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Integrated Scheduled Waste Management System in Kuala Lumpur Using Expert System

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1. Introduction

Over the past decade, Malaysia has enjoyed tremendous growth in its economy and population, this resulted in an increase in the amount of waste scheduled generated. Furthermore, scheduled waste management has long been a problem area for local authorities in Kuala Lumpur. Continued illegal dumping by waste generators is being practiced at large scale due to lack of proper guidance and awareness. This paper reviewed discussed and suggested about service provided for scheduled waste management by an authority and international scenario of scheduled waste management. An expert system was developed to integrate scheduled waste management in Kuala Lumpur. The knowledge base was acquired through journals, books, magazines, annual report, experts, authorities and web sites. An object oriented expert system shell, Microsoft Visual Basic 2005 Express Edition was used as the building tools for the prototype development. The overall development of this project has been carried out in several phases which are problem identification, problem statement and literature review, identification of domain experts, prototype development, knowledge acquisition, knowledge representation and prototype development. Scheduled waste expert system is developed based on five types of scheduled waste management which are label requirements, packaging requirements, impact of scheduled wastes, recycling of scheduled wastes, and recommendations. Besides, it contains several sub modules by which the user can obtain a comprehensive background of the domain. The output is to support effective integrated scheduled waste management for KL and world-wide as well.

2. Scheduled wastes

Even though use of information technology plays a major role in application of technology nowadays, application of artificial intelligence (AI) is still in its infancy in Kuala Lumpur. During the last decade AI has grown to be a major of research in computer science. Varieties of AI-based application programs have been developed to address real life problems and have been successfully field-tested (L.C. Jayawardhanaa et al, 2003). As Kuala Lumpur still lacks proper systems of information assimilation, archival and delivery, AI tool can effectively be employed to solve for the management of scheduled waste.

Scheduled wastes are defined as wastes or combination of wastes that pose a significant present or potential hazard to human health or living organisms. This definition specifically excludes municipal solid waste and municipal sewage. Scheduled wastes are broadly classified into the categories of chemical wastes, biological wastes, explosives and radioactive wastes (Chapter 5 Waste Disposal). Scheduled waste management has long been a problem area for local authorities in Kuala Lumpur. Continued illegal dumping by waste generators is being practiced at large scale due to lack of proper guidance and awareness. In 2007, the Department of Environment Malaysia (DOE) was notified that 1 698.118 metric tones were generated. In addition, Kuala Lumpur has enjoyed tremendous growth in its economy. This has brought about a population growth along with a great influx of foreign workforce to cities. It resulted in an increase in the amount of waste generated. The main reason attributable to this deficiency is the lack of expertise in the scheduled waste management domain. The aim of this research is to address scheduled waste management in Kuala Lumpur by providing an expert system called Scheduled Waste Expert System (SWES). Currently, there are various facilities have been approved for management of scheduled wastes in Malaysia. These include 211 licensed waste transporters, 76 recovery facilities (non e-waste), 85 partial recovery e-waste facilities, 35 on-site incinerators, 3 clinical waste incinerators and 2 secured landfills (Department of Environment, Malaysia, 2008). For Kuala Lumpur, in 2007, there are 11 licensed waste transporters and 6 local off-sites recovery facilities (Laporan Tahunan Jabatan Alam Sekitar Wilayah Persekutuan, Kuala Lumpur 2002-2007). However, there are many of other potential sites which could be used as illegal dumped area. To guide the proper implementation of scheduled waste management, the need of expertise, in the form of human expert or a written program such as an expert system is crucial factor. In order to convey the expert knowledge to the operational level personnel, the most convenient and cost effective means is an expert system (Asanga Manamperi *et. al*, 2000).

3. International scenario of integration of scheduled waste management

Scheduled waste management has different meaning and classification according to the country. For example, most of the waste is classified under hazardous waste (HW) because of their physical characteristics that suitable with HW. HW can be classified on the basis of their hazardous nature which includes toxicity, flammability, explosively, corrosively and biological infectivity (Moustafa, 2001). According to Chinese law, solid waste is classified into three types: industrial solid waste (ISW), municipal solid waste (MSW) and hazardous waste (HW). According to the environmental statistics for the whole country in 2002, the quantity of ISW generated in China was 945 million tons, of which 50.4% was reused as source material or energy, 16.7% was disposed of simply, 30.2% was stored temporarily, and 2.7% was discharged directly into the environment. In recent years, the quantity of ISW generated in China has been increasing continually. Compared with 1989, the quantity of ISW generated in 2002 had increased by 66%. The categories of ISW are closely related to the industrial structure in China. (Qifei et. al, 2006).

