Eco-Friendly Integrated Green Technology Expert System for Sustainable Green Infrastructure

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ABSTRACT

Urbanization is accelerating in Malaysia. Rapid urbanization has known to have several adverse impacts towards hydrological cycle due to increasing impervious surface and degradation of water quality in stormwater runoff. One of the negative effects of urbanization is the overloading of the stormwater drainage system leading to flash flood problem and water quality deterioration. In the past urban waterways have been confined to narrow river corridors with the channels canalised and concrete and other man-made materials forming the bed and banks of the river. At the same time, the waterways located in or near urban area are adversely influenced by solids in stormwater runoffs. Apart from that, stormwater pollutants such as litter, debris and sediments in drainage system are common problems which lead to flooding problems and the degradation of water quality. Stormwater pollutants such as litter, debris and sediments in drainage system are common problems which lead to flooding problems and the degradation of water quality. Many urban rivers have been converted into concrete channels, and now receive both storm drainage and raw or dilute sewage from the surrounding area. The pollutant loading also frequently leads to poor water quality, indeed this adverse impact of urbanisation often extends to the waterways downstream of the urban area. In some cases the bacteriological or chemical quality of urban streams may present a severe threat to public health. The result is that many urban waterways have virtually no aesthetic or amenity value, support a limited range of ecosystems, and do not meet the water quality objectives prescribed by the DID and DOE. DID has taken pro-active actions by establishing Manual Saliran Mesra Alam (MSMA) (DID 2000 & DID 2011) to control the stormwater quantitatively and qualititatively. Since the introduction of MSMA Manual 1st Edition, many aspects of water quantity and quality treatment are still relatively less understood and yet to be fully studied and documented. To solve this problem, stormwater BMPs proves very promising due to its near natural characteristics and multiple effects on the drainage of stormwater runoff in urban areas. However, the judgment of whether a local area is appropriate to be drained in this way and which stormwater BMPs measures are optimal is rather complex and involves analysing a set of influential factors. This judgment depends on not only relevant theoretical considerations, but also a large amount of practical experience and the availability of relevant data, as well. Such a judgment is an unstructured problem and relates to changeable knowledge. To fulfill this task, the so-called integrated green expert system, or green knowledge-based system, is introduced. One of the advantages of an expert system is that it provides automation of expert-level judgement. This is extremely helpful when an expert-level judgment is needed repeatedly for a large amount of cases, like in the

planning of stormwater BMPs for an entire city catchment. This paper describes a self-developed expert system tool for developing rule-based expert systems, as well as a case study: using an expert system for the selection of stormwater BMPs measures for the selected area in Kuala Lumpur.

KEYWORDS
Urbanization, MSMA, Stormwater, BMPs, Stormwater Management, Expert System

INTRODUCTION
Malaysia faces serious challenges in urban water management. In terms of stormwater management, even with the introduction of MSMA in 2001 (Urban Stormwater Management Manual for Malaysia), many new technologies have yet to be studied in depth especially the interrelation between water quantity and quality. Water pollution originates from many human-induced actions such as effluents from industrial wastewater, land use changes and urbanisation. There is an emerging transdisciplinary approach that utilises the understanding of relationships between hydrological and biological processes to improve water quality, biodiversity and sustainable development at the catchment scale. The approach implementation is based upon restoration and optimization of the ecosystem. This approach is based on three fundamental, i.e., synergising catchment water cycle and dynamic of its biotic component, harmonizing existing and planned hydrotechnical solutions with ecological biotechnologies, and integrating complementary synergistic measures of all scales.

Expert systems are generally considered a branch of AI with a knowledge base and they are considered as the most important branch of AI (Cohn and Thomas, 1987). By definition, an expert system is an interactive computer program/model incorporating judgment, experience, rules of thumb, intuition, and other expertise to provide knowledgeable advice about a variety of tasks to non-specialists (Gasching et al., 1981; and Saunders et al., 2005). These systems can function as experts to make higher-level decisions based on varying performance levels (Basri, 1999). They can be described as new software technology that allows the formalisation and representation of knowledge as well as experts.

Rapid urbanization has known to have several adverse impacts towards hydrological cycle due to increasing impervious surface and degradation of water quality in stormwater runoff. Waterways located in or near urban area are adversely influenced by solids in stormwater runoffs (Roesner, L. A., 2007). Stormwater pollutants such as litter, debris and sediments in drainage system are common problems which lead to flooding problems and the degradation of water quality.

