EXPERT SYSTEM FOR REAL TIME OPTIMIZATION OF SOLID WASTE MANAGEMENT IN MALAYSIA

By

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Abstract of thesis presented to Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Doctor of Philosophy

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As in every developing nation, increasing revenues in urban areas attract masses of population to move to these areas which indirectly increase the rate of solid waste generated. Malaysia being one the developing countries in South East Asia also faces the same problem due to the lack of comprehensive data and public awareness towards this issue. Hence a novel expert system using combination of Linear Model as the engine and the IF-THEN rule concepts was created to predict rate of solid waste generated so that users could be given advices and appropriate steps to be taken regarding integrated solid waste management. The system, named OpSWaste was designed based on information from journals and /or interview sessions conducted with known experts within the field. Users of this system only have to separate their solid waste materials into different categories according to the system requirement. From the processed data, users could obtain amount of solid waste produced in each categories and appropriate actions could be taken to optimize the waste materials. Samples of solid waste were collected from Balakong, Selangor and they were used to test and validate the operation and function of this system. From the sampling done, it was found that the actual waste composition generated for a month in residential, shopping and industrial area in Balakong was approximately 5,344.00 kg, 9067.90 kg,864.95 kg, respectively. Based on this data, OpSWaste system processed and produced an output forecasting that within 12 months the amount of solid waste generated at residential, shopping and industrial areas would

be 8,555.92 kg, 14,516.56 kg and 1,384.81 kg respectively. Moreover, this system could be applied by a particular user in determining preliminary module for recycling process and could controlled and optimized the amount of generated waste composition that were usually sent to the landfills or other waste treatment facilities. OpSWaste system also integrates Life Cycle Assessment (LCA) which involves evaluation process of inputs and outputs of material, energy and waste flows associated with a recycling product over its entire life cycle. Overall, the output of OpSWaste could predict waste generation growth, revenue from recycling and give out recycling process options in real time basis. OpSWaste system could be applied together with other systems such as URUS SISA, being similar but only focused on the selection of treatment technology based on Analytical Hierarchy Process (AHP) that could be divided into three hierarchy level; objective, criteria and alternatives. In conclusion, the integration of OpSWaste could help to make prompt decision based solely on accurate amount of solid waste composition taken from collectors' to enable better decision making among policies makers, stakeholders and relevant agencies in solving the problem of solid waste management in Malaysia.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

SISTEM PINTAR UNTUK PENGOPTIMUMAN MASA NYATA PENGURUSAN SISA PEPEJAL DI MALAYSIA

Oleh

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Secara asasnya dalam setiap negara yang sedang membangun dengan peningkatan sumber ekonomi yang baik, akan menyebabkan berlakunya lambakan penduduk dikawasan Bandar dan secara tidak langsung akan menjadi punca kepada kenaikan penghasilan sisa pepejal dikawasan tersebut. Malaysia merupakan salah sebuah negara yang terkenal di Asia Tenggara dan sudah tentunya akan mengalami masalah ini berikutan ketiadaan data yang komprehensif dan kurangnya kefahaman berkenaan masalah tersebut oleh masyarakat. Oleh itu satu kajian berkenaan sistem pakar yang menggunakan Model Linear sebagai enjin dan teknik perwakilan menggunakan konsep" JIKA" dan "TINDAKAN" telah direka khas bagi membuat ramalan keatas kadar penghasilan sisa pepejal dan membantu pengguna mendapatkan nasihat dengan menggunakan konsep berasaskan pengetahuan berkenaan pengurusan sisa pepejal secara bersepadu. Sistem yang dikenali sebagai OpSWaste telah direka bentuk berdasarkan maklumat yang diperolehi daripada pelbagai sumber seperti jurnal, buku dan sesi temuduga yang dijalankan bersama pakar pakar pengurusan sisa pepejal dan yang berkaitan dengan bidang ini. Sementara itu pengguna hanya perlu menggunakan konsep mengasingkan sisa pepejal tersebut mengikut kategori yang disediakan oleh sistem bagi mengetahui jumlah sisa dan dapat mengoptimumkan penghasilan sisa pepejal tersebut. Sampel jumlah sisa pepejal telah diambil dari kawasan kajian di Balakong Selangor untuk membuat pengesahan terhadap fungsi dan operasi sistem OpSWaste, sebagai

