, seiso, seiketsu* and *shitsuke*; five Japanese words to describe a workplace organisation methodology
ACH		Air Change Rate
AEC		Architectural, Engineering and Construction
BEI	:	Building Energy Index
BES	:	Building Energy Simulation
CA	:	*Cawangan Arkitek* (Architect Branch of JKR)
CAST	:	*Cawangan Alam Sekitar dan Tenaga* (Environment and Energy Branch of JKR)
CCC		Certificate of Completion and Compliance
CFO		Certificate of Fitness for Occupation
CPC		Certificate of Performance Completion
D&B	:	Design and Build
DANIDA		Danish International Development Agency
ED		Environmental Design
EE	:	Energy Efficiency
EPU	:	Economic Planning Unit (of Malaysia)
GBI	:	Green Building Index
HODT		Head of Design Team
HOPT		Head of Project Team
IBS	:	Industrialised Building System
IEQ		Indoor Environment Quality
ICT		Information and Communication Technology
IT		Information Technology
JKR	:	*Jabatan Kerja Raya* (Public Works Department of Malaysia)
KPI	:	Key Performance Indicator
LAM		*Lembaga Arkitek Malaysia* (Board of Architects Malaysia)
LJM		*Lembaga Jurutera Malaysia* (Board of Engineers Malaysia)
M&E	:	Mechanical and Electrical
MoE	:	Ministry of Education
OTTV	:	Overall Thermal Transfer Value
PAM	:	*Pertubuhan Akitek Malaysia* (Malaysian Institute of Architects)
PMD		Prime Minister’s Department
PPMA	:	*Penerapan Pembangunan Mapan dan Mesra Alam* (Sustainable Development and Environment Friendly Application)
PTM	:	*Pusat Tenaga Malaysia* (Malaysia Energy Centre)
RMK-9	:	*Rancangan Malaysia ke-9* (9th Malaysia Plan)
SDP		Schematic Design Phase
SKALA	:	*Sistem Pemantauan Projek* (Project Monitoring System of JKR)
SO		Superintending Officer
SOP		Standard Operating Procedure
SPK	:	*Sistem Pengurusan Kualiti* (Quality Management System of JKR)
UBBL		Uniform Building By-Laws
UKTB	:	*Unit Kepakaran dan Teknologi Bangunan* (Expert and Building Technology Unit)
UNEP	:	United Nation Energy Program

URBF Kesihatan	:	*Unit Reka Bentuk Fasiliti Kesihatan* (Health Design Facility Unit)
URBF Pendidikan	:	*Unit Reka Bentuk Fasiliti Pendidikan* (Education Design Facility Unit)
URBF Pendidikan Tinggi	:	*Unit Reka Bentuk Fasiliti Pendidikan Tinggi* (Higher Education Design Facility Unit)
ZEO	:	Zero Energy Office

CHAPTER 1

INTRODUCTION

1.1 Introduction

This thesis addresses the barriers to the employment of Building Energy Simulation (BES) by architects of a government department - Jabatan Kerja Raya (JKR) or Public Works Department of Malaysia. Chapter 1 presents the doctoral dissertation in general. In Section 1.2, the chapter introduces the background study and key issues relating to the research. Problem Statement, Research Questions and Objectives are presented in Section 1.3, while in Section 1.4; Gaps in Research. Point of Departure is discussed in Section 1.5, and in section 1.6 onwards, there are general introduction to other chapters of this thesis; Literature Review, Research Methodology, Results and Discussion and finally, the Conclusion.

1.2 Background Study

When APEC raised the price of crude oil during the oil embargo in 1973, there is a huge concern to conserve energy. Although there is a gap of interest for energy conservations in the late 80s, the efforts picked up again in the early 90s since there is a dire concern over environmental pollution, climate change, CO2 and harmful emission. In the effort to mitigate, reduce and control excessive energy consumption, governments all around the world had developed energy related policies and standards to regulate energy consumption especially for the construction of new buildings.

These worldwide concerns relating to the construction industry has given “a need to integrate sustainability within the whole life cycle of a building from design through construction to operation” (Dawood, et.al, 2009). Traditionally in the architectural, engineering and construction (AEC) industry, architects are the ones to conceptualise a building design and planning, thus responsible to initialise the first source of environmental impact. Therefore, architects must have the knowledge to reduce the impact of buildings on the environment through designing an energy efficient building. Unfortunately, most design decisions made by the architects are taken only for aesthetic reasons and there is little or no consideration on the environmental impact of the building which only means to produce aesthetic design images.

Improvements towards energy efficiency of the building are possible if certain energy targets and parameters have been set during the design with regards to energy consumption, glare, heat gain, natural light and ventilation optimisation and indoor comfort conditions.

Consequently, to produce energy efficient (EE) building design, there is a complex computational quantitative calculation that must be done to predict the energy performance of a building. Therefore, an ideal practice is to adopt a digital design or ICT solution using IT based tool in building design since a computer support tool is expected to reduce the complexity of system equation and lessen the input and computational load (Crawley, et al., 2001). This digital design solution is known as Building Energy Simulation (BES). This simulation effort will help prevent overheating problem thus will contribute and support decision towards risk management – to address a potential problem before it happens.

BES started in the 60s when a group of engineers designed a fallout shelter and a system was developed to predict the indoor temperature and humidity of the underground shelter (Kusuda, 1999). The range of application for BES is not only to investigate new cognitive ideas for optimisation of bioclimatic design, but also to check compliance with building energy codes (Hensen, et. al.,1993). Figure 2.7: Comparison between Some of World Environmental and Energy Related Policies and BES Software Developments (between the year: 1960 – 2010), revealed that BES's proliferation is closely associated with the government's development of building energy codes because it can be assumed that BES development is taking advantage of the available government funds.

As shown in Table 2.1: Comparison between Some of the Environmental and Energy Related Policies from the World and Malaysia, as far as the world energy standards and policies are concerned, Malaysian Government is not far behind. Unfortunately, since its inception in 1989 until 2005, Malaysia's first energy standards; **MS 1525:** "**Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Buildings"**, has not been considered by local architects since no known building has been certified by such standards. Malaysia energy standards and policies lack implementation and are stopping short at the very level of the same government agencies that have established the policy without it ever being implemented among building projects.

At present, there are two measurements methods to be met in MS 1525: 2007; prescriptive based and performance based. With prescriptive based standards, the designer will need to prove that the overall thermal transfer value of a building (OTTV) has not exceeded 50 W/m^2. While for performance based standards, a building has met the energy compliance if the energy consumption of the building is less than 200 kWh/m^2/year. However, both measurements are not suitable to be implemented during SDP when most information about the data of the building is not available.

