APPLICATION OF ARTIFICIAL INTELLIGENCE IN TRANSPORTATION DEMAND MANAGEMENT: DEVELOPMENT AND IMPLEMENTATION OF E-SUTRA

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Abstract

Allowing traffic to grow to a level at which there is extensive and regular congestion is economically inefficient. Although the construction of additional roads can alleviate some of the effects of congestion, the benefits may be counterbalanced unless the growth in traffic volumes can be restrained. Therefore, another alternative is by implementing Transportation Demand Management (TDM), which means people still travel but at the same time the private car usage is reduced. This paper presents the development of an expert system for sustainable transportation (E-SUTRA) through implementation of TDM. The overall result of 69% accuracy indicates the high possibility of the E-SUTRA system to be used as an advisory tool for sustainable transportation through TDM.

Key Words: expert system**,** transportation demand management, sustainable transportation.

Abstrak

Lalulintas yang dibiarkan tumbuh dengan bebas sehingga menyebabkan kemacetan yang luas dan terus menerus secara ekonomi tidak efisien. Meskipun menambah jaringan jalan dapat mengurangi beberapa akibat kemacetan, manfaat itu dapat dirasakan bila pertumbuhan volume lalulintas dapat dikendalikan. Oleh karena itu, alternatif lain adalah dengan menerapkan manajemen permintaan transportasi, yang berarti orang masih dapat melakukan perjalanan tetapi pada saat yang sama penggunaan mobil pribadi dibatasi. Makalah ini menyajikan pengembangan sistem pakar untuk transportasi yang berkelanjutan, yaitu E-SUTRA, melalui penerapan prinsip manajemen permintaan transportasi. Hasil dengan tingkat akurasi 69% menunjukkan peluang sistem E-SUTRA untuk digunakan sebagai alat bantu dalam perencanaan transportasi berkelanjutan melalui manajemen permintaan transportasi cukup tinggi.

Kata-kata kunci: sistem pakar, manajemen permintaan transportasi, transportasi berkelanjutan.

INTRODUCTION

The demand of travelling increases basing on the assumption that private cars are the best or the only solution to mobility. The supply of infrastructure increases proportionally to traffic volume. At certain point, the supply cannot meet the demand due to certain factors such as budget constraints, land, or space issues (Litman, 2009). Today congestion and traffic-related pollution have increasingly become the major problems in towns and cities worldwide. According to the Kuala Lumpur Structure Plan 2020, released by "Dewan Bandaraya Kuala Lumpur", the number of private cars is rising dramatically. Between 1985 and 1997 the modal share of public transport decreased from 34.3 percent to

19.7 percent. This represents a major shift away from public transport and in particular bus transport; this phenomenon is partly attributable to higher personal affluence leading to an increase in car ownership and to deficiencies in the bus services. Kuala Lumpur City Council (DBKL) stated in its report on Kuala Lumpur Structure Plan 2020 that if the current trends continue, motorised trips by car are expected to almost double in 2020 compared with those of 1997. Increasing road capacity by constructing new roads and widening existing roads do not, in the long run, resolve the traffic situation but simply postpone the problem until more roads need to be built. Most areas in the city, especially the central business districts, are now densely developed with commercial buildings; land acquisitions for road construction are increasingly cumbersome and expensive. Forecasts suggest that, without any action taken, the number of private cars will continue to grow substantially over the next 25 years, adding more vehicles to our roads. As traffic grows road congestions worsen and are more widespread; and they occur for longer periods in a day. Once the traffic passes the capacity limit of a particular road or network, incidences of congestion will increase, and small volumes of additional traffic will have a disproportionate adverse effect on the network. If traffic is allowed to grow unchecked, road congestion will worsen, and in 25 years' time it will incur much higher social, economic and environmental costs than now. Provision of more road space to keep pace with traffic growth is not the answer. It is far too expensive and socially disruptive, and will exacerbate the long-term problems the relevant authorities try to tackle. Some people argue that traffic should find its own level, thus forcing drivers to find alternative ways of travel, or not to travel at all. However, it is believed that this would mean abdicating the economic, social, and environmental responsibilities. In the meantime, the countryside and urban areas would both suffer significant deterioration. The only realistic option is to seek ways of first controlling, then reversing the growth in traffic. This procedure needs to be carried out in the most equitable way, taking into consideration that certain segments of the society have limited choices in the mode of transportation.