In order to address the stormwater quality problem due to Non-Point Sources (NPS) pollution generated from stormwater in urban areas, DID has taken pro-active actions by establishing Manual Saliran Mesra Alam (MSMA) to control the stormwater quantitatively and qualititatively. Thus, MSMA Manual suggested various storm water BMPs in storm water management at the end of water conveyance system to trap stormwater pollutants (DID, 2000). The performance of storm water BMPs is strongly dependent on specific site criteria including type of land use, hydrological data and maintenance frequency.

In Malaysia, MSMA Manual has introduced various storm water BMPs as treatment control BMPs to be installed at the downstream end of drains or engineered waterways (DID, 2000). The installation of storm water BMPs at downstream end of drains or engineered waterways has become common practice since the introduction of the new Urban Stormwater

Management Manual (MSMA) (DID, 2000 & DID, 2011). This structural measure of urban stormwater is based on the concepts of "control at source" with the objective to control stormwater quantity and quality (Mohd Sidek et al., 2006). However, there is only limited performance data for locally installed Stormwater BMPs as there is little research done in this area. A comprehensive study on Stormwater BMPs performance will help in determining the devices' trapping efficiency based on Malaysian conditions.

Therefore, this study aimed to enhance the developed innovative green expert system by incorporating local data to estimate stormwater pollutant loading emanated from different type of land use. Therefore, the aim of this study is to give background to the problems caused by stormwater pollutants. The other aim is to monitor loads of stormwater pollutants generated from different type of land use during storm events. This study also aims to collect performance data for selected device used to remove stormwater pollutants from within the urban drainage network. Finally, the result of this study will be incorporated into an innovative green expert system that enable to assist engineers and local authorities to choose the most suitable stormwater BMPs to be installed according to specific site characteristic.The GENIUS will be a reference tool for engineers or decision maker in selecting and designing appropriate stormwater BMPs for given resources and management needs, based on understanding of stormwater pollutant movement and trapping.

The development of the innovative green expert system also aimed to assist the engineers and local authorities to select the most appropriate strategies for trapping stormwater pollutants in urban area and also to expand the sources for managing stormwater pollutants in order to rehabilitate the river system. The system also able to assist in preparing budget estimation of using Stormwater BMPs in terms of installation and maintenance cost annually including the Life Cycle Cost analysis. The major impact of the research will be tremendous reduction in the maintenance cost and improve the efficiency of stormwater pollutant traps in urban drainage system and rivers.

METHODOLOGY

The GENIUS project provides new tools, techniques and procedures to enhance waterways located in urban areas. These tools should provide enough scope to cover the differing, multi-functional uses of urban waterways and their adjacent communities across Malaysia. GENIUS provides the best and most innovative practice with which to develop a comprehensive storm water BMPs measures that will achieve the "maximum ecological potential" requirements of the DID and DOE. As integrated storm water management involves many aspects, the project is targeted at different institutions involved in the enhancement of waterways at all levels. In this research, a knowledge based expert system name GENIUS was developed as a tool to minimize erosion and sedimentation due to stormwater in Malaysian construction sites. This system gives recommendations on how to minimise erosion and sedimentation by installing the best management practice which are suitable to site characteristics. The current system has been integrated into an optimization technique for selecting the best stormwater control measure based on some criteria and criterion's weight. This system can be used by engineers, contractors, and decision makers. GENIUS can be considered as part of the "Green Technology Tool" since it helps in protecting the environment in Malaysia. GENIUS able to predict the soil loss and sediment yield generated from construction sites based on guidelines for erosion and sediment control in Malaysia (DID 2010). After estimation of soil loss and sediment yield generation, the system will recommend the Best Management Practices for minimizing erosion and

sedimentation and selects the best measure using multi criteria analysis technique. Apart from that, GENIUS also enable user to design the dry and wet sediment basins. This system also equipped with preliminary design, inspection and maintenance guide for each recommended BMPs.

GENIUS also estimates the quantities of gross pollutants emanating from different type of land use, load capture, and effective cost of using GPTs. Furthermore, it provides detailed design facilities for proprietary and non-proprietary GPTs. Other than that, the decision support system features information on gross pollutant characteristic. A database on inventory of GPTs in Malaysia.

Information and techniques arising from the development of the new integrated assessment tools will be refined into a decision making support methodology. As a result GENIUS will provide planners and environmental authorities, for the first time, with a DSS tool which could be used to justify, prioritise and plan urban river rehabilitation schemes in the future. In addition this tool will allow authorities to address some of the content of the *water management plans* that are required as part of the DID and DOE requirements.