PTM (Malaysia Energy Centre) has championed MS 1525 for the building industry and finally, as PTM has its own building in 2005, the building is certified with MS 1525. Indeed, it can be said that PTM building is a showcase design for an energy efficient (EE) public building. Generally, JKR as the biggest technical government agency will implement all government projects. However, for the PTM building and the new Ministry of Energy, Water and Communication building in Putrajaya were designed by private consultants and tendered by design and built (D&B) contracts. For both of the buildings, energy consultants were appointed and energy simulation was performed.

Despite the availability, advantages and benefits that Building Energy Simulation (BES) as a prediction tool for evaluating building performance can offer the AEC industry, its application is still not prevalent among architects in Malaysia especially for JKR architects. If the technology is so good and Malaysian Government supported the efforts, why are the JKR architects not using it? There somehow exists barriers to employ BES in building design and this study is to elaborate on the barriers of BES employment faced by architects in the JKR agency in its increasing adoption of IT technology. Malaysian Government's commitment at national and ministerial level is clear, however, it is yet to be seen practised amongst the architectural discipline of this government agency. There are many reasons why JKR architects are not adopting BES. While Malaysia's energy standards and policies deal with key planning, sustainable materials and best practice, there is no guideline to those designing for energy performance buildings.

The study further explored and identified the barriers towards employing BES and the necessary actions to improve the acceptance of JKR architects towards BES as a sustainable design decision tool during Schematic Design Phase (SDP). With the introduction of BES as a design and analysis software to produce energy efficient building, JKR architects are expected to question the idea, especially when the practice is different from what they are comfortable and familiar with. Understandably, they will reject the tool at first for many reasons; technical as well as behavioural. This has heightened the need to review the existing JKR architects' standard operating procedure (SOP) regarding design process since the process has become more important and relevant. To outline the current status, the next section is giving a description of JKR architects; their background and design practices.

1.2.1 JKR Architects

Jabatan Kerja Raya or JKR, as it is commonly known in Malaysia, is the Public Works Department of Malaysia. It is a huge government technical agency and there involved a very complex nature of interfacing and interaction with many professionals which is described briefly in the JKR SPK MS ISO 9001 (Table 1.2).

JKR architects have been selected for this case study because the amount of projects they were involved in and the position they held as government officers to uphold all government policies. Any improvement (or lack of it) will affect hundreds if not thousands of building projects all over Malaysia. Historically, JKR professionals were made up of mostly civil engineers. Historically, JKR professionals were made up of mostly civil engineers, and it was believed that the ratio of JKR professionals is; 4:1:1:1:1, that is for every four civil engineers there will be one architect, quantity surveyor, mechanical and electrical engineer. In the latest JKR website it was recorded that there were 2,085 civil engineers, 458 quantity surveyors, 418 mechanical engineers, 369 electrical engineers and 330 architects (https://mykj.jkr.gov.my/index.php?action=utama).

Since the 70s buildings designed by JKR architects are known for their standardised design plans especially for office buildings and schools. It was a popular quote amongst the design community in those days regarding JKR buildings: JKR buildings were like the Indian-made cars – they will never change regardless of time and aesthetic concerns. With relatively little fund available in those days for constructing government buildings, these standardised design plans proved effective in terms of time and cost saved in designing and constructing of the buildings.

However, as Malaysia's economy improved and more funds are allocated for developments, the Malaysian AEC industry is experiencing rapid growth. During these better times, JKR building designs have been evolving and there are chances for the JKR architects to experience with new building design moving away from the standardised plans they were used to in the past. Among the example of JKR buildings that have been developed during the 1990s were the National Science Centre, Masjid Wilayah Persekutuan, Matrade Building and Public Services Department Building (now Open University KL). Even government schools have opted for new design to accommodate urban setting where the site has become restricted thus more than one schools have to share facilities such as the playing field and school hall.

The adoption of ICT technology in JKR building design is not unusual. An article in an in-house magazine called Kursor Magazine (Figure 1.1) proved that CAD had been utilised even in the late 1980s. In the early 90s another JKR architect - Ar. Abdul Haiyee bin Hasshim who designed the new Masjid Wilayah Persekutuan had used AutoCAD as a drafting tool and 3D Studio for presenting a digital model of the *masjid*. This shows that IT applications are not totally new to JKR architects and not far behind the world‘s CAD technology as shown in Table 2.5, where 3D Studio was made available in 1990.

However, the implementation of Building Energy Simulation (BES) has seen a different scenario. There existed several researches in Malaysian universities that use BES evaluation tool but it has not been applied into practice by local architects. Doctorate theses produced by Dr. P.S. Kannan (1996), Dr. Azni Zain-Ahmed (2000) and Dr. Abdul Razak Sapian (2003) are such cases. It shows that there is awareness of the existence of the tool, however, its utilisation among Malaysian architects is still very rare or none at all. Although there are a few buildings such as Penang UMNO ‗Bioclimatic Tower‘ by Dr. Ken Yeang (completed in 1998) that used Computational Fluid Dynamic (CFD) to predict the natural flow of air. While Securities Commission Building (completed in 1999) by Ar. Hijjas Kasturi employed simulation for its double skin thermal flue, however, the BES application of the simulation were done by overseas consultants.

The tool is almost unheard of within the Malaysia's architectural design circle before the design team from DANIDA (Danish International Development Agency) – IEN Consultants offered their expertise to help design the new Ministry of Energy, Water and Communication office building in Putrajaya in 2001. The software Energy-10 was utilised to simulate the energy consumption of the building during early design phase of the project. This experiment using Energy-10 is done early during the project inception and local architects and engineers are working closely together and started using the tool as early as possible. It is imperative that designers have accessed to the building simulated prediction result to make early design proposal. Later, the program was introduced to Malaysian architects by its inventor Dr J. D. Balcomb on 15th January 2004 at the "E-10 Train the Trainer" seminar held at Colma Tropical, Bukit Tinggi, Pahang between 15 to 17 January 2004 (Chan, 2004).