contoh jumlah sebenar komposisi sisa yang dijana selama sebulan dengan menggunakan sistem OpSWaste di kawasan kediaman, pasar raya dan kawasan perindustrian adalah masing masing bernilai kira kira 5,344 kg, 9067,90 kg, 864,95 kg. Setelah itu, sistem OpSWaste meramalkan kadar penghasilan komposisi sisa pepejal untuk jangka masa selama 12 bulan dikawasan perumahan sebanyak 8,555.92 kg dan kawasan pasar raya sebanyak 14,516.56 kg juga diikuti oleh kawasan industri sebanyak 1,384.81 kg dikawasan yang sama. Secara asasnya, data sisa pepejal yang diperoleh sistem OpSWaste boleh membantu dalam menentukan modul rekabentuk awal dalam proses kitar semula dan dapat mengawal kuantiti sisa pepejal secara optimum daripada terus dihantar dan dilupuskan di tapak sisa pepejal atau di tapak kemudahan rawatan teknologi sisa pepejal yang lain. Sistem OpSWaste juga mengintegrasikan kaedah Penilaian Kitaran Hayat (PKH) yang melibatkan proses penilaian daripada input, output bahan, tenaga dan aliran sisa terhadap produk kitarsemula yang dihasilkan secara terus. Secara keseluruhannya, fungsi OpSWaste dapat menentukan ramalan penghasilan komposisi sisa pepejal, nilai pendapatan kitar semula dan mencadangkan pemilihan rekabentuk proses kitar semula serta Penilaian Kitaran Hayat (PKH) secara masa yang sebenar. Manakala sistem pintar yang lain di Malaysia seperti sistem Urus Sisa memfokus kepada kaedah pemilihan rawatan sisa pepejal berasaskan Proses Analisis Hierarki (PAH) dimana masalah kajian dibahagi kepada tiga aras hierarki iaitu matlamat, criteria dan alternatif. Secara kesimpulannya sistem OpSWaste di Malaysia juga dapat membantu pelbagai pihak seperti pembuat keputusan dan polisi, pihak berkepentingan serta seluruh masyarakat dengan hanya menggunakan data sisa pepejal yang diperolehi secara cepatdan berkesan bagi menyelesaikan masalah sisa pepejal di Malaysia.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ABC	- A Beautiful and Clean
COMP	- Computer
DM	- Multi Criteria Decision Making
EPA	- Environmental Protection Agency
ES	- Expert System
Etc	- Etcetera
GDP	- Gross Domestic Product
GNP	- Gross National Product
GIS	- Geographic Information System
HTML	- Hypertext Markup language
IETF	- Internet Engineering Task Force
KPI	- Key Performance Index
LA	- Local Authorities
LCA	- Life Cycle Assessment
MHLG	- Ministry Housing and Local Government Ministry
MPSJ	- Majlis Perbandaran Subang Jaya
MPKJ	- Majlis Perbandaran Kajang
MSW	- Municipal Solid Waste
MySQL	- My Sequel Query Language
NGO	- Non Governmental Organization
NSP	-National Strategic Plan
OpSWaste	- Optimization of Solid Waste
PHP	- Personal Home Page
SWMP	- Solid Waste Management Policy
SWMS	- Solid Waste Management System
TCP / IP	- Transmission Control Protocol / Internet Protocol
UNDP	- United Nations Development Programme
URL	- Uniform Resource Locator

CHAPTER 1

INTRODUCTION

1.1 Generation of Solid Waste

Due to the rapid rise of urbanization around the world, an effective and efficient solid waste management system is equally required to meet the development rates. It is worth noting that solid waste management in developing countries has received less attention from policy makers and academics in comparison to other urban environmental problems, such as air pollution and wastewater treatment (Martin, 2000).

Solid waste generation has doubled and/or tripled in some industrial based countries over the last two decades; developing countries, which are aspiring industrial nations, are also producing Municipal Solid Waste (MSW) at an alarming rate. It is becoming increasingly difficult to ignore that even Malaysia is severally lacking in MSW data (Agamuthu and Fauziah, 2006; Agamuthu and Khan, 1997).

Generally, increment of solid waste generation occurs because of rapid increase in population, improvement in wages, massive expansion of the urban areas and the changing lifestyle or better standard of living as well as improvement in technology (Ajadi and Tunde, 2010).

Urbanization is one of the most evident global changes worldwide. The rapid and constant growth of urban population has led to a dramatic increase in urban solid waste production, with a crucial socio economic and environmental impact. However, the growing concerns for environmental issues and the need for sustainable development have brought the management of solid waste to the forefront of the public agenda. Legislation and regulations have been introduced in local and national levels to guide waste management, and techniques for appropriate waste treatment and disposal. Moreover, strategies for sustainable waste management have put an emphasized on the requirement to minimize waste production, increase waste recovery and reduce the use of landfill sites. Nowadays, there is a general agreement on the best practices for sustainable management of urban solid waste, but only isolated efforts have been made so far in this domain, which were adapted to specific regulations and needs of each national or regional authority (Leao et al, 2001).