The total volume of hazardous waste generated in Thailand in 2001 was 1.65 million tons, of which 1.29 million tons (78%) were generated by the nonindustrial (community) sector. As well as the industrial and nonindustrial sectors, a main source of hazardous waste generation is the transport of hazardous wastes from foreign countries into Thailand. More than 70% of the hazardous waste generated in Thailand is in the form of heavy metal sludge and solids. Other important groups of hazardous waste are oils, acid wastes, infectious wastes, solvents, and alkaline wastes. It has also been reported that petroleum refineries and the electroplating, textile, paper, and pharmaceutical industries are the primary producers of hazardous wastes in Thailand. Besides, for the nonindustrial hazardous waste is generated from everyday activities in nonindustrial or community sources, such as automotive repair shops, gas stations, hospitals, farm and households. Hazardous waste from community sources consist primarily of used oils, lead acid and dry-cell batteries, cleaning chemicals, pesticides, medical wastes, solvents, and fuels (Hiroaki et.al, 2003).

Amounts of wastes generated from industries in Dar es Salaam are estimated at 76 326 tonne per year (about 203.6 tonne per day or 58 kg per capita per year). The hazardous waste generation from industries in Dar es Salaam as estimated was a total of 46 340 tonne per year (about 127 tonne per day or 29 kg per capita per year). Assuming a negligible annual increase, the hazardous wastes production is about 40% of the total waste production in Dar es Salaam industries. The hazardous waste production levels in Dar es Salaam (Tanzania) can be estimated at 95 000 tonne per year or 3.8 kg per capita per year. The per capita waste generation rate is about 60% of that of Japan, 17% of Denmark and 3.8% of the Netherlands (Mato et. al, 1999).

In India, the HWs (Management and Handling) Rules, 1989, as amended in 2003 defined 36 industrial processes, which generate HW (HWM Rules, 2003). In order to encourage the effective implementation of the HW (M&H) Rules 1989 as amended in 2003. The key issues in India for HW management are the environmental health implications of uncontrolled waste generation, improper waste separation and storage prior to collection, multiple waste handling, the poor standards of disposal practices, and the non-availability of treatment/ disposal facilities. The most influential issue is the scarcity of resources (skilled human as well as budgetary) in the country. The majority of the problems and challenges facing by India in managing HW are detailed.

4. Computer technique in waste management

There are many computer techniques in managing the waste worldwide. As an example, for Sri Lankan solid waste composting, BESTCOMP is used. BESTCOMP is one of the Expert System. BESTCOMP is short form from 'Born to guide for Solid waste COMPosting'. This system is based on several phases including problem identification, knowledge acquisition, knowledge representation, programming, testing and validation. It is composed of several basic components such as the user interface, knowledge base, inference mechanism and the database (L.C. Jayawardhanaa et. al, 2003).

Another Sri Lankan alternative is BESTFill for landfilling applications. An expert system was developed to assist proper implementation of landfill technology in Sri Lanka. This system contains several sub modules by which the user can obtain comprehensive background of the domain. The output is expected to support effective integrated solid waste management (Asanga et. Al, 2000).

Besides, for environmental site evaluation of waste management facilities, EUGENE model is used. This model is a sophisticated mixed integral linear programming model developed to help regional decision makers on long-term planning for solid waste management activities. The method used to embed waste management environmental parameters in the EUGENE model consists in building global impact index (GII) for all site or facility combinations (Vaillancourt et. al, 2002).

In addition, fuzzy goal programming approach is used for the optimal planning of metropolitan solid waste management systems. This system demonstrates how fuzzy, or imprecise, objectives of the decision maker can be quantified through the use of specific membership functions in various types of solid waste management alternatives (Ni-Bin et. al, 1997).

Another system that had been used was Analytic Network Process (ANP) and Decision Making Trial and Evolution Laboratory (DEMATEL) to evaluate the decision-making of municipal solid waste management in Metro Manila. ANP has a systematic approach to set priorities and trade-offs among goals and criteria, and also can measure all tangible and intangible criteria in the model while DEMATEL convert the relations between cause and effect of criteria into a visual structural model (Ming-Lang, 2008).