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CADD

Syarikat 'GABLE CAD Systems Ltd.', UK. telah membuat satu rencana khas dalam keluaran 'GABLENEWS'nya untuk bulan Julai 1988, mengenai perkembangan CAD di JKR; berikut adalah petikannya :

GABLE 4D Series at core of largest CAD installation in the Far East

GABLE CAD Systems Ltd have recently secured a significant order in the Far East from JKR (Jabatan Kerja Raya) Malaysia, for what could eventually become the largest CAD installation in South East Asia. The deal was signed after 19 months of intensive systems evaluation by JKR through Far East Computers who are GABLE's distributor in the Far East.

Based on Apollo Domain workstations the system will have a phased installation over a two year period. The first phase consists of 23 workstations which could grow to 180 on completion over a number of sites. GABLE 4D Series will be at the core of the software with links to TAS (Thermal Analysis Software), GTSTRUDL (Structural Analysis Software), and MOSS (Terrain Modelling System), to provide a comprehensive AEC applications package for the customer.

Chris Jones, one of GABLE's application support team has just returned from a 3 month training operation in the CAD unit at JKR. The unit, used by architects, mechanical, structural and electrical engineers is using GABLE as a central information base, which is being shared by the multiple disciplines. Architects are modelling buildings from sketch to detail design stage for the production of keyplans, elevations and sections. These are subsequently detailed and analysed by specialists draughtsmen to produce comprehensive working drawings with window and door schedules, electrical and services layout drawings and quantitites etc. By digitising site plans into GABLE's ground modelling system building models are being added for site layout and landscaping. Typical design work conducted by the JKR office includes government offices, hospitals and police buildings.

(Sambungan dari ms. 14)

JKR would expand its information processing to include mapping (water supply lines, roads) and facilities management, and the future would see JKR dealing with the private sector mainly via electronic media. This is beginning to occur, since some surveys conducted by private surveyors are required to be submitted to JKR with the survey data on diskettes. This will result in the "spreading of the culture" to the private sector, and this involvement with state-of-the-art technology, new skills, and higher productivity will all contribute in no small measure to the concept of Malaysia Incorporated.

In 4 to 5 years, Artificial Intelligence in the form of Expert Systems should be making a strong showing, and again JKR should take the lead. The workstation should arrive at the desk of even the most remote JKR officer; and that is where it belongs - at the workplace, not just at a computer centre - because the workstation is a daily productivity tool, and should be available and used as such!

Figure 1.1. Newspaper Clipping about The Application of Gable CADD in JKR in 1988. Source from Kursor Magazine, JKR Library Collection.

Kursor Magazine was an in-house magazine produced by Information and Technology Unit in JKR where one of the sections was a CADD unit. This article showed that CAD had been utilised even in the late 1980s. It has reported the use of CAD as a drafting tool when Gable CAD system was utilised for the new Science Centre building at Bukit Kiara (Figure 1.1). The project was implemented by JKR and under the supervision of Commander Ar. David Wee who is one of the senior architects in JKR at that time.

So far, interview results with some of the JKR architects have suggested that they do not use BES as their design tool although some do consider passive design when designing buildings as best practice or rule of thumb. They also confirmed that as long as no regulation such as Uniform Building Bye-Laws (UBBL) is imposed as a professional practice, they will not include it in their design process. JKR architects will only design to the minimum basic requirements since they were given only limited time to tender and meet the SKALA requirements. Currently, MS 1525 is not yet included in the Malaysia's Uniform Building by Laws (UBBL) although there are plans to do so in the next revision (UBBL has not been revised since 1984).

1.2.2 Design Standards in JKR

The JKR design office has over 300 architects and is responsible for designing and implementing projects for most of the government ministries including the Ministry of Education, Ministry of Finance, Ministry of Health, and Prime Minister's Department to name a few. The architects are involved in designing government buildings among others; schools, offices, embassies, residential quarters and hospitals.

Design practices by JKR architects are observed and analysed because according to Fallman (2003) there are evidences to show the existence of structure, control, predictability, and rigorousness while designing even during Schematic Design Phase (SDP). Architects do follow a certain rule in designing and designs do not just 'happen' (Fallman, 2003).

In an effort to extract and illustrate the process, strategies, behaviour, the activity, the task, the people involved and to obtain more elaborate view with due regards to the decision taken by JKR architects during SDP, this research reviewed existing study done by Sulaiman (2010) about JKR design process.

In general, there are two bodies that regulate the architects' profession in Malaysia; *Lembaga Arkitek Malaysia* (LAM – the Board of Architects Malaysia) and *Pertubuhan Akitek Malaysia* (PAM – the Malaysian Institute of Architects). LAM has the jurisdiction given by the Minister in the Ministry of Works to act on his behalf to legislate rules and methods to regulate architects professional practise (Section 35 Architects' Act 1967: Revised April 2007). LAM is a statutory body that is subjected to the Section 3(1) of the Architects' Act 1967: Revised April 2007 and one of its responsibilities is to register and deregister Graduate Architects, Professional Architects and Registered Building Draughtsmen.

PAM, however, served as a platform for architects to gather and associate within the architects' community while its role and existence is bound under the Societies Act. The membership is voluntary with the mission "to promote the advancement of architecture and the architectural profession for the betterment of society" (http://www.pam.org.my).

Although as a professional, JKR architects are bound with LAM's and PAM's code of ethics, but as a government employee, JKR architects are answerable first as a government servant. JKR architects responsibilities in the profession will be viewed collectively as a whole organisation and not as an individual. If a building is completed and JKR has issued a Certificate of Performance Completion (*Sijil Perakuan Siap Kerja*) (Form JKR.PK(O).04- SRA.9) then there is no need for Certificate of Fitness for Occupation (CFO) which is under the local authority jurisdiction to be issued.

However, in 2007, with the issuance of CCC (Certificate of Completion and Compliance), JKR architects role and responsibilities have a need to be reviewed. CCC is to replace CFO and it is to certify that the building has completed and complied with standard regulatory requirements. Professional Architects who are registered with LAM, Professional Engineers who are registered with LJM (Board of Engineers Malaysia) or Registered Building Draughtsmen are to be the Principal Submitting Person to apply for CCC as provided for in the Road, Drainage and Buildings Act: Revised 2007 and UBBL (Uniform Building By-Laws 1984).

The role of architects in JKR is different from that of private consultants'. A practising architect in a consultant office is responsible to make decision regarding the building proposal and to chair meetings between all parties involved in the project during the duration of the project from inception until the handover of a building. JKR architects, on the other hand, are involved during the inception and up to tender stage only.