In the last few decades, traffic engineers and practitioners had come to the conclusion that traffic problems can be overcome only through the introduction of appropriate TDM measures rather than through the provision of new highway infrastructure (Papaioannou and Georgiou, 2003). The implementation of TDM requires experts or professional advisers because with their specialised knowledge, they can give advice on the most suitable TDM strategies based on the purposes and locational details.

The downside is that the number of these traffic experts is very small; they are not available most of the time for consultation and to give advice on traffic data. This shortage of traffic professionals causes time wastage in rescheduling appointments and interviews, leading to delay of the whole project.

METHODOLOGY

Expert systems provide the advices and assistance for solving problems that are normally undertaken by human experts. According to Aronson and Turban (2001), expert systems are problem-solving packages that mimic a human expert in a special area. These systems are constructed by eliciting knowledge from human experts and coding it into a form that can be used by a computer in the evaluation of alternative solutions to problems within that domain of expertise as shown in Figure 1.

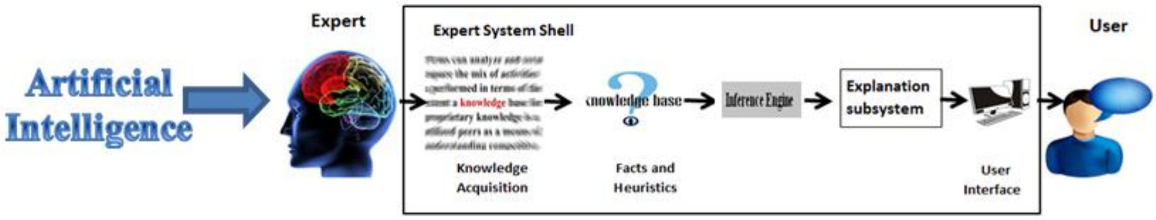

Figure 1 Artificial Intelligence in Expert System Application

The computer tool used to develop the expert system in this research is by using open source software called Kappa-PC version 2.4. The first step is to create a hierarchy from the TDM strategies towards specific objectives, main purpose, choice of area and the final three advices respectively. Kappa-PC provides a developer with the flexibility and power required in supporting complex applications (Intellicorp. Inc., 1997). It allows a knowledge engineer to develop a prototype using the hybrid knowledge representation technique.

RESULT AND ANALYSIS

System Architecture of E-SUTRA

E-SUTRA is developed for young and inexperienced transport engineers and planners, who are involved in the strategy planning and implementation of transportation demand management (TDM). Such expert system is capable of providing them with reliable advices in order to effectively determine TDM strategies during the planning and implementation of project phases. Figure 2 represents the top-level hierarchical architecture of the object model developed for the E-SUTRA domain. The class of E-SUTRA represents the overall prototype that comprises nine major subclasses. The module names in Figure 2 are boxed to indicate that their subclasses are not shown. There are a total of 27 hierarchies in subclasses according to the main objective of TDM Strategies.

Illustration Example of the module in E-SUTRA

As an illustration of a typical object representation in the E-SUTRA domain, the hierarchy of *Crimproved transportoption class*, which is a descendant of the *Congestion Reduction class* shown in Figure 1. *CRITO Large Urban class*, is a geographical area entity that represents appropriate condition of the area where implementation of TDM strategies is needed. It contains the slots: (i) PublicTransportImprovement1, which indicates the strategy on Public Transit (also called Mass-Transit), including various services using shared vehicles to provide mobility to the public; (ii) NonMotorTransportPlan1, which indicates Non-Motorised Transportation (also known as Active Transportation and Human Powered Transportation), including walking and bicycling, and variants such as Small-Wheeled Transport (skates, skateboards, push scooters, and hand carts) and Wheelchair travel; (iii) Ridesharing1, which refers to carpooling and vanpooling (the term is sometimes applied to public transit, particularly commuter express bus), in which vehicles carry additional passengers. Carpooling uses participants' own automobiles. Vanpooling usually uses rented vans (often supplied by employers, non-profit organisations or government agencies). Most vanpools are self-supporting, in which the operating costs are divided among members. Vanpooling is particularly suitable for longer-distance commutes. These slots are inherited from the parent class *Crimproved transport option*, which is a descendant of the *Congestion Reduction class*.