5. Methodology

Expert system (ES) has been chosen to organize part of the knowledge domain in scheduled waste management from all data collected to non-expert users (Nassereldeen, 1998). This knowledge should support them in term of label and packaging requirements, impact and recycling of scheduled wastes, recommendations, besides predicting the scheduled waste generated and population in Kuala Lumpur.

5.1 Visual Basic Expert System (VBES) development

Figure 1 below shows the flow diagram of this project, problem identification, problem statement, literature review and identifications of domain experts are done. For other phases

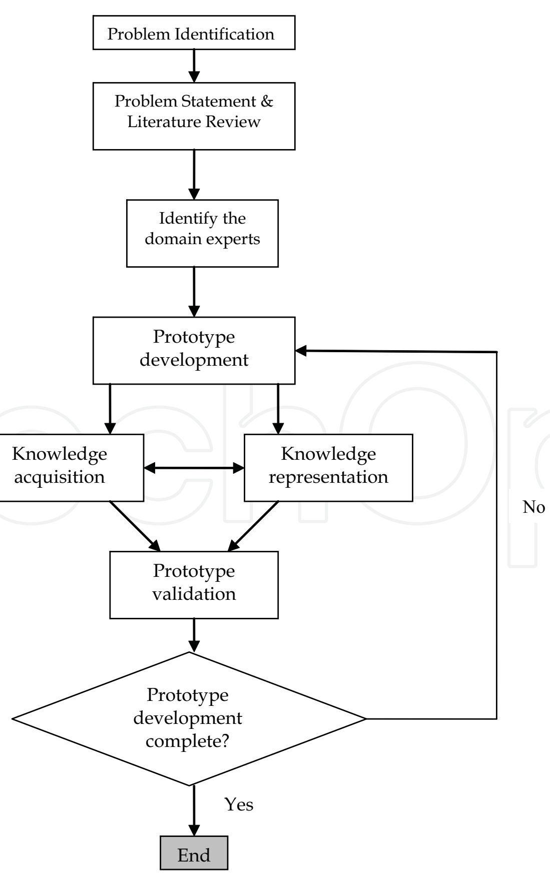

Fig. 1. Flow Diagram for Scheduled Waste Expert System

are elaborated below. Several entities in the integration of scheduled waste management system in KL. Five different entities of this process, each of which has many sub entity:

- Label Requirements
- Packaging Requirements
- Impact of scheduled waste
- Recycling of scheduled waste
- Recommendation