Sustainable waste management seems far from being attained. Reduction of waste produced is still a mere hope more than an achievement in most countries. The net waste production increases as population grows, and per capita generation of waste is also increasing, particularly in developing countries (Nikolaos et al., 2006). In regards to the governments from developing countries such as Malaysia, should consider the best

approaches of handling and management of municipal solid waste that gather the standards of economic, hygienic, and local ecology (Iwan et al., 2012).

It was estimated that the 6 billion human population in 2004 generated approximately 1.2 trillion kg of MSW, with the annual generation of MSW estimated to increase by 7% (Governing Council of the United Nations Environmental Programme, 2008). Increasing production of waste, minimal available land for storage and disposal in rural areas, and the limited development of appropriate strategies and legislation for waste management has led to a state of severe environmental degradation in many parts of the a particular nation (Andrew, 2012).

As more countries in Asia realize their annual economic goals, there will be an increase in the standard of living. With increased affluence come increased consumption and increased waste generation. Increased waste generation is a major driver catalyzing the growth of the waste management industry (Agamuthu and Suhaila., 2009). The unique set of drivers serves as a starting point to design waste management strategy or policies. This is based on tangible local trends or evidence, rather than adopting best practices from elsewhere which may not address local characteristics, customs, peculiarities or waste composition. Policies are ideal when pro actively driven by trends/evidence/facts (Wilson, 2007) and tailored for each unique local scenario.

1.2 Problem Statements

The problems associated with the management of solid waste in today's society are complex due to several factors: a) diverse nature of the wastes together with the development of extensive urban areas, b) the lack of public services in many large cities, c) the impact of technology, d) and the rising limitations in both energy and raw materials. (Syed, 2006). In addition, all of the selected treatment and disposal of solid waste are depending on the quantity and types of waste composition (Agamuthu, 2001). Thus, the quantity of waste generated increased together with the complexity of waste where plastic and other mixed waste became a significant portion in the entire waste stream (Agamuthu and Tanaka, 2010).

Knowledge on quantity and composition of municipal solid waste (MSW) is fundamental for the planning of waste management systems. Most previous studies investigated on the characteristics of municipal solid waste at the final disposal sites (Martin el al., 1999). With waste management strategies shifting more towards recycling, determination of the quantity and composition of waste at the sources of generation is getting more attention (Atkinson and New 1993, Abu Qdais et al., 1997).

In solid waste management planning, a workable alternative program is usually developed, in most situations this programme and plans must be presented to the public and decision makers for consideration, selection, and adoption (Syed, 2006). However, the major concerns resulting from waste generation and management processes can be associated with numerous policy fields which stress the significance of resource

depletion issues and different types of environmental pollution such as the waste impact on air pollution, climate change, ozone depletion, etc (Eduardo, 2002).

In Malaysia, urban waste generation increased 3% annually due to urban migration, affluence and rapid development (Agamuthu, 2001). In year 2003, 17, 000 tonnes of solid waste generated by all regions of Malaysia Peninsular was estimated. On average, solid waste per capita output is about 0.85 kg / capita / day (Iwan, 2012). In 2008, approximately 31,000 tonnes of waste were disposed into 260 landfills in Malaysia (Agamuthu and Suhaila, 2009).

The availability of comprehensive data on solid waste composition on a national scale is embarrassingly limited. A study conducted by the Ministry of Housing and Local Government (MHLG, 2002) reported that the solid waste composition in Malaysia was dominated by organic waste, followed by papers in the total waste stream such as waste from residential, industrial and commercial areas. The characteristics or the composition of Malaysian MSW is different from other countries. Due to its tropical climate with heavy rainfall, the Malaysian MSW contains high moisture content ranging from 52.6 % to 66.2 % (Hassan et al 2001). Another relevant characteristic is the high biodegradable or organic matter contents (Chua et al, 2011).

Economic development, urbanization and improved living standards in cities increased the quantity and complexity of generated solid waste in Malaysia. Wastes are generated continuously in different ways from our daily activities. Each activity will generate different types of waste which will require its own separate or specialized treatment, hence the real data optimization is critical to control waste quantity in term of their statistics on waste generation from a particular sources (Nganda, 2007).

1.3 Expert System as a Solution

Expert systems (ES) are computer programs that contain expert knowledge about a specific domain and capability to apply on useful inferences and to provide expert level advice to the user of the system (Fang et al., 1990). An expert system typically contains two parts: a database that contains specified knowledge in a given area; and a set of rules for reaching a conclusion (Durkin, 1994).

