A MULTI-CRITERIA GENERIC PROCESS MODEL FOR SELECTING FIRE PROTECTION SYSTEM

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ABSTRAK

Jurutera mekanikal telah berusaha merekabentuk dan memasang sistem perlindungan kebakaran untuk berbagai jenis bangunan. Sistem perlindungan kebakaran di dalam bangunan yang sedang beroperasi diperlukan bukan sahaja untuk memadamkan api, tetapi juga untuk menyelamatkan nyawa dan harta benda. Reka bentuk perlindungan kebakaran merupakan aspek kejuruteraan yang kompleks dimana ia memerlukan pertimbangan pendekatan bersepadu oleh jurutera yang berpengalaman. Disebabkan oleh kekurangan garis panduan dan pengetahuan, jurutera mekanikal kini berusaha untuk memilih sistem perlindungan yang paling sesuai berdasarkan pengalaman projek-projek yang lepas dan rujukan kod undang-undang. Satu model penilaian adalah diperlukan. dan perisian untuk membantu jurutera menilai kesan kebolehpercayaan, prestasi, kos dan kebolehsesuaian sistem perlindungan kebakaran, sebagai rujukan adalah penting. Sehubungan dengan ini, matlamat kajian ini adalah untuk membangunkan satu model proses generik bagi menilai kesesuaian sistem perlindungan kebakaran bagi bangunan dan memilih sistem yang paling sesuai. Model ini mengambil kira satu set kriteria setara yang mempengaruhi pemilihan sistem perlindungan kebakaran di dalam sesebuah bangunan. Ini akan dicapai melalui tiga objektif yang berkaitan: 1) mengenalpasti hubungan di antara pelbagai pembolehubah bagi sistem perlindungan kebakaran yang aktif; 2) membangunkan sistem pemilihan model perlindungan kebakaran; 3) menilai dan mengesahkan model tersebut. Pendapat dan pengalaman merupakan data yang dikumpul melalui kaedah temuduga dengan lima belas responden yang terdiri daripada perunding kebakaran, jurutera kebakaran, kontraktor pelindung kebakaran dan pembekal pelindung kebakaran. Data yang dikumpulkan telah diproses kepada data yang boleh diukur secara subjektif dengan menggunakan Proses Hierarki Analitik (AHP). Satu model proses generik dibangunkan menggunakan IDEF-0 yang menyediakan garis panduan pemilihan sistem perlindungan kebakaran bagi membantu perunding kebakaran, jurutera kebakaran, pembekal serta klien untuk memilih sistem perlindungan kebakaran yang sesuai.

ABSTRACT

Fire safety engineers have been trying their best to design and install fire protection systems in various buildings since the past decades. Fire protection is needed for every building in operation, not only for fire extinguishment, but also as a means for saving life and property. Fire protection design is a complex engineering aspect which needs an integrated approach consideration by engineers with enormous experience. Nowadays, due to the lack of proper guidelines and knowledge, fire engineers are trying their best to select the most suitable fire protection system by relying on their past experience, past projects and code references. In order to help designers in assessing the impact of reliability, performance, cost and adaptability of fire protection systems, assessment tools and software are essential. Hence, the aim of this research is to develop a generic process model to assess the suitability of fire protection systems for buildings and to select the most suitable system. The model takes into account a set of standard criteria that influences the implementation of fire protection system in a building. This is achieved through three interrelated objectives: 1) to identify the relationship between various variables for active fire protection system; 2) to develop a fire protection system selection model; 3) to evaluate and validate the generic process model. Opinions and experiences are the nature of data collected by interviews with fifteen fire expert respondents consisting of fire consultants, fire engineers, fire contractors and fire suppliers based on fire protection system selection for a building. Data collected were converted into subjective ranking measureable data using Analytical Hierarchy Process (AHP). A generic process model was developed using IDEF-0 that provides fire protection system selection guidelines that will help fire contractors, consultants, suppliers, engineers and clients in selecting a suitable fire protection system.