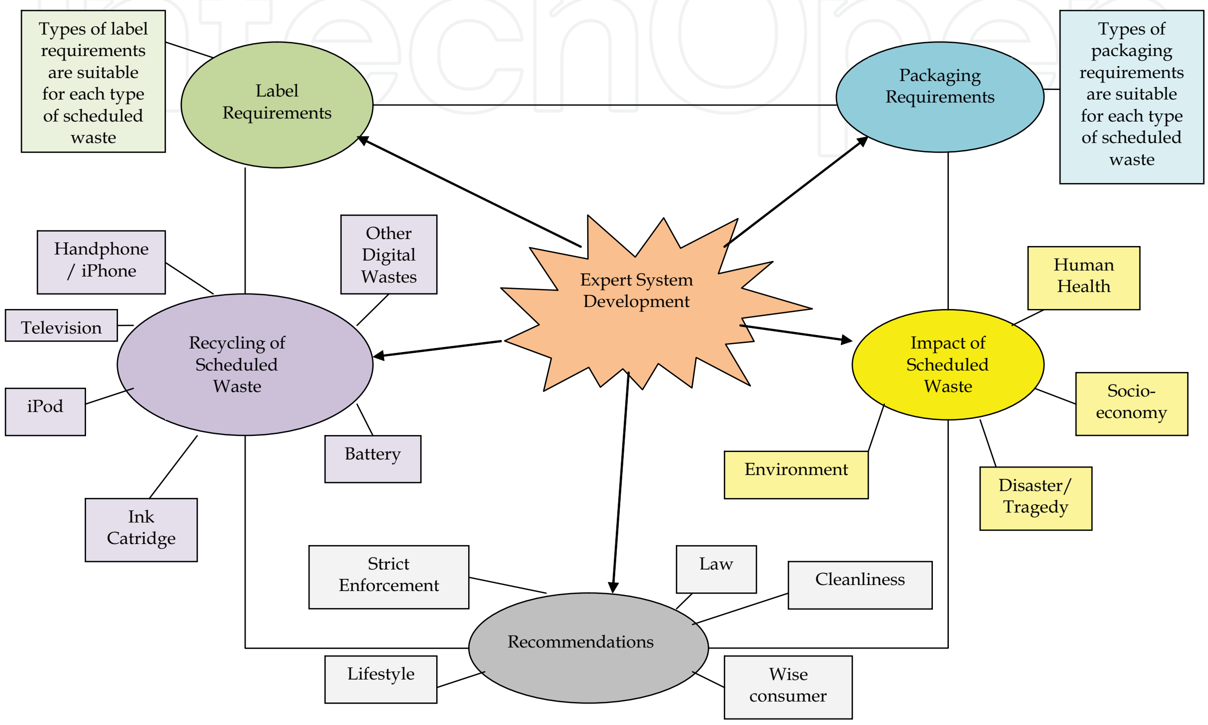

Fig. 2. Five Different Entities of Expert System Development

5.2 Building tool

For the development of Scheduled Waste Expert System (SWES), an expert system shell, Microsoft Visual Basic 2005 Express Edition, was preferred over conventional programming languages. This software was used because of its user friendly. In fact, many books that guide the author how to use this software are available in the library.

5.3 System requirements

- Operating System
  The user must have Windows 2003, XP, or 2000; Windows NT, 95, 98, or ME will not work.
- Available hard drive space
  The requirement varies with the edition and type of installation and whether other components such as Internet Explorer (IE) already are installed on the computer. The user should plan on the total installation taking between 2GB and 5GB (gigabytes). A large (at least 80GB) hard drive is relatively inexpensive and easy to install, so if remaining space on the existing hard drive is scarce, the user may wish to consider upgrading before installing Visual Basic 2005.
- Processor

According to Microsoft, a processor speed of 600 MHz (megahertz) is the minimum and 1 GHz (gigahertz) is recommended. Because upgrading a processor by replacing the motherboard is not so inexpensive or easy, another alternative is boosting your system RAM, discussed next if the user is on the borderline.

- RAM
  According to Microsoft, 128MB (megabytes) is the minimum, and 256MB is recommended.

5.4 Knowledge acquisition

Knowledge acquisition is the lengthiest process in building of an expert system. However, it is the single most important process of the knowledge engineer upon which quality of the expert system depends on. The central core of the knowledge base was acquired from the published text books, journals, magazines, experts, meeting authorities and pamphlet. This knowledge consists of well established facts, rules, theory and guidelines that had been practiced over many years. Annual Report of Department of Environment (DOE) related to statistics of scheduled waste generated have provided very valuable sources of information. This source of information provided a means to build a unique knowledge base for Scheduled Waste Expert System (SWES). All the sources are come from Department of Environment, Kuala Lumpur (DOE), Kuala Lumpur City Hall (DBKL), and Alam Flora Sdn. Bhd (AFSB).
Knowledge acquisition has now become relatively easy than two decades ago, due to the advancement of Internet facilities. Much valued information about management of scheduled waste of Kualiti Alam and Radicare, organization, companies, recycling procedure and so on, were acquired through the Internet. These were helpful in building the sub modules of the Scheduled Waste Expert System (SWES).

6. Results and discussion

6.1 User interface

Proper organization of the user interface is important since it is the part of the expert system that interacts with the user. The presence of a standard user interface framework not only simplifies development efforts, but also reduces user training and support requirements for users. In the SWES, the knowledge base was divided into five categories which are label requirements, packaging requirements, impact of scheduled wastes, recycling of scheduled wastes, and recommendations as shown in the Figure 3.

Fig. 3. Main User Interface of SWES

6.2 Rules for the ES

Through studying the annual report, magazine, journal, book and web sites, knowledge was translated into five sets of rules:

i. Label requirements
ii. Packaging requirements
iii. Impact of scheduled wastes
iv. Recycling of scheduled wastes
v. Recommendations

The major operations that can be done on the ES as in figure 4 are:

i. Clear, this command removes selected text in the text box
ii. Recommendation, Solution, Result & Comment, these commands give the best solution and comment about the selected case.
iii. Help, this command help the user how to use this system.
iv. Quit, this command prompts exit SWES.