This methodology will be designed to be an easy to use procedure giving results based on sound scientific principles, but for use by non-scientific staff. It will incorporate physical, chemical, biological, aesthetic, social and economic factors. Central to determining the appropriateness and success of policies to promote sustainable development is the development of indicators of sustainability. GENIUS will develop sustainability indicators specific for waterway rehabilitation. In giving a standard methodology it will again be transferable across Malaysia, and give a frame of reference for the associated information and results. Figure 1 illustrates the process of GENIUS development.

As shown in Figure 1 below, the process of GENIUS development started with the knowledge acquisition in which the knowledge required to develop the system is acquired from various sources like guidelines, journal papers, conference proceedings, and the human expert. The acquired knowledge is classified and arranged to be ready for coding (algorithm development). The data is collected from the DID and other organizations to be used in system validation. Following the data collection, the prototype is developed which represents a small portion of the entire system. The purpose of the prototype is to make sure that the system can function effectively. Development of the prototype and the entire system is fulfilled using Visual.Net software which is an effective tool for developing the decision support systems. GENIUS has been verified during the system development process and after the system is entirely developed in which errors in programming, ambiguity, incompleteness, and knowledge representation errors are removed. Eventually, GENIUS is validated using real data in Malaysia and proves to be effective in dealing with real cases.