The knowledge-based expert system can be used to solve new problems once it has been known to solve other domain's problems (Lucien, 2012). Expert system is a program that will function even with an incomplete and undecided data from the first time it was executed in non-programmable task. Expert system provides consistent advice as well as reducing the error rate. Besides that, expert system can handle uncertainties expresses as probabilities. The process depends on the inference engine of the particular expert system. In addition, expert system can be used as a training vehicle for users who lack expertise in areas involved and will provides monetary savings once implemented. It would save cost when not in used as human expertise is not needed most of the time.

The implementation of expert system technology is relatively a new approach in solid waste management applications. In addition, ES may be extremely valuable tools in certain aspects of waste management planning (Thomas et al., 1990). As mentioned earlier some expert system applications deal with the design and setting of landfills and the determination of feasible waste treatment alternatives. Expert system is also used to increase the capabilities of waste management decision support systems. Those applications enforce the belief that expert system can deal with solid waste management problems more efficiently than conventional computer programs, if the capabilities of expert system are used promptly by the researchers. Thus, endeavor in other branches of engineering to utilize this new computing technology indicates that solid waste expertise in various forms has a tremendous potential to be encoded successfully in expert systems (Basri and Stentiford, 1995).

1.4 Objectives of the Study

The aim of the study is to develop an expert system for real time optimization of solid waste management in Malaysia. Hence, this research has been carried out with the following objectives as follows:

i. To develop a prototype of expert system database on solid waste management using open sources software.
ii. To estimate the composition and growth revenue of municipal solid waste generated.
iii. To design a modular system process to manage the solid waste composition based on integrated solid waste management.

1.5 Scope of the Study

The scope of the study is focus towards significance of using ES's estimation of waste generation and growth revenue in a municipal area. This study also emphasis on the application of modular system for the recycling process and the application of Life Cycle Assessment. The synchronization between programming language HTML, PHP and MYSQL as construction equipment is to ensure the developed prototype expert system can be used with internet application.

This study will also present information about solid waste management process in Balakong, Selangor area, to show the mechanism of the prototype expert system and displays some of its properties. Data validation for prototype expert system also used the primary data of waste composition, collected from household and industrial area in Balakong, It is hoped, by using the prototype expert system, users can share the information with policy makers to improve decision related with optimization of municipal solid waste.

The flexibility to design, adapt and operate the system in ways which most suitable meet current social, economic and environmental condition are some of the aspects of an

effective integrated scheme. These will likely change over time and geographic factors. The use of a range of waste management options in an integrated system gives the flexibility to channel waste via different treatment as economic or environmental condition change. For example, papers can be recycled, composted or incinerated as sources of energy. This option, utilizes the system development can be varied according to the economics of paper recycling, compost production or energy supply prevailing at the time. The target of the end user for this system are individuals, stakeholder or industry groups which are involved in solid waste management planning.
The importance of expert system to optimize development of solid waste management in order to manage solid waste composition effectively and efficiently based on real time data in Malaysia. It is also important for private and local authority to determine the waste composition generation data, growth revenue, recycling process and life cycle assessment on daily, weekly, monthly or yearly basis by using online system or portable system.

1.6 Thesis Organisation

"An Expert System for Real Optimization of Solid Waste Management in Malaysia" is a thesis based on real scope to produce a new system that can help in problem solving of solid waste generation and management in Malaysia. Overall, this thesis comprises of six chapters with the purpose to facilitate understanding and writing process. Therefore, chapters in this thesis have been compiled as following:

Chapter 2 discusses generally about solid waste generation in municipal areas of developing countries. Discussions also involve factors regarding problem on solid waste management in Malaysia, solid waste composition, sources and characteristics of solid waste, recycling program, integrated solid waste management and solid waste enforcement.

Chapter 3 involves descriptions about the methodology used for this investigation. It is divided into four parts, namely expert system development, application of linear model, application modular system process, life cycle assessment and waste composition study. Discussions also focus on conceptual model of expert system development. Besides that, selection and type of expert system prototype tools are discussed as well in this chapter.

Chapter 4 explains on expert system architecture which is divided into three parts which are application of linear model to estimate real composition and growth revenue, application of modular system process and life cycle assessment. Other than that, discussions also involve interfaces in expert systems prototype and target of end users to use this prototype.

Chapter 5 involves discussion on verification and validation processes to evaluate expert system potential by applying the data obtain from Balakong, Selangor area as real case studies. Besides that, evaluation process also had been done for users interface to evaluate the efficiency and effectiveness of the expert system.

Chapter 6 is the last chapter which provides some conclusions and state important points gathered throughout this study and provide a few suggestions in order to improve effectiveness of the system.

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