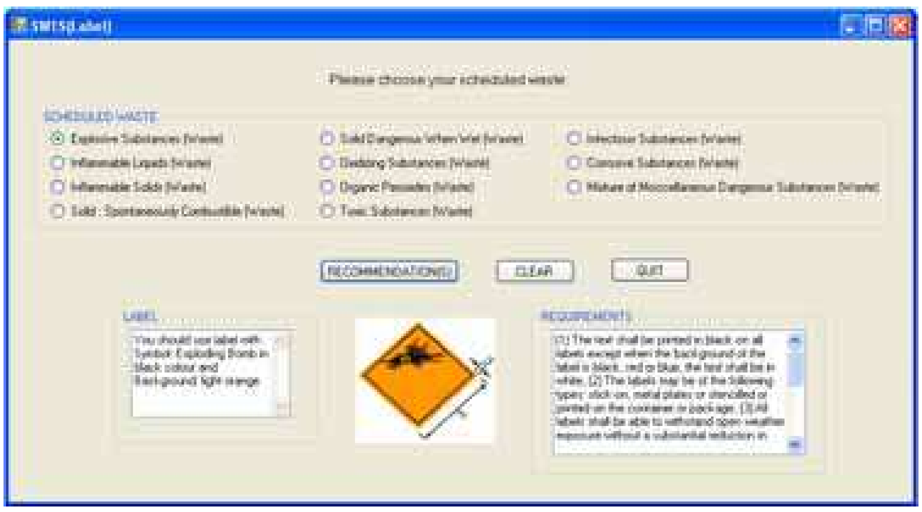

Fig. 4. The output after user click on any radio buttons

6.3 Rules for impact of Scheduled Wastes

The information is converted into ES rules in a simple language as in figure 5.
The rule will be in a form of radio button and the meaning of the rule is:
If the selection is RadioButton1, then Example SW 110 E-Waste <> (1) Toxic ingredients in E-Waste such as lead, beryllium, mercury, cadmium and bromibated flame retardants can pose both occupational and envitonmental health threats. (2) E-Waste that are lanfilled produce highly contaminated leachate which eventually pollutes the environment especially surface water and grounwater. (3) Acid and sludge obtained from melting computer chips if disposed into the ground will cause acidification of soil and subsequently contamination of groundwater. (4) Brominated flame retardant plastic or cadmium containing plastics are landilled, both polybrominated diphenyl ethers (PBDE) and cadmium may leach into the soil and groundwater. (5) Combustion of E-Waste will emit toxic fumes and gases that pollute the surrounding air. When E-Wastes are exposed to fire, metals and other chemical substances, extremely toxic dioxins and furans will be emitted. The toxic fall-out from open burning affects both the local environment and broader global air quality, depositing highly toxic byproducts in many places throughout the world. (6) If E-Wastes are discarded together with other household wastes, the toxic compnents will pose a threat to both health and the vital components of the ecosystem; if the selection is RadioButton2, then Example SW 311 Oil <> (1)

IF selection is RadioButton1
THEN Example SW 110 E-Waste <> (1) Toxic ingredients in E-Waste such as lead, beryllium, mercury, cadmium and bromibated flame retardants can pose both occupational and envitonmental health threats. (2) E-Waste that are lanfilled produce highly contaminated leachate which eventually pollutes the environment especially surface water and grounwater. (3) Acid and sludge obtained from melting computer chips if disposed into the ground will cause acidification of soil and subsequently contamination of groundwater. (4) Brominated flame retardant plastic or cadmium containing plastics are landilled, both polybrominated diphenyl ethers (PBDE) and cadmium may leach into the soil and groundwater. (5) Combustion of E-Waste will emit toxic fumes and gases that pollute the surrounding air. When E-Wastes are exposed to fire, metals and other chemical substances, extremely toxic dioxins and furans will be emitted. The toxic fall-out from open burning affects both the local environment and broader global air quality, depositing highly toxic byproducts in many places throughout the world. (6) If E-Wastes are discarded together with other household wastes, the toxic compnents will pose a threat to both health and the vital components of the ecosystem.

IF selection is RadioButton2
THEN Example SW 311 Oil <> (1) Oil that is illegall dumped can contaminate groundwater and nearby rivers, affect public health and financial implications. (2) The health impacts of direct and indirect exposure to oil include carcinogenic effects, reproductive system damage, respiratory effects, central nervous system effects and many more.