According to the JKR's SPK document: Guideline on architects work process in the implementation of a project, JKR architect's role as Head of Design Team (HODT) usually starts with an appointment by Head of Project Team (HOPT) and ends once the project has been tendered. In short, JKR architects will only be responsible for their design up to designing stage but not the completed building since he will not be held responsible on site, therefore, the end product of his design will be an interpretation of the SO at the site.

With the CCC requirements, JKR architects who signed the drawings need to take the same responsibility as that of private consultants' architects, which is an unfair trade. JKR architects are made to take additional responsibilities although they are not directly involved with the end product of the building.

This new regulation has caused negative perception within the JKR architects' community. Registered Professional Architects with professional qualification in JKR are more vulnerable now than ever and since they are not doing the project for profit and no added incentive in spite of all the added responsibilities they have to carry. There is little wonder that up until this thesis is written, less than 10% of JKR architects have voluntarily taken and passed the LAM's Part 3 architectural professional practice exam.

This phenomenon has shown that although JKR architects are part of the 'government team' that implemented LAM Part 3 Professional Examination, very few of them regarded the qualifying of the exam as important. Adhering to standards and documents for professional practice is regarded as merely a voluntary effort since they will not be rewarded for holding such qualification nor will they be penalised, such as; not getting promoted by not taking the qualifying exam.

(a) PAM Design Process

According to PAM's website (Architectural Services section), the normal process for designing building is divided into five stages: (1) Inception and Feasibility, (2) Outline Proposals and Sketch Design of Schematics, (3) Design Development and Production Information, (4) Tender Documentation and Tender Action, and (5) Project Planning, Operations on Site Completion (PAM, 2005).

(b) JKR Architects Design Process

When new architects started to work in JKR, as an officer in a government office, they will be given a document: Manual for Work Procedure (*Manual Prosedur Kerja*) where it will serve as an SOP for the architects regarding their function, objective, procedures and responsibilities to get the work done in an organise manner for each activities in their line of duty (Government of Malaysia, 1991).

In this Manual for Work Procedure includes information such as; organisation background, objective, organisation chart, main function, activities for each function, work process for each activity, workflow chart, list of responsibilities and relationship between other officers, rules for administration for each activities, work process, workflow chart, checklist and so on.

In addition, JKR architects are to support general design guideline as specified in the JKR SPK MS ISO 9001 (Table 1.2) to make sure that they performed their work according to the standard procedure. However, the outlined SOP in the documents is meant only for generic process and neither these documents has offered details for design workflow utilising IT or digital design tool within the architectural practice. In a conversation with Samilah Mahsuri (personal correspondence) – one of the JKR architects involved in the formulation of JKR SPK architectural design process in the late 90s – mentioned that the process is derived from scratch and by collecting personal experiences from mostly senior architects in JKR.

1.2.3 JKR SPK MS ISO 9001:2008

In June 1997, JKR started compiling Work Procedure and Quality Document for MS ISO 9000:1994 with Design Procedure (JKR.PK(O).02) as one of the Quality Procedures in an effort to standardise design output and practices in JKR. JKR has been certified with MS ISO 9000:1994 compliance in June 2000 (Jabatan Kerja Raya Malaysia, 2008). JKR Work Procedure has evolved and finally on 30th June 2009 it is known as SPK JKR MS ISO 9001: 2008. SPK is a system and work process to implement and manage JKR projects based on Quality Management System MS ISO 9001.

JKR's SPK describes activities involved in the design process from appraising the client's requirements through to submitting tender drawings and documents. It divides the design process into three phases i) Conceptual Design Phase, ii) Early Design Phase and iii) Detail Design Phase. In general, phases i) and ii) are focused on project feasibility, responsibility and design while stage iii) is mainly concerned with tender process. The critical activities which can be extracted from the three phases are shown in the following Table 1.1;

Table 1.1. The Three Phases of Design and Activities in the JKR's SPK

i) Conceptual/Initial Design Phase (with technical information)	ii) Early Design Phase (when conceptual design has been agreed by client)	iii) Detail Design Phase
formalities - appointments of HOPT, HODTs (players/actors)	determined inter & intra-departmental relationship	interaction between disciplines – room data requirements
project information - project brief, ceiling cost, client's brief	prepare Early Design (architectural)	prepare detail drawings
prepare and verify Design Plan (D-Plan)	prepare Early Design drawings (architectural, civil and structural, M&E)	synchronise detail drawings by other disciplines
site visit	prepare Preliminary Detail Abstracts (PDA)	surrender tender drawings to QS's HODT
desk study, prepare Conceptual Design and estimated project cost	approvals from Economic Planning Unit (EPU) and client to approve design by signing the 1:100 scale drawings & Schedule of Accommodation etc.	tender process -As Tendered Detail Abstracts (ATDA), print tender drawings and prepare tender documents
client to verify brief, conceptual design and cost estimates	Plan Approval from Local Authority	M&E detail design and bill of quantities for M&E subcontractor

JKR SPK MS ISO 9001 is a quality procedure to standardise design output and practices in JKR (Table 1.2). It started as a Work Procedure and Quality Document MS ISO 9000:1994, and finally on 30th June 2009 it is known as SPK JKR MS ISO 9001: 2008. JKR's SPK describes activities involved in the design process from appraising the client's requirements through to submitting tender drawings and documents.

Table 1.2. JKR Architects' Conceptual Design Process from JKR SPK MS ISO 9001

2.1 Project Brief

2.1.1 JKR DG received client's project brief
RO — JKR DG/ JKR A-DG, Client

2.1.2 Appointment of HOPT
HOPT — HODT

2.1.3 Identify project team and appoint HODT with approval from RO and open project file. HODT appoint HODT architect as lead HODT
HOPT — RO/ HODT

2.1.4 Distribute and check client's project brief
HOPT — HODT

2.1.5 Register project with SKALA
HOPT

2.2 Analyse and check project brief

2.2.1 Analyse client's project brief:
Detail scope of work
Resources available
Project site
Estimated Cost/ ceiling
Economic Planning Unit (EPU) approval etc.
HOPT — RO

2.2.2 Check estimated time, budget and prepare a report to include:
Client's need
Preliminary project implementation schedule
Cost estimate
Human resources
Technical resources
Related forms
HOPT — HODT

2.2.3 Report to be forwarded to RO to determine the method of implementation
HOPT — HODT

2.3 Determine Method of Implementation

2.3.1 Discuss with RO regarding all project aspects
HOPT — RO

2.3.2 Approval from JKR DG/ JKR A-DG on method of implementation, either:
Conventional – inhouse
Conventional - consultant
Design & Built – tender
Design & Build – direct negotiation
RO — HOPT