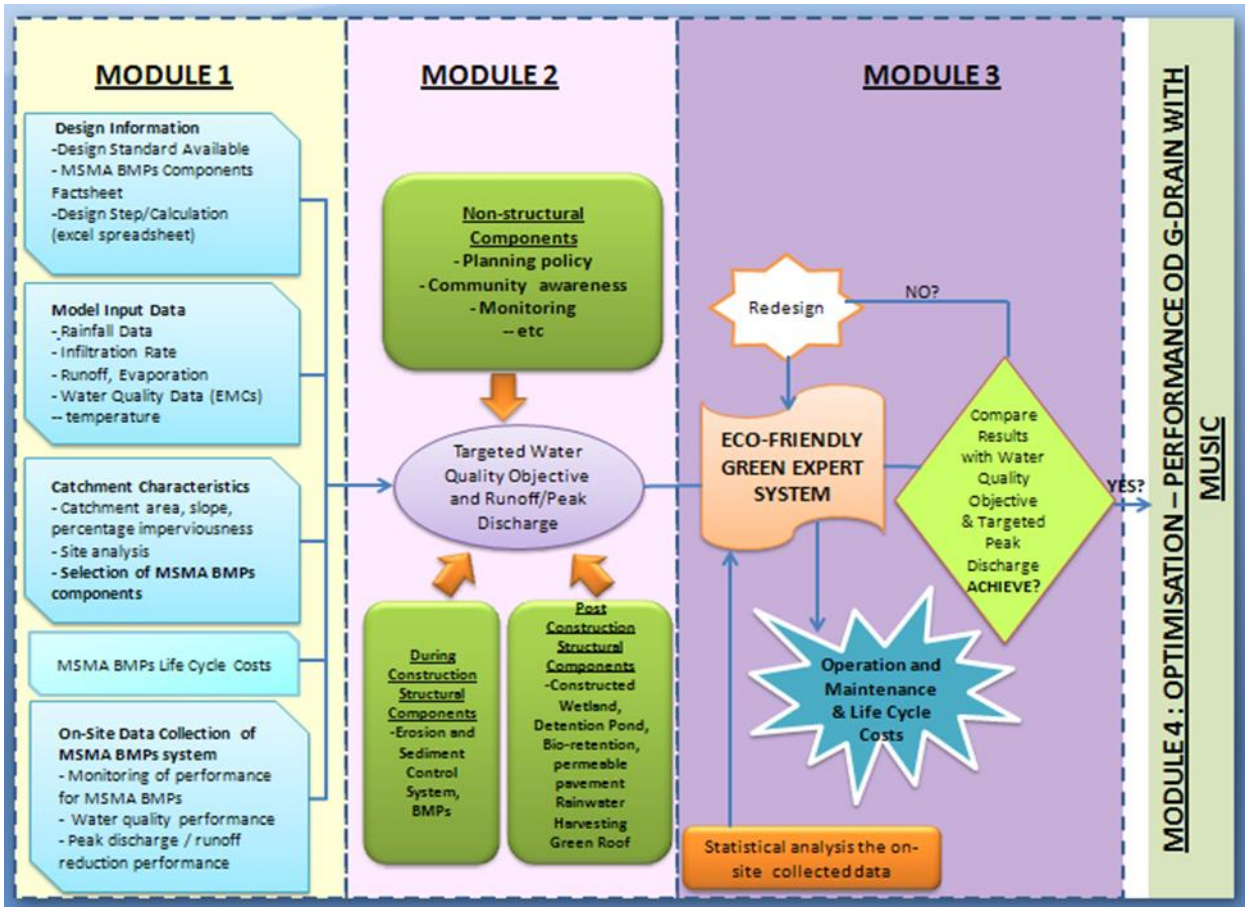

Fig 1. Process for GENIUS development RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The results obtained from the GENIUS software were compared with the observed results obtained from the field. The knowledge engineer divided the system into five major tasks to achieve simplicity and knowledge organization. In each task, the type of data required, options to select, user selections, and GENIUS recommendations were addressed. The results obtained from the GENIUS software are evaluated by experts, and the software is pronounced satisfactory as shown in Figure 2. The results obtained from the GENIUS involves estimation of the storm water pollutant loading and monitoring the pollutant loading generated from different type land use as shown in Figure 3.

Fig 2. Main interface window for GENIUS

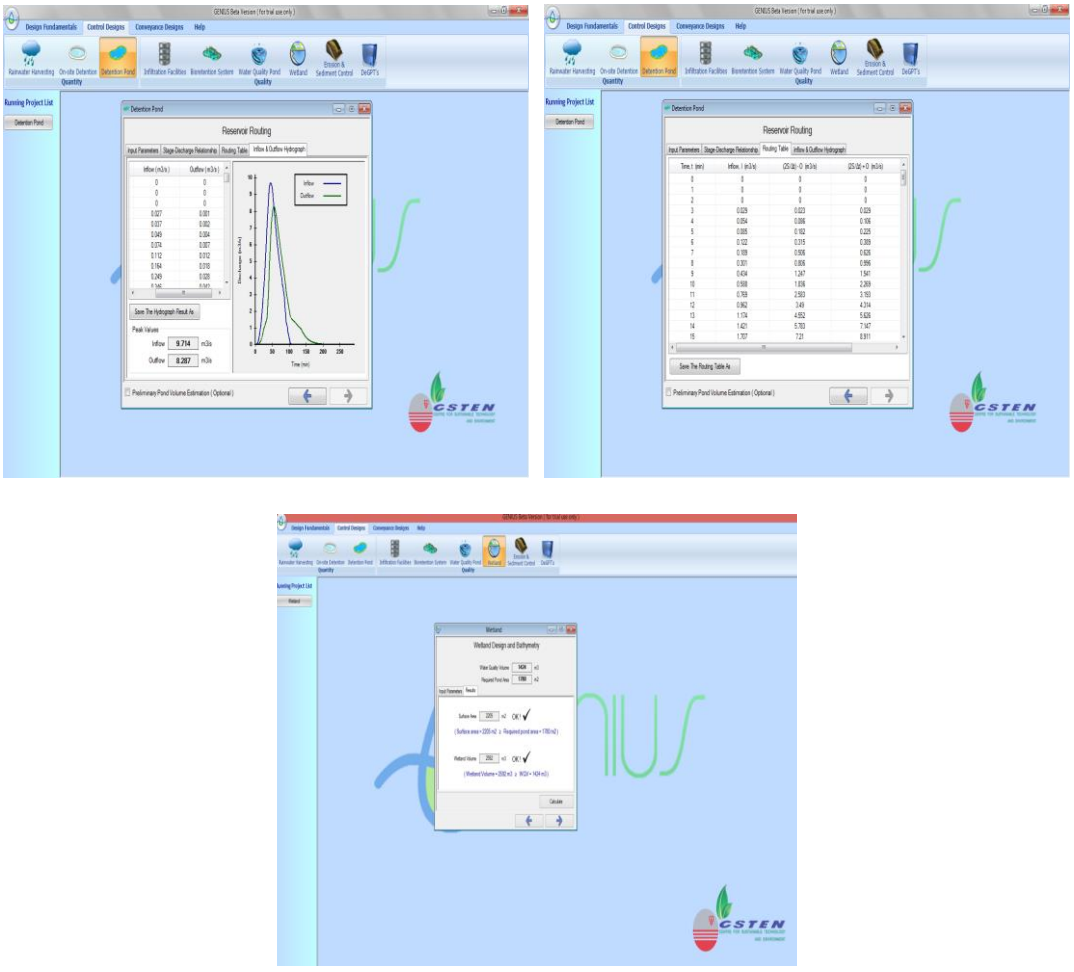

Fig 3. Some of the interface window for GENIUS

As shown in Figure 2 above, GENIUS contains six main components they are; quantity design fundamentals, quality design fundamentals, quantity control designs, quality control designs, conveyance designs, and erosion and sediment control component. Each of these components contains number of categories to perform different design for different facilities. These components are validated separately and then the entire GENIUS is validated.