The rule in VB language;

```
If Me.RadioButton1.Checked Then
  Me.TextBox1.Text = ("Example SW 110 E-Waste <> (1) Toxic ingredients in E-Waste such as lead, beryllium, mercury, cadmium and bromibated flame retardants can pose both occupational and envitonmental health threats. (2) E-Waste that are lanfilled produce highly contaminated leachate which eventually pollutes the environment especially surface water and grounwater. (3) Acid and sludge obtained from melting computer chips if disposed into the ground will cause acidification of soil and subsequently contamination of groundwater. (4) Brominated flame retardant plastic or cadmium containing plastics are landilled, both polybrominated diphenyl ethers (PBDE) and cadmium may leach into the soil and groundwater. (5) Combustion of E-Waste will emit toxic fumes and gases that pollute the surrounding air. When E-Wastes are exposed to fire, metals and other chemical substances, extremely toxic dioxins and furans will be emitted. The toxic fall-out from open burning affects both the local environment and broader global air quality, depositing highly toxic byproducts in many places throughout the world. (6) If E-Wastes are discarded together with other household wastes, the toxic compnents will pose a threat to both health and the vital components of the ecosystem.")
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Fig. 5. Rules for Impact of Scheduled Waste

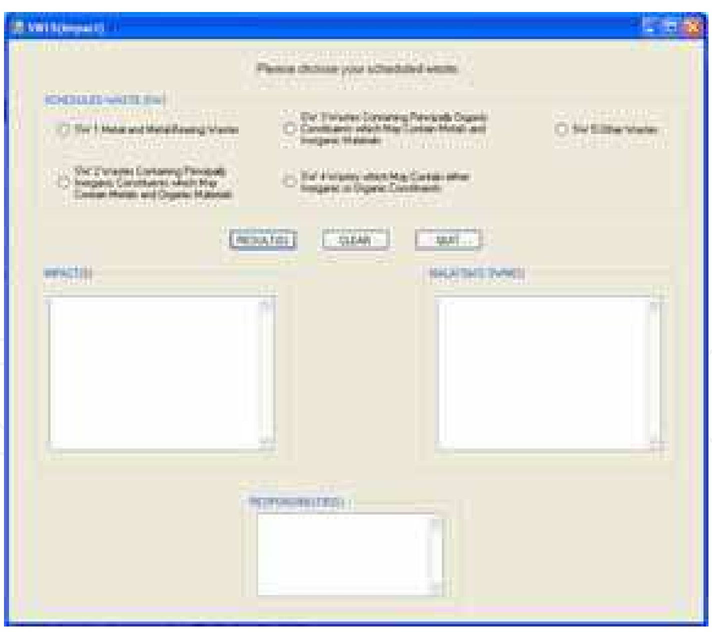

Fig. 6. Choices of Impact of Scheduled Waste

Oil that is illegall dumped can contaminate groundwater and nearby rivers, affect public health and financial implications. (2) The health impacts of direct and indirect exposure to oil include carcinogenic effects, reproductive system damage, respiratory effects, central nervous system effects and many more. The selection is continuously until RadioButton5.

Figure 6 shows the translation of the rule into impact of scheduled waste using VB while figure 7 shows the output after the user click on any radio buttons.

6.4 Scheduled Waste Expert System (SWES)

Fig. 7. Interface for Scheduled Waste Expert System

Once the user clicks on the SWES button at the main user interface, they will be five categories listed as in figure 7. Then, user can choose any categories and the system will give user the best solutions. The system will produce the answer through texts, graphs and pictures within a single form. Scheduled Waste Management module has been designed for the use of the novices to the field. It has been divided into premises and companies handling scheduled waste in Kuala Lumpur, labeling and packaging requirement, transportation, and process flow. For process flow, it divided into two which are Kualiti Alam's process flow and Radicare's process flow as in figure 8.