2.3.3 Notify client about the above decision and appoint Town Planner consultant to get Development Order from local council (if required)
HOPT — Client

2.3.4 Apply budget for preliminary works (if required)
HOPT — Client

2.4 Carry out Survey Works & Pre-com Plan

2.4.1 Prepare preliminary cost for Survey Works and Pre-com plan (if required)
HOPT — HODT

2.4.2 CKJG to carry out Survey Works
HOPT — HODT (Geotechnical)

2.5 Propose Conceptual Design

2.5.1 Brief all HODTs about scope of works, ceiling cost and implementation order
HOPT — HODT

2.5.2 Perform desk study for :
Project brief & project cost & location plan
Land Survey Works plan
Technical orders & Standards/ specification
Regulatory/ Rules/ local council & department orders
Infrastructure and utilities available
HOPT — HODT

2.5.3 Site visit
HOPT — HODT

2.5.4 Prepare input for conceptual design
HOPT — HODT

2.5.5 Meet all HODTs for coordinated conceptual design
HOPT — HODT

2.5.6 Conceptual design consideration:
Conventional design construction
IBS,MC system, EE &
Environment friendly building
HOPT — HODT

1.2.4 Role of JKR's Architects in JKR's SPK

Traditionally, architects acted as design leaders in a project team. Other disciplines such as civil and structural engineers, mechanical and electrical (M&E) engineers and quantity surveyors (QS) will proceed with what an architect produced – a design concept in the form of a drawing.

According to Table 1.2, the architect as the leader of Head of Design Team (HODT) will chair meetings between other professionals during all the design stages until tender stage where the working drawings will then be given to a quantity surveyor (QS) to prepare documents for tender. The HODT architect is not necessarily the project architect. He or she has an architectural team and his/ her role is to oversee the project up until tender stage. Once the project has been tendered, a district engineer will take over as representative of Superintending Officer (SO) during the construction of the building until handover.

The Schematic Design Phase (SDP) in this study is where the identified activity is to prepare Conceptual Design where the Input by HODT Architect is to analyse the Site and Zoning Plan. The expected Output is Conceptual Design for: (i) Zoning and Architectural Massing, (ii) Architectural Images and (iii) Gross Floor Area.

In this task, the architect is expected to get input from the civil, structural road and geotechnical engineers regarding the site analysis. While the electrical engineer should give information regarding the electrical and telecommunication loads for the site and the mechanical engineer will give information regarding the water pressure. The environment and energy branch will advise architects on the Environmental

Impact Assessment (EIA) for the project. In the expected output, the electrical and mechanical engineers should be able to provide the architect with M&E conceptual design regarding the (i) the M&E space requirements, (ii) the M&E estimated load and (iii) M&E Preliminary Detail Abstracts.

1.2.5 Energy Standards

Energy standard is such a dry and uninteresting subject that most professionals avoid from discussing it let alone practising it. Furthermore, compliance towards energy standards is too complex to be understood (USDOE, 2008) and for many people, the word "regulation" is related to telling individuals and businesses detailed rules of what they can and cannot do (ABRB, 2007).

Although the ultimate objective of energy efficient design in Malaysia is to comply with building energy standard requirement such as MS 1525: "Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-Residential Building" or Malaysia Green Building Index (GBI), nonetheless, the scope of this thesis is not to discuss energy standards but rather **to achieve the energy requirements during SDP in a much practical way through utilisation of IT design tool that will be a better justification for practising sustainable design as a voluntary practice rather than just compliance towards standards alone.**

1.2.6 Meeting Malaysian Government's Objectives

a) RMK-9 Projects for Residential Quarters

In Malaysia Plan 9 (RMK 9), the Malaysian Government has pledge to provide residential quarters for government employees to promote living in a conducive environment which is closer to where they work and help solve housing problems for more than one million of its employees. These residential quarters will be provided according to the officer's grade and position.

Referring to EPU's circular (EPU, 2005) an A-Class and B-Class quarters will be reserved for senior executives (JUSA) and ministerial post, while a C-Class is for Grade 45 and above. For professionals, Grade 44 and below a D-Class quarters. For the supporting staffs, E-Class, F-Class, G-Class and H-Class will be provided accordingly (Table 1.3). There is a huge demand for E-Class, F-Class and G-Class quarters since they represented the most number of staffs in the police force, fire fighters and government technicians. Since early 2000, Jabatan Kerja Raya (JKR) has held several design competitions amongst its architects to design buildings such as quarters and schools that optimised on sustainability such as Industrialised Building System (IBS) and energy efficiency (EE).

Table 1.3. Type of Residential Quarters for Government Employee

Class	Area (m^2)	Grade
A	415	JUSA
B	345	JUSA
C	265	45 –54
D	200	41 - 44
E	140	1 - 40
F	120	1 - 40
G	110	1 - 40
H	93	1 - 40

Source from (EPU, 2005) & Public Services Department Service Circular no. 4, 2002.

Jalan Dutamas Quarters Design Problems

In the year 2002, about 800 units of residential quarters were built in two different phases at Jalan Dutamas, Kuala Lumpur. The design of the quarters has not taken serious consideration to sustainable measures. It was found that some of the units were very dark as a result of poor planning and configurations. Consequently, some of the occupants kept the lights on even during broad daylight. On the other hand, some units have windows that are facing direct sunlight without protection from heat and glare, thus, in order to keep comfortable, the occupants kept the air-conditioning on and curtain drawn most of the times.

The Expert and Civil Engineering Branch (*Cawangan Pakar dan Kejuruteraan Awam*) of JKR has presented a report on 'Energy Efficiency Performance & Comfort Level Study for JKR's Quarters for a few units of the Jalan Dutamas quarters in the year 2007. The study has recommended change of material, better configuration and protected windows. These design improvements were recommended to be solved early during the design phase for the residential units to achieve maximum thermal comfort and energy efficiency.

b) Ministry of Works Key Performance Indicator (KPI)

In the Ministry of Works Strategic Plan KKR 2011 – 2012 (KKR, 2012), there are 6 Key Thrusts with 60 Key Performance Indicators (KPI). In Key Strategic Thrust 3, it includes KPI 12.2 which is "to expand the energy efficiency concept in government buildings". JKR as one of the agencies under Ministry of Works is going to implement the KPI and so far, 11 building projects in JKR have been selected for the Minister's KPI and to meet energy index and EE objectives.