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LIST OF SYMBOLS

NFPA	–	National Fire Protection Association
MEP	–	Mechanical, Electrical and Plumbing
AHP	–	Analytical Hierarchy Process
IBC	–	International Building Code
UBBL	–	Uniform Building By Law
CO^2	–	Carbon Dioxide
FEO	–	For Exposition Only
FP	–	Fire Protection
FIDO	–	Fire Incident Data Organisation
FiRECAM™	–	Fire Risk Evaluation and Cost Assessment Model
ISO	–	International Organisation for Standardisation
FIERA	–	Fire Evaluation and Risk Assessment
FPEtools	–	Fire Protection Engineering Tools
HVAC	–	Heat Ventilation Air Conditioning
CFAST	–	Fire Growth and Smoke Transport Modeling
HAZARD I	–	Fire Hazard Assessment Method
BS	–	British Standard
MS	–	Malaysian Standard
IDEFØ	–	Integration Definition for Function Modeling
CIC	–	Computer Integrated Construction
SWOT	–	Strengths, Weakness, Opportunities and Threats
MEP	–	Mechanical, Electrical and Plumbing
SADT	–	Structured Analysis and Design Technique
FCRC	–	Fire Code Reform Centre
FEO	–	For Exposition Only
PFD	–	Process Flow Description

OSTD	–	Object State Transition Description
ICOM	–	Input, Control, Output and Mechanism
IDEF	–	Integrated Definition
P.E	–	Professional Engineer

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CHAPTER 1

INTRODUCTION

1.1 Background of Studies

Research development and legislation on problems of fire and buildings have three main aims (Eric, 1972). First is to reduce or ideally to eliminate the risk of personal injury or death due to fire. The second aim is to reduce the total loss of buildings, plant and goods. The third aim is to protect the public at large, e.g. the community by ensuring that fire in a building is confined to that building, where possible. Understanding of these three main aims, the nature scope of fire loss problem is necessary to provide basis for reducing losses. Losses offer valuable lessons because they provide information that are needed to prevent or reduce the impact of similar losses in future (Schroll, 2002). Lessons learned from losses incurred in fire and prevent it in the first place before the fire break out and take away all of our valuables. With the three guidelines stated previously fire prevention should be initiated to serve the massive building and human with the right protection.

Investment in constructing a commercial building is around ten to fifty millions of ringgit for the sake in future it will get returns in term of profit (Morgan, 2009). With this huge amount of money spending on a building in term of duration, the building must be protected by business property insurance which secures the business from a minor interruption to a major financial loss. Owning a building, lease a workspace or work at home, insurance protect all business' physical assets either the interior as well as the whole entire physical of building. Unfortunately, buildings face their own enemy which is fire that cause damage or even destroy the entire of it. Results, fire protection system are the engineering method used by commercial property insurance companies which turn on for superior coverage and to serve and maintain building from fire strike disaster (Morgan, 2009).

Installation of fire protection is an important part of modern architecture to ensure that protection to the building and the occupants inside the building. Fire systems are effective in detecting, containing, and controlling as well as including extinguishing fire in early stage. Therefore, some little investment must be allocated in insurance to protect it against fire disaster where utilisation of fire protection system for a building will be the insurance to save lives, saving property and preserving business continuity.

Table 1.1 illustrates the small share of fires that account for major losses. Trend of the table shows ten years case where there is major fire loses three to fours years in sequence. Fire protection principles reflected in National Fire Protection Association's codes and standards are essential if we are to reduce the occurrence of large-loss fires and explosions in the United States. Proper guideline design with early maintenance factor consideration and method operation of fire protection systems including features can reduce the fire losses damage due to fire disaster.

Table 1.1: Fire Losses Property Damage in United States, 2000-2009.