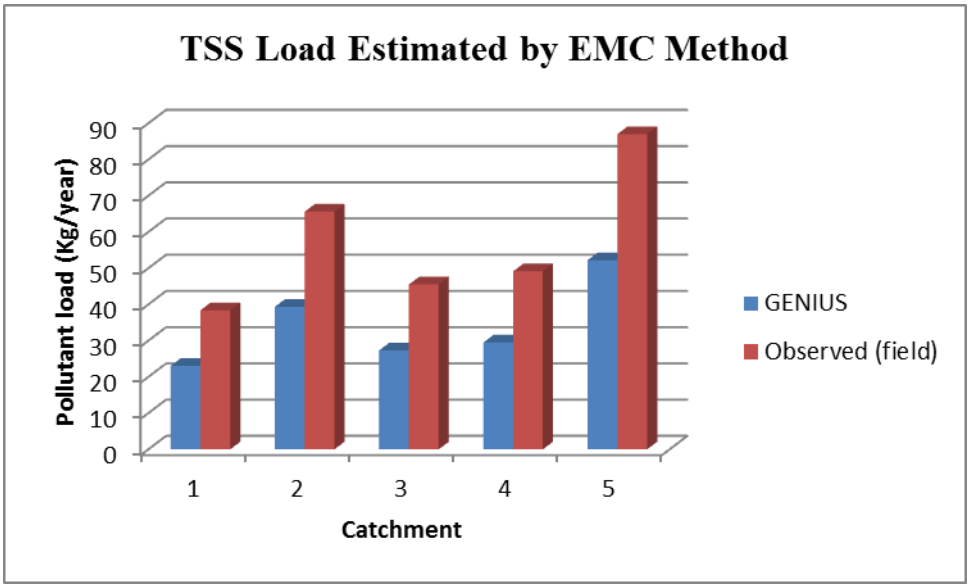

Fig 4. Pollutant Load Estimated by the GENIUS

Performance data for selected device used to remove stormwater pollutants from within the urban drainage network is collected. Finally, the result of this study is incorporated into an innovative green expert system that enable to assist engineers and local authorities to choose the most suitable stormwater BMPs to be installed according to specific site characteristic.The GENIUS can be used as a reference tool for engineers or decision maker in selecting and designing appropriate stormwater BMPs for given resources and management needs, based on understanding of stormwater pollutant movement and trapping.

CONCLUSIONS

In order to address the stormwater quality problem due to Non-Point Sources (NPS) pollution generated from stormwater in urban areas, DID has taken pro-active actions by establishing Manual Saliran Mesra Alam (MSMA) to control the stormwater quantitatively and qualititatively. Thus, MSMA Manual suggested various BMPs to alleviate the flooding problem and water quality issues. However, the performance of storm water BMPs is strongly dependent on specific site criteria including type of land use, hydrological data and maintenance frequency. However, the information should be captured in the knowledge management expert system. To fulfill this task, the so-called integrated green expert system, or green knowledge-based system is developed. One of the advantages of the GENIUS is that it provides automation of expert-level judgment. This is extremely helpful when an expert-level judgment is needed repeatedly for a large amount of cases, like in the planning of stormwater BMPs systems for an entire city catchment.

The findings are incorporated in the development of innovative green expert system with the objective to assist engineers and local authorities to select the most appropriate strategy for storm water BMPs trapping stormwater pollutants in urban area during construction and post-construction. The unique about the GENIUS is that it can predict the pollutants and runoff generated from the development during the construction and post construction based on local data and provides the best strategy for the development. GENIUS can provide the detail design for each selected storm water BMPs based on MSMA 2nd Edition. It is also expands the sources for managing stormwater pollutants in order to rehabilitate the river system and prepare a budget allocation of using storm water BMPs in terms of installation cost and maintenance cost annually including the Life Cycle Cost analysis. In the long term, the urban water systems is improved and meet the target of DID to Class II of clean, living and vibrant river. The developed of an innovative green expert system is definitely contribute significantly to the enhancement of knowledge in stormwater BMPS. In the long term, this study supports the government aspiration to promote green technology in Malaysia.

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