Fig. 8. Interface for Scheduled Waste Management Sub Module

6.5 System validation

In validating the scheduled waste expert system, it should be remembered that the purposes of the study are to develop on integrated scheduled waste management system in KL by using Visual Basic Expert System and to recommend a new approach for integration of scheduled waste management system in KL. Many expert system prototypes were tested and validated using case studies, the results of which were analyzed internally by the system developers themselves. Similarly in the case of the SWES, it was validated in two steps. As the first step, the system validation involved program debugging, error analysis as in the Figure 9 below, and output generation. After the code is corrected, no error occurs anymore as in the Figure 10. So, the program can be debugged.

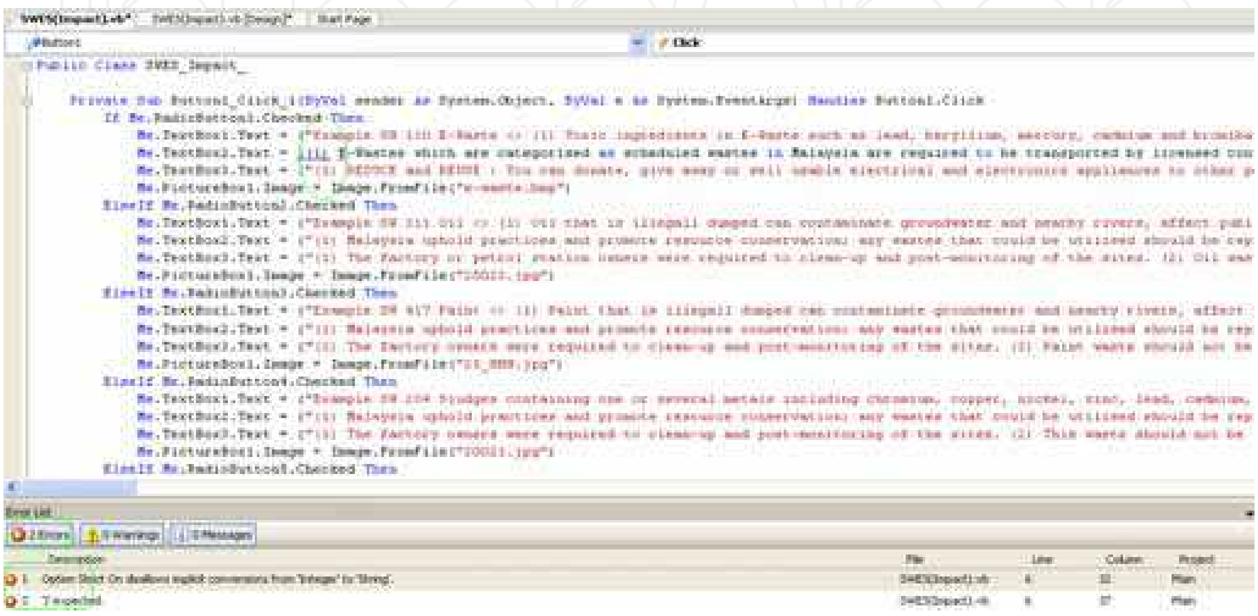

Fig. 9. Area in the circle shows error occurred during coding

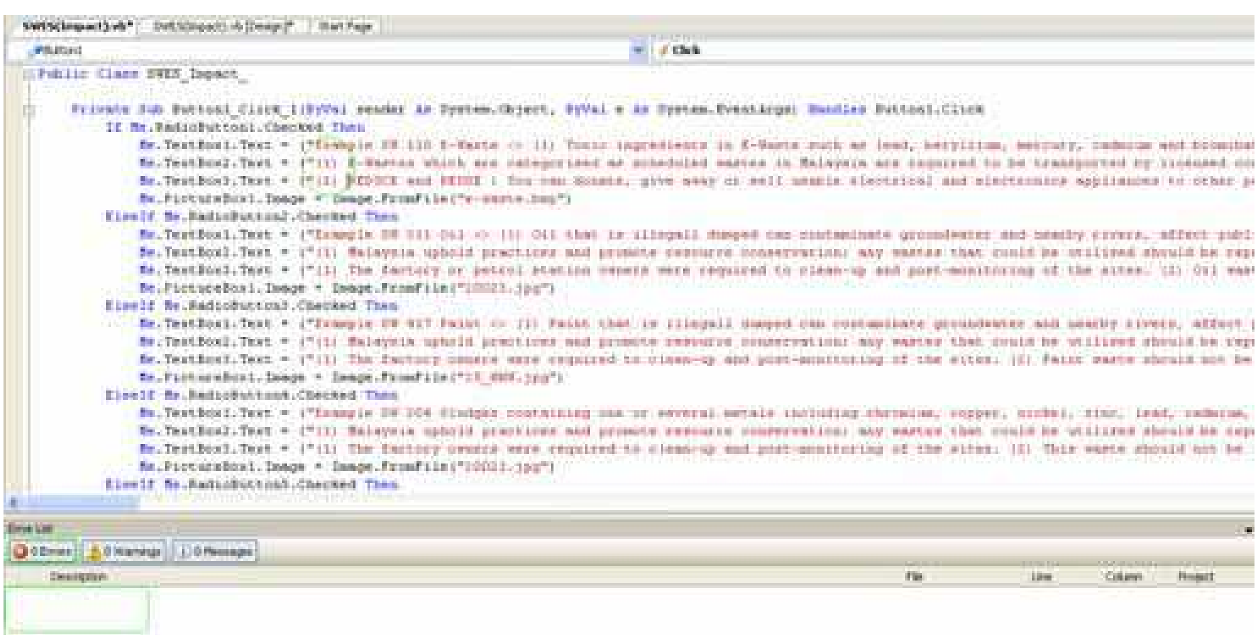

Fig. 10. Area in the circle shows no error occur after the code is corrected

Secondly, empirical data from DOE's data, journal and authority agents validated its performance. The objective was to evaluate the SWES's diagnostics capability by comparing its output with the data which were collected and documented during the knowledge acquisition phase. As an example, the output for estimation of scheduled waste generated and population in KL are validated with the statistics provided by the DOE and journal. According to DOE, scheduled waste generated is estimated increasing every year while according to the journal, population in KL will increase 4% every year. For label and packaging requirements and impact and recycling of scheduled waste are validated through the various sources such as magazines, DOE's annual report and web sites. For example, Figure 11 shows scheduled waste generated in 2002 is 1 560.420 tonne metric while Figure 11 shows scheduled waste generated in 2007 is 1 698.118 tonne metric. According to the DOE's statistics, the outputs show scheduled waste generated in 2002 and 2007 are same. So, the outputs are corrected and validated.

Fig. 11. Area in the circle shows scheduled waste generated in 2002 is 1 560.420 tonne metric

7. Conclusion