Year	Number of Fires	Number of Fires Causing $10 Million or More in 2000 Dollars	Direct Property Damage (in Millions) As Reported	In 2000 Dollars
2000	31	31	$1,814	$1,814
2001*	19	15	$762	$702
2002	25	22	$562	$509
2003	21	17	$2,623	$2,417
2004	16	9	$337	$242
2005	16	6	$217	$101
2006	16	13	$380	$305
2007	45	33	$3,393	$2,709
2008	35	23	$2,372	$1,794
2009	24	17	$940	$693

* Excluding the 9/11/01 World Trade center Incident from the loss totals but not the fire incident totals.

Source: NFPA's Fire Incident Data Organisation (FIDO, 2010)

Deborah (2010) professional engineer from Society of Fire Protection Engineers insist that *"Fire protection engineers must be involved in all aspects of the fire design in order to ensure a reasonable degree of protection of human life from fire and the products combustion as well as to reduce the potential loss from fire i.e., real and personal property, information, organisational operations"*. Fire protection must be integrated into the preliminary conceptual design process and coordinated throughout construction period. Sometimes the fire protection design approach is different for new construction than for existing buildings, but the underlying design principles are the same.

Jane (2003) stated that effectively integrating fire protection requires deep familiarity to the construction, layout, and occupancy of the building and knowing the functions that the fire protection systems are expected to serve. Planning for fire protection inside or outside a building involves an integrated systems approach that enables the designer to analyse all of the building components as a total building fire safety system package. Jane (2003) also explained that design analysis not only concentrate on code compliance or meeting the minimum legal responsibilities for protecting a building; but on the same time building and fire systems are intended to protect against loss of life and limit fire impact on the community and necessarily protect the mission or assets, or solve problems brought upon by new projects with unique circumstances. Therefore, it is necessary to creatively and efficiently integrate code requirements with other fire safety measures as well as other design strategies to achieve a balanced design that will provide the desired levels of safety.

Fire protection systems may not be installed in all kind of buildings, but they stand ready to raise the alert, control, extinguish a fire in terms of protection to occupants and building.*"Fire protection systems are complicated and sophisticated and are different for just about every building. You need to look beyond a systems standpoint and examine as a whole, how all the components work together."* noted by Jeffrey (2008) from an organisation of fire protection and security consultants based in Chicago.

Fire protection systems are complicated and sophisticated which need advanced knowledge and understanding of these systems may offers advantages and alternative methods in protecting the content of a property because there are different types of fire protection systems available that use different detection techniques and suppression gas other than water that we have commonly used. New strait times (1998) writer said that some not only detect fire at early stage and give alarm to alert occupants for evacuation, but they also control, suppress and extinguish in a way to avoids additional damage to the surrounding area. While there is no standard fire protection design blueprint for any building, the systems found in any building typically include detection, alarm and notification and suppression basic component. All components of modern fire protection systems need to work together to effectively detect, contain, control and extinguish a fire in its early stages and to make survival for occupant during the fire. To achieve the beneficial symbiosis between these components, it's best to involve an experienced system designer, such as a fire protection engineer in the early planning and design stage (Lau, 1996).

Fire protection system cannot be taken for granted, so selection of fire protection system is not a one day task which can complete with simple step, but it consists of code references, experience of the system functional, criteria's require which need to be considered during the design stage. Complexity of selecting a suitable fire protection system which incorporating the consideration of design factors that are available, reliable and contributing in eliminating fire risk is important. However, fire engineers need a tool to consider and measure all criteria before deciding the best fire system for a building. Therefore there is a need of guideline tools which can work into the symbiosis of fire protection system which serves the best result for building and occupants itself.

1.2 Statement of problem

In current construction practice, incorporating fire protection system into a building by an architect and engineer is merely the "compliance of fire code and building code". However what is the purpose of our codes? Will the code provide adequate information in detailed or it is only a general guideline for us to refer? Normally, the first chapter of a code references reads "the purpose of this code is to establish the minimum requirements for the installation of fire protection system in different size and different height of building in order protect life and property from fire and to provide safety to firefighters and others that respond during emergency operations" (NFPA, 2002). Consideration of minimum requirement is inadequate to select the best fire protection system for a building itself.