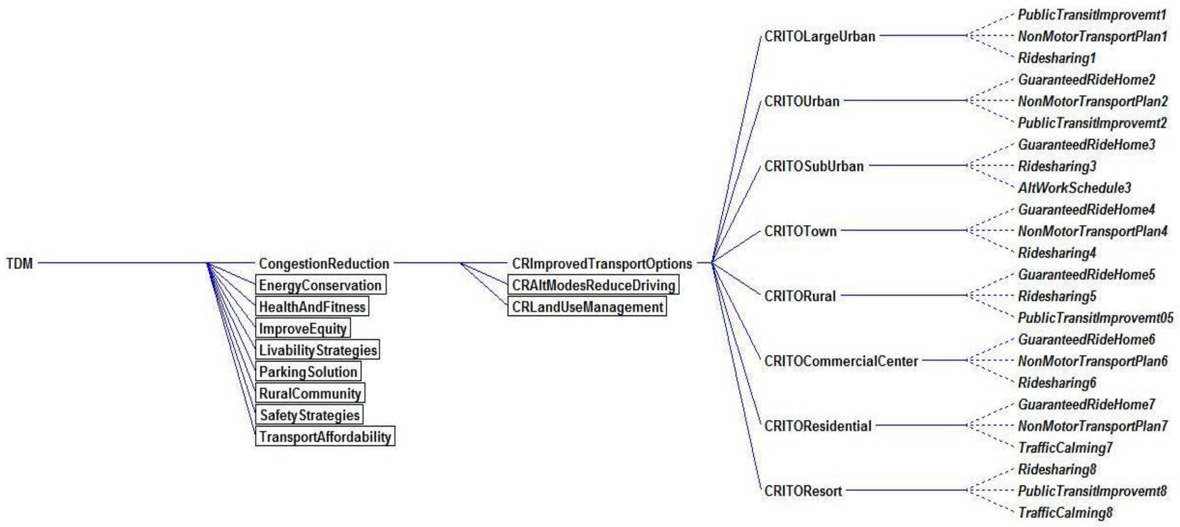

Figure2 Hierarchical Architecture of E-SUTRA

Knowledge Based Model of E-SUTRA

The E-SUTRA knowledge base is made up of nine class modules as mentioned in the previous section, each of which deals with a specific strategy of the TDM domain. These are the steps necessary to launch the E-SUTRA expert system; first, open the Kappa-PC software, then open the E-SUTRA (.kal), and continue by opening the session to start the system. After the program is loaded, the general information interface appears (Figure 3) in the centre of the display area if the computer has resolution of 1366 x 768 pixels (32 bits).

Figure 3 General Information Interface

Clicking on the OK button closes the general information interface and invokes the main E-SUTRA window, as shown in Figure 4. Two-way communications between user and E-SUTRA have been started in this interface. Figure 3 shows the E-SUTRA main menu from which the expert system for TDM can be accessed with the help of appropriate buttons. The main menu screen has e-library and ABOUT buttons to give information on all TDM strategies used in this system.

Figure 4 Graphical User Interface-Main Window

Expert System Module

Since the E-SUTRA system used in this research is based on the "objective to implement of TDM" as the input, clicking on the ADVISORY SYSTEM button leads the user to nine main objectives of implementing TDM, as shown in Figure 5.