In summation, although Malaysian Government is very supportive of energy conservation efforts, very few public buildings have been designed with EE strategies and objectives. Part of the responsibility is shouldered by the JKR architect who is among the first person to develop the design concept of public buildings. It was found from the interviews that JKR architects' design decision regarding EE buildings (if any) mostly used the rule of the thumb and best practices and did not consider BES as their sustainable design decision tool. There are many problems and barriers that influence the JKR architects' inability to employ BES as a sustainable design decision tool.

1.3 Problem Statement

A complex computational quantitative calculation is involved to predict the energy performance of a building; therefore, an ideal practise is to adopt Building Energy Simulation (BES) as a prediction tool for architects to make sustainable design decisions during Schematic Design Phase (SDP). However, its application is still not prevalent among architects in Malaysia especially for Jabatan Kerja Raya (Public Works Department) architects. An acceptance of BES in the JKR architects' design practice will lead to the improvement of many of the government's buildings energy performance and significant measurable impacts towards the Malaysian Government energy savings policy.

There are many reasons for JKR architects for not adopting BES. While energy standards and policies deal with key planning, there is no guideline to those designing for energy performance buildings. At present, there are two energy measurements to be met in Malaysian Standards MS 1525: prescriptive based and performance based. However, both compliance measurements are too complex to be understood and not suitable to be implemented during SDP when most information about data input of a building is not available. What the JKR architects need is a **simple energy objective and guideline that is flexible enough to be used with limited knowledge in the environmental design, but can be convincing with measurable outputs.** The study put two objectives to be met during SDP. These were represented using Action Workflow Theory which consists of flexible loops with measurable energy performance in the form of 1) time: 80% of 8570 hours of indoor temperature within 24.5°C – 28°C comfortable range; and 2) MS 1525 lux indices for rooms to utilise daylight.

1.3.1 Research Questions

The main research question is:

RQ. Why JKR architects do not use BES as a sustainable design decision tool during Schematic Design Phase (SDP)?

To answer the main question, there is a need to subdivide the question into sub-questions. The other sub-questions are:

Sub RQ1: What are the challenges/barriers faced by JKR architects when they wanted to use BES during SDP?

Sub RQ2: What are the necessary adjustments to be made to the JKR design process workflow to encourage JKR architects to use BES?

1.3.2 Research Objectives

The main research objective is concerned with integrating and transforming JKR architects existing work practices and procedure that can break down the barriers and increase the appreciation and influence JKR architects to favour using BES as a sustainable design decision tool during SDP thus making BES a common practice in JKR architects' workflow.

Table 1.4 shows the research Eagle Table which is a summary of Research Questions and Research Objectives.

Table 1.4. Eagle Table (Level 1) Adapted from Ibrahim (2008)

Main Research Question:

How to Integrate BES Procedure in JKR Architects Design Practices during SDP?

Description of RQ 1 (BES) Construct

Research Question Construct	Description of Research Question Construct	Description of Sub-Research Question	Description of Research Objective
What 1	BES barriers	What are BES barriers faced by JKR architects?	To determine the BES barriers faced by JKR architects

Description of RQ 2 (JKR Design) Construct

Research Question Construct	Description of Research Question Construct	Description of Sub-Research Question	Description of Research Objective
What 2	JKR Architects Design Practices	What are the existing JKR architects design practices?	To identify JKR architects design practices

Description of RQ 3 (Workflow) Construct

Research Question Construct	Description of Research Question Construct	Description of Sub-Research Question	Description of Research Objective
How	Integrated workflow	How to integrate BES in the JKR architects design practices?	To develop a flexible workflow that integrates BES into JKR architects design practices during SDP

BES : Building Energy Simulation
JKR : Jabatan Kerja Raya (Public Works Department)
SDP : Schematic Design Process

Since performance based design involves explicit definition of performance objective for building behaviour, there must be a need for building design process workflow to be developed to find an appropriate balance between theory and practice and to support good sustainable design practices in the early stages of a design phase.

It is important to emphasise that the proposed building design workflow process is a sub-process and is an extension of the JKR's SPK and not intended to replace the existing document; rather its role is to support the incorporation of guidelines into the architect's design work stages outlined by the JKR's SPK. The roles of the design workflow are; i) to provide practical guidance on when and how to use BES, ii) to achieve/exceed building performance requirements while iii) to support strategic design decision during the building design process.

1.3.3 Research Limitations

The thesis is limited to demonstrating a proof-of-concept model that the need for a proper design workflow process is a cause for accepting Building Energy Simulation (BES) as building performance evaluation by architects.

The employment of BES will be considered for architects that have very limited knowledge of environmental science and will be done during the Schematic Design Phase (SDP). It is also proposed that at this early phase, the building should be evaluated using passive design strategies. This is due to the fact that most information about the M&E system of the building is only available during advance stage of building design.

1.3.4 Significance of the Research

The significance of this research is that it tackles some of the unsolved problems in the architectural design process where there is a complex phenomenon in a design process that involves an architect's experience, knowledge and background (qualitative/ artistic) and the effects of an intervention – building performance evaluation, (quantitative/ technical). Based on business process point of view (achieving customer's satisfaction) this research combines a workflow theory (ActionWorkflow) with existing design process (JKR SPK) and process that includes IT application (Sulaiman, 2010) for deploying tasks during SDP, which can be considered as a paradigm change.

While key planning for energy standards and policies exists at national level, there is no clear guideline for JKR architects to use to perform energy performance evaluation during SDP. This study has developed a flexible workflow that integrates JKR architects design practices and BES procedure in a single activity loop.

1.4 Gaps in Research

Although the JKR's SPK was drafted in 2008, there is no indication of employing IT tools during design process. It is presumed that the JKR's SPK is just another conventional precedent-based method that benefit from tacit knowledge and lessons learned from professional practise. It is also found that although the JKR's SPK included many detail collaborative practices to meet scheduling requirement, architects cannot rely on the JKR's SPK to solve building design problems. Design process and guideline in JKR is still lacking in providing a strategic design decision utilising IT tool especially where building energy performance is concerned. Traditional JKR architects design practices have been inadequate to face the new environmental challenges. Furthermore, rule of thumb can no longer always work since building performance includes arriving to a measurement.

The challenge is for the architects to meet sustainability concerns but they lack the tacit understanding necessary to guide energy efficiency decision making in design without additional resources (Hui, 1996). In a strategic design, there should be a considerable impact to the process.