We interpret few news from the News Strait Time on 25 July 1998 reported that an estimate of 200 staffs were seeking for help at the roof top of Menara Lion, Jalan Ampang during fire break in the middle floor of the building when the fire protection system was unable to function to extinguish the fire. Unfortunately, the fire spread and took over the lives and properties. Another case happened in John Sevier Retirement Center, Johnson City, Tenn was an eleven storey building caught in fire at the first floor causing 16 deaths due to the bad fire safety system design (Joseph, 1992). Therefore, we know that fire is a threat and enemy to a building which lead to installation of fire protection system to protect them against destroy and damage. Thus, it is important to choose a fire protection system that is incorporating the functionality of the system for a building.

The answer is still remaining in doubt when designing a fire protection system for building because there are myriads of alternative systems, factors, technology improvement and conflicting regulations. All these considerations must be taken into account not only comply to the building authority fire regulation and code but also to enhance the design needs, cost, life safety, hazardous area, aesthetic view, environment pollution and the most important is the fire protection system ability to extinguish fire in a safe duration of time (Jane, 2003). Although the entire factors are listed out, architects and engineers may not consider all the factors during designing a fire protection system.

Buildings are designed on the need of fulfillment to many needs. They must have adequate area, serving particular of functions and particular number of occupants. Besides, the structural, electrical and mechanical systems are designed to fulfill applicable requirement and code. Ahmed (2009) mentioned meeting fire protection goal required coordination integration into the design process throughout the construction process. This is because at anytime, any other discipline changes a design, the fire protection has to be checked. Design process starts from the conceptual design going up to preliminary design, detail design and construction stage includes handing over with inspection. On top of design team view, fire protection system must be effectively integrated within the early design stage, construction stage, layout, and occupancy of the building and knowing the functions that the fire protection systems are expected to serve by eliminating the hazards. Chapter-2 will discuss in more detailed on the building design process with illustration incorporating with fire safety requirement throughout the whole construction.

In market, there are too many active fire protection systems such as fire alarms, automatic sprinklers, gas suppression systems, fire extinguishers, hose reels and hydrant to be chosen by the designers, contractors and engineers. Selection on the effectiveness and efficiency of fire protection systems based on specific requirements is not an easy task. With updated technologies, fire protection evolving into a more advance system which gives extra protection and extinguishment towards fire. This makes selecting the best fire system with consideration of surrounding factors a little complicated and guidelines needed. Architects, engineers and contractors who lack of proper guidelines and knowledge are trying to select a fire protection system relying on their past experience on past projects and code practice references (Deborah, 2010). Hence, there are many disadvantages when designers are more heavily relied on experience from previous work and rules of thumbs. As such, by developing a detail guideline it will helps to generate more information for future references.

To select a suitable system and evaluate both advantages and disadvantages in the aspects of cost, quality, performance and reliability of each system, the fire experts need some decision. To help designers in building officials' assessment, the impact of reliability, performance, cost and adaptability of fire protection systems, assessment tools and software are essential. This is where the idea of research begins to find a tool consist of fire protection system concept model development with compilation of all criteria variables and factor circumstances which faced by the industry nowadays can be overcome. Knowledge and experience by fire expert alone are not enough to design a fire protection system (Andrew, 2003). Tools are vital to fire expert designers where enable them to investigate many alternative and scenario which will ultimately yield an optimum selection fire protection system. Therefore, we need a model to determine the type of fire protection system that is needed in a building by considering all criteria involved. Towards selection of fire protection system in commercial building this generic process model will show in flow diagram all the criteria needed for selection of fire protection system.