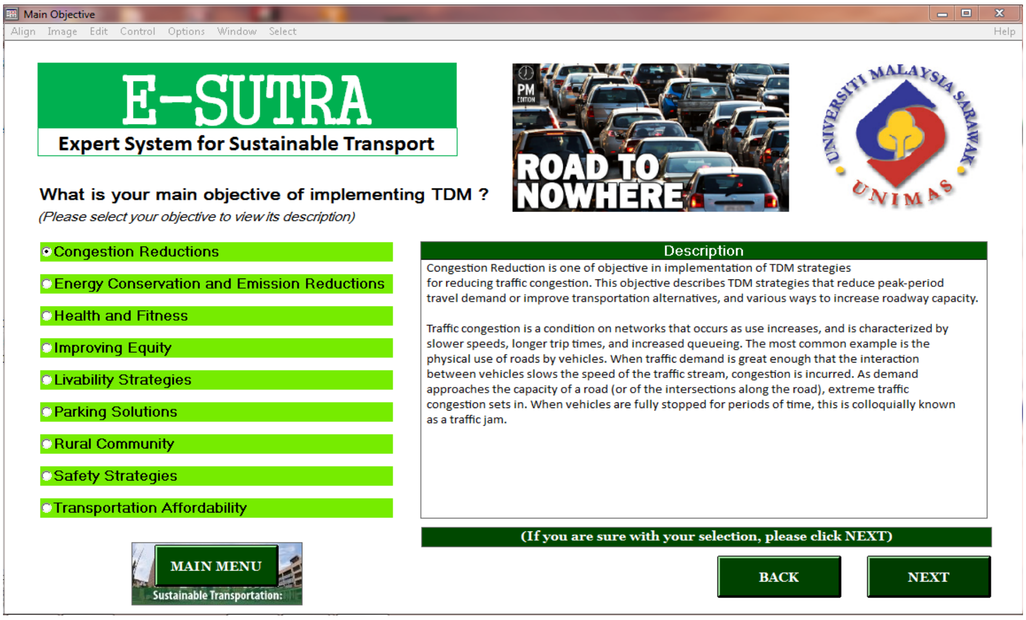

Figure 5 TDM Main Objective Interface

There are nine main objectives associated with this interface as defined inputs. By selecting one that matches the problem encountered in the current situation, the user can see the full description about the objective. In this example, Congestion reduction has been selected. As a result, the description of this TDM strategy appears on the specific box allocated. If the user is certain of his intention and confirms the input (correct main objective), clicking on the NEXT button will call up the viewing window that displays the "Specific Aim to Achieve the Main Objective Interface", as shown in Figure 6.