1.5 Point of Departure

This research will enable the study of new area and theory building in the architectural design practices which described and explained a complex phenomenon in a design process that involves architect's experience, knowledge and background (qualitative/artistic) and the effects of an intervention – building performance evaluation, (quantitative/technical). This complexity of 'marrying' a qualitative and quantitative design process during Schematic Design Phase (SDP) represented an effort to apply building performance evaluation in a government design office in Malaysia.

After forty years of its existence, the most challenging problem in BES application is to understand why architects are not using BES and how to get architects to effectively interact with BES.

As far as designing building during the Schematic Design Phase (SDP) is concerned, architects usually rely on their intuition, background and experience (Lawson, 1997), while Suwa and Trevsky (1996) translated this design ability to cognitive behaviours. There will be a never ending issue of quantifying how an architect designs during SDP which is more of qualitative in nature.

Developed from results of BES barriers, the three most influential constructs for effective employment of BES is shown in Table 1.5. As presented in Table 1.5, the first BES issue is about making strategic design decisions with passive design considerations during Schematic Design Phase (SDP). During this phase, one of the major BES barriers identified is Functional Performance Requirement. In this Functional Performance Requirement one of the sub-barriers involved is the management of data which is not flexible enough for architects. The architects were supposed to feed detail input parameters (for the active cooling calculation and requirement of a building) into BES software which may not be available during early design.

Table 1.5. The Three Most Influential Constructs for Effective Employment of BES

Constructs	Architects' Requirements
(1) strategic design decisions	Need for BES software that has functions to support design decision
	Need of function to generate design alternatives and informed choices between different BES design options
	needs of a method on how IT tool implementation can support policy and strategic decision making towards BES
	Need for a new design process that utilise innovative use of computer as a tool that support architects to make strategic design decision during BES
(2) design workflow process	Need of guidance to use BES during conceptual design phase
	Need of a supportive BES network
	Need an organisational framework
	Need of qualitative and overall design direction

	Need in-house procedures
(3) building performance evaluation	Need an application during conceptual design phase
	Need of building and system optimisation

Nonetheless, the architects were supposed to make crucial building design decision such as orientation, facade design and room layout and configurations. Therefore, to avoid this time consuming step, it is proposed that during SDP design consideration should only be given to low level building detail (not technically specific), generic recommendation (default materials) and passive design strategies (best orientation, sunshading) where the input for active cooling equipment and schedule of occupancy is more or less not required.

The second issue is concerning design workflow process which will guide architects through building design process from inception (receiving of project brief) to end of SDP (presenting design proposal to client). This issue has also been mentioned as one of the barriers where there is no specific workflow for the architects to use while employing BES. Traditional way of doing design can no longer support the architects. With issues like the designing of sustainable and green building: first wave architecture –Marsh (2005) to Building Information Modelling (BIM) a second wave architecture - Seletsky (2005). The ability of BIM process to hold data and seamlessly transfer information to other non-BIM computer programs (but Object Oriented Language and Programming) has reduced the issue of integration, interoperability and compatibility between software (Attia, et. al., 2009).

The liiterature findings have also suggested that the inclusion of an IT supported design process in an existing design process such as RIBA (Royal Institute of British Architects), has enhanced the architects' workflow (Morbitzer, 2003; Loh et. al., 2010; Hopfe, 2009).

Architects need a new work process that take into consideration sustainable measures with the help of computer as a tool which in turn will address the third issue - building performance evaluation.

A theory and a set of research questions to be answered have been stated in the study proposition to hold the structure of the research together. Theoretical proposition is the most preferred strategy to guide the study, therefore; in order to limit the research scope, draw attention to, identify the relevant information and suggest possible link between phenomena of design workflow process, strategic design decisions and building performance evaluation, with these three keywords, the researcher put forth these categories as a basis for the research proposition:

> *Building performance evaluation could be successfully supported in the design workflow process if required to be employed by JKR architects as strategic design decision in the form of passive design solution and potential variation during Schematic Design Phase (Figure. 1.2).*

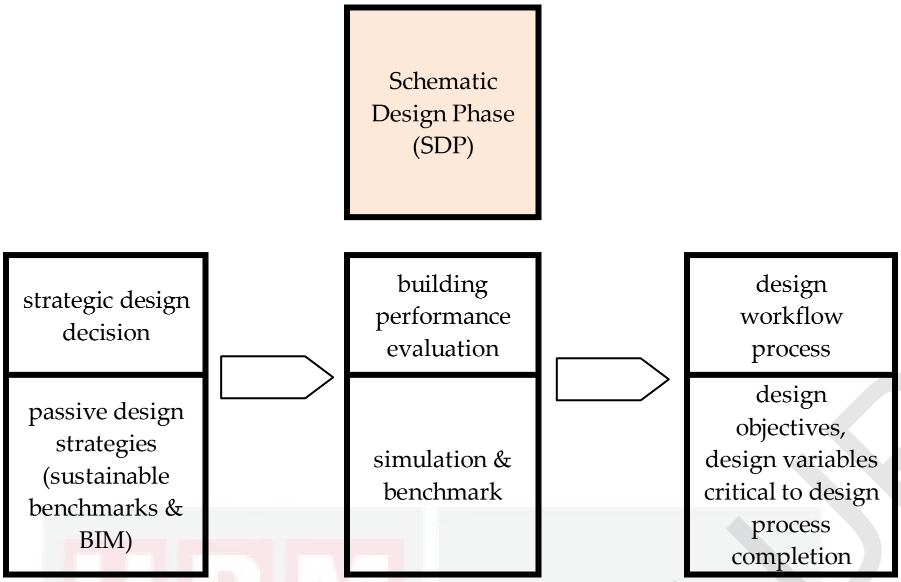

Figure 1.2. The Integration of Design Workflow Process in The Passive Design Strategies during Schematic Design Phase

1.6 Thesis Organisation

Chapter 2: Literature Review

Chapter 2 has reviewed many of the important issues related to the background research developments such as energy-related sustainable development policies, development of digital technology and BES to emphasize their early roles in promoting BES. This review has been continued further to show the barriers of employing BES and the variables were subdivided into a table of categories and subcategories of barriers as shown in Figure 1.3.