Many researchers has done on the fire protection regulation, fire protection smoke management, fire life safety, fire evacuation, reviewing of existing fire system, reviewing on how design being adapted by experts. Models like FiRECAM™, FRAMEworks (Richard, 1996), FIERA System, FPEtool (Deal, 1995), FASTLite (Portier et al, 1996), CFAST (Peacock et al, 1993), and HAZARD I (Bukowski et al, 1989) and CRISP2 (Fraser, 1994) concentrate only on fire hazard and risk assessment. However, by referring to the models created, there is no recommendation on how to select a fire system in conjunction to prevent or eliminate or extinguish fire during fire occurs. As a conclusion, there is a need to map out a generic process model based on consideration of criteria’s to find out what type of fire protection system suitable to be used in a building.

1.3 Aim and Objectives

The aim of this research is to develop a generic process model to select fire protection systems for commercial buildings. The model takes into account of standard criteria that influences the implementation of a fire protection system in a building. This will be achieved through interrelated general objectives which are:

1) To identify the interrelationship factors that influences the designer in selection of active fire protection system.
2) To develop a generic process framework to design and evaluate active fire protection system.
3) To evaluate and validate the proposed generic process framework.

1.4 Scope of work

The scope of work for this research is focus on developing a generic process model that is used as a tool for selection of active fire protection systems in commercial building which consist of hotel building between five to twenty storeys. Five storey and above building consist of more complicated active fire protection system required by regulation (UBBL, 2005). Active fire protection system listed in regulation will be discussed further in Chapter-2. Resources are gathered from fire contractor experts, fire system designers and fire professional engineers inside fire protection industry in Johor Bahru. Detail particular of fire expert are listed in Chapter-4. Once the generic model is developed, it is evaluated by fire expert for upgrading and practical purpose.

1.5 The Importance of Research

Importance of this research is an improvement development of a generic process model to select and install a comprehensive fire protection system in every building so that the cost of loss and damage due to fire can be kept to a minimum. Commercial buildings are often accommodated by a vast number of occupants with many sophisticated technologies automation, aesthetic interior and fit-outs. There is a significant need to adopt a suitable, reliable and effective fire protection system which helps in saving lives and properties damage. Hence, this research is to develop a generic process model level that can be used for evaluating and selecting an efficient and effective fire protection system for a commercial building.

1.6 Organisation of Research Chapter

This section briefly state about the organisation of the whole research dissertation and the content of each chapter that can be divided into seven (7) chapters as follows:

Chapter 2: Prescriptive of Fire Protection System Design

This chapter consists of fire protection system design, fire code practices and standard references, fire protection system assessment tools description, description of active fire protection system and design principal criteria selection in fire protection system.

Chapter 3: Research Methodology

This chapter discuss about the research methodology overview approach, listed out data required for the research, source of data for this dissertation, methodology tools for fire protection system selection, data collection integrated with analytical hierarchy process rating technique, data segregation and compilation inside AHP, developing a generic process model and evaluation and validation of the model.

Chapter 4: Analytical Hierarchy Process (AHP) Data Analysis

This chapter starts from introduction of analytical hierarchy process, assembly of data before AHP analysis, organizing and analysis data using AHP rating score and the rating score will be converted into development of a generic process model using IDEFØ. Idea of concept modeling development stated briefly.

Chapter 5: IDEFØ Model and Modeling Technique

This chapter looks into the modeling concept development, modeling development and modeling layer in Computer Integrated Construction (CIC). IDEFØ funtion model which consist of IDEFØ Modelling, IDEFØ Concepts, IDEFØ Syntax and Cell Modeling Graphic Representation will be used to develop this dissertation generic process model. Strengths and weaknesses of IDEFØ discussed in this chapter.

Chapter 6: Generic Process Model Performance Validation

This chapter discusses about the developed generic process model validated by the professional engineers in consultancy firm including recommendation given.

Chapter 7: Conclusion and Recommendation

These chapters conclude the whole research outcome and future recommendation for researcher references.

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