The purpose of the study includes understanding scheduled waste generated in Kuala Lumpur and service provided for scheduled waste management by the authority which is Department of Environment (DOE). In addition, scheduled waste management system in Kuala Lumpur will be developed by using Visual Basic Expert System (SWES). Finally, a new approach for integration of scheduled waste management system in Kuala Lumpur is recommended.

From the result obtained, the project can be considered as successful as the integrated program for scheduled waste management system had been developed. Scheduled waste expert system is developed based on five types of scheduled waste management which are label requirements, packaging requirements, impact of scheduled wastes, recycling of scheduled wastes, and recommendations. The knowledge base of this system is based on ruled-base expert system which is IF THEN rule and the acquisition knowledge that is gathered for this study is organized into this rules. The development of scheduled waste expert system consists of six main forms or interfaces which are photo gallery, scheduled waste management, literature, legislations, training tool, and scheduled waste expert system itself. It has been incorporated with several user interfaces in order to make the system user friendly as much as possible. SWES can also be used as a stand-alone learning tool in environmental studies and by others. Thus a system of much versatility has been developed.

This is use of tools of information technology to help in solve local problems in managing scheduled waste in an informative manner.

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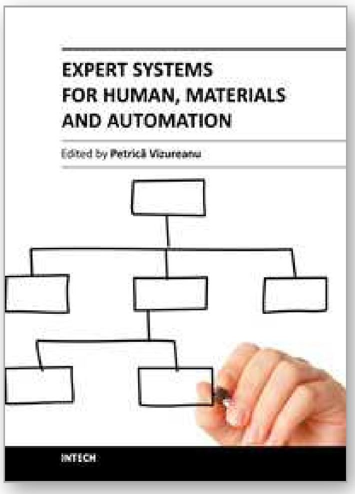

Expert Systems for Human, Materials and Automation

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The ability to create intelligent machines has intrigued humans since ancient times, and today with the advent of the computer and 50 years of research into AI programming techniques, the dream of smart machines is becoming a reality. The concept of human-computer interfaces has been undergoing changes over the years. In carrying out the most important tasks is the lack of formalized application methods, mathematical models and advanced computer support. The evolution of biological systems to adapt to their environment has fascinated and challenged scientists to increase their level of understanding of the functional characteristics of such systems. This book has 19 chapters and explain that the expert systems are products of the artificial intelligence, branch of computer science that seeks to develop intelligent programs for human, materials and automation.

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