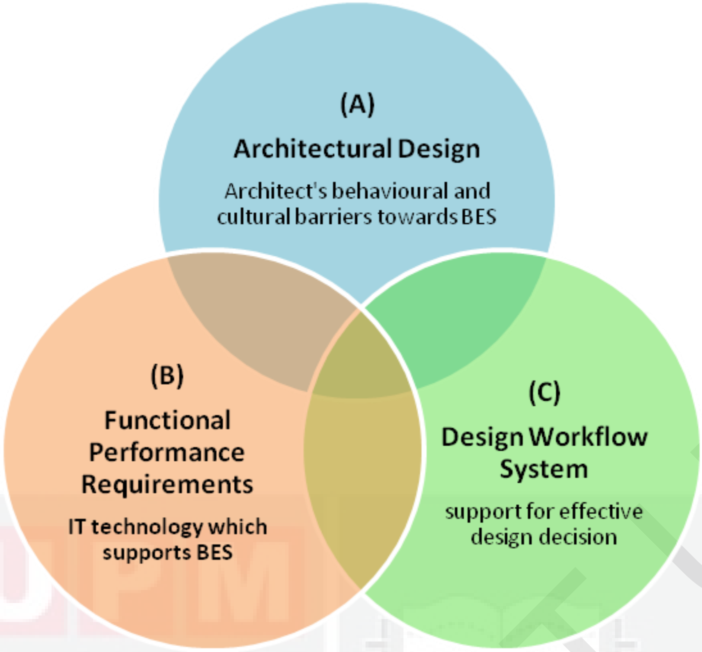

Figure 1.3. BES Barriers Represented by Categories

There are many reasons, factors, barriers and challenges that influence the employment of BES by architects. A literature review section in Chapter 2 has been dedicated to exploring these issues in details. It is also necessary to understand the architects' behaviour regarding computer in design since computer as a tool has become important for improving the performance of building (Augenbroe, 2002). The next section is an introduction of the JKR architects as selected subjects of the study.

The identification of the JKR architects' design process has become very important towards shedding some light to encourage the employment of BES during architectural design. Thus, to identify the design process is through an analysis of the

JKR architects' design practices where literature, documents and interview scripts concerned with the JKR architects' design process are presented (Figure 1.4).

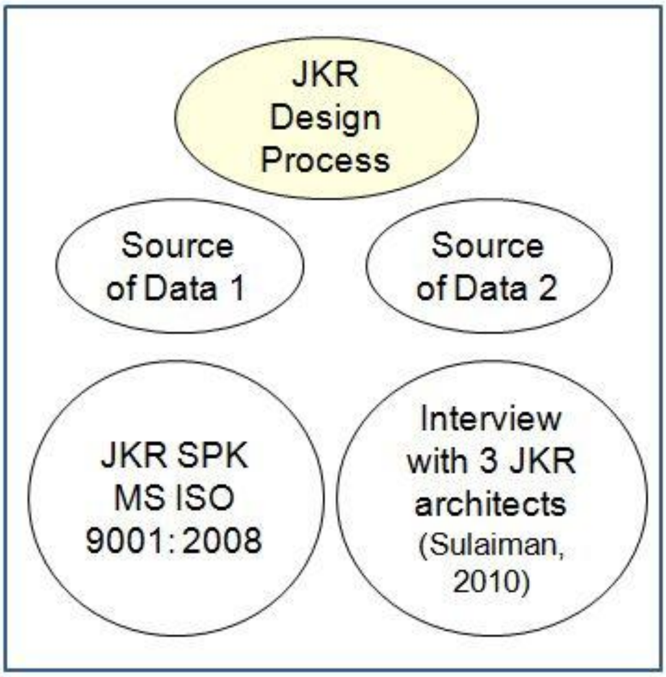

Figure 1.4. Diagram Showing JKR Design Process Data Sources

These data were analysed as representation of (a) how architects approach design problems in an office environment, (b) what systems and tools were used (technology), (c) what are their needs and requirements, (d) who are the person(s) involved and (e) tasks and subtasks that were performed. Consequently, based on these aspects, an output in the form of a workflow design process is proposed. The data collected for analyses is primarily sourced from JKR SPK MS ISO 9001: 2008 and interview scripts from three JKR architects extracted from Sulaiman (2010) Masters Thesis.

i) Interview

To discover why JKR architects are not using BES, the research used variables from Figure 1.3 to formulate questionnaires for an interview session with the JKR architects. This approach is to study the JKR architects' behaviour towards the implementation of BES. The methodology to discover the variable of the barriers towards employing BES by the JKR architects is divided into two parts. The first part consisted of a literature review on BES barriers, necessary to understand the 'shortcomings' of the tool to the architects in general. These barriers are then organised in Table 2.20 with a set of categories and subcategories of the BES barriers. The second part is based on interviews and email surveys targeted at the JKR architects. There were 14 architects involved in the interview - selected mainly because of their involvement in either energy efficiency related projects, have gone to a BES software training, are knowledgeable about computer assisted software for architects, have done research for sustainable building design or have experience monitoring D&B projects that has EE Need Statement (that includes measurement of building energy performance).

ii) Simulation

After the potential barriers towards implementing BES were identified, the flow of information became more complex with the increasing level of details. This led to another methodology needed in the search of results – simulation model. The steps taken by the respondents were analysed and simulation was introduced in the design process which validate the BES parameters and the simulation procedure. This section has enabled data searching for the appropriate BES parameters and simulation procedure. This method of simulation has helped to identify the tasks involved and the design process breakdowns to enhance the application of BES in a proposed workflow design process.

Chapter 4: Results and Discussions

All of the results and analyses obtained from Chapter 2, and 3 are discussed in this chapter. The design process breakdowns in Chapter 4 has tracked complex systems in a JKR design process which may consider certain criterion such as identifying the actors and the roles or functions they perform in the design process ('actors' could be people or institutions, and one actor may perform multiple functions); the actions, strategies or behaviours of the actors, and the forces driving those behaviours; and interactions (if any) among the actors.

The conception of exploring the JKR design process was an effort to integrate BES as a tool to quantify the passive design strategies in the Schematic Design Phase (SDP).

The output of the JKR design process analysis was to enable the identification of the representation of the design decisions, the tool and mechanism that have used the inputs and outputs in a very transparent, explicit knowledge form. After analysing the JKR design process from Sulaiman (2010), the researcher found three major flows of works performed by the Actor (architect) involving; design objective, structure and tool and output.

At the end of the Chapter 4, Sulaiman (2010) design process is then compared, adopted and adapted to an enhanced version of the 'JKR architects - BES' design process.

Chapter 5: Conclusion and Recommendation

This chapter has summarized the whole thesis and offer possible research regarding BES barriers and their integration and interaction with the JKR architects in the design process in the future.

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