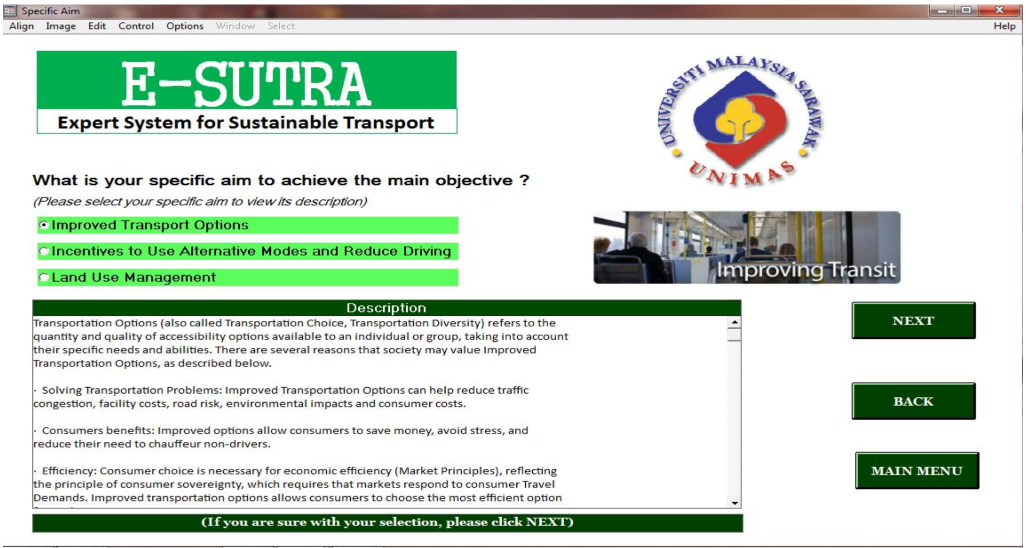

Figure 6 TDM Specific Aim Interface

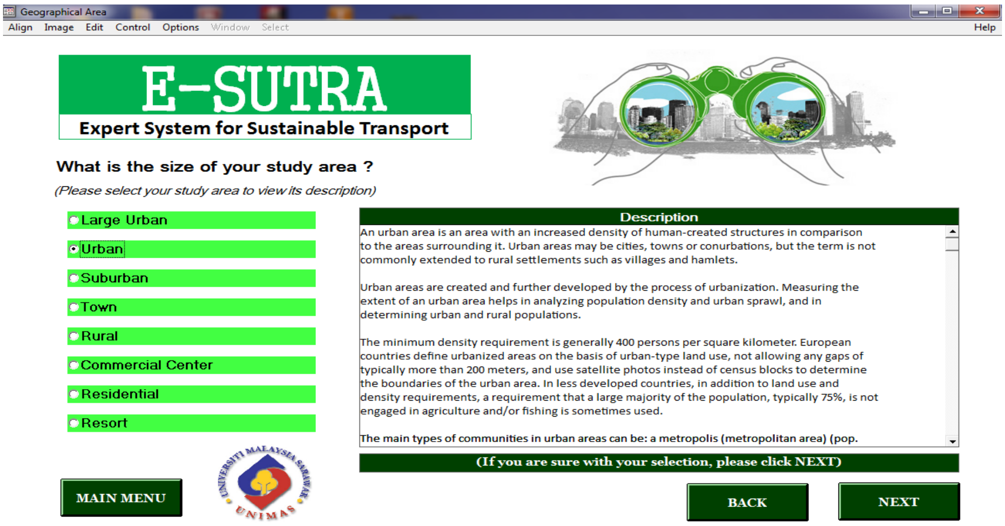

Figure 7 Geographical Area Interface

This dialogue window (Figure 6) is designed to ensure the user chooses appropriate input to avoid wrong advice in appropriate strategy. In this example, the user chooses Improved Transport Options as the specific aim to achieve the main objective, which refers to the quantity and quality of accessibility options available to an individual or group, taking into account their specific needs and abilities. If the user is certain of his intention and he or she confirms the selection, clicking on the NEXT button will call up the viewing window that displays the Geographical Area interface, as shown in Figure 7.

After selecting the specific objective, the size of study area or the areas that need implementation of TDM are listed on the left-hand side of interface window. In this example, the user has selected "Urban" as the size of study area. By clicking on the NEXT button, the user calls up the viewing window that displays Advised TDM Strategies (Figure 8).

Figure 8 Advised TDM Strategies Result Interface

It displays three appropriate strategies which are the most suitable TDM approaches to be implemented based on the input selection. The system suggests three strategies for the user to consider and make a decision to choose a suitable TDM strategy. Descriptions of all three strategies are provided in the dialogue box to help and guide the user. The user can click the VIEW IMPACT button and Advised Strategy Impact Summary will be displayed on the interface, as shown in Figure 9.

As an example, Figure 9 shows the advised strategy for the “non-motorised” travel. The result shows that the travel impact in terms of total traffic reduction is significant, as rating “2” is shown (beneficial). On the benefit summary, most of the objectives are given rating “3” (very beneficial), which is significant in reducing automobile use, providing affordable mobility and increasing travel choices. The advice strategy summary shows the travel impact, benefit and equity if the strategy chosen is implemented. Based on the travel impact summary, the user can easily identify the effectiveness of a strategy in reducing the number of trips or total traffic. The degree of effectiveness is stated in the summary using a rating scale; the rating ranges from 3 (very beneficial) to -3 (very harmful); 0 indicates no impact or mixed impact on the objective if the user implements this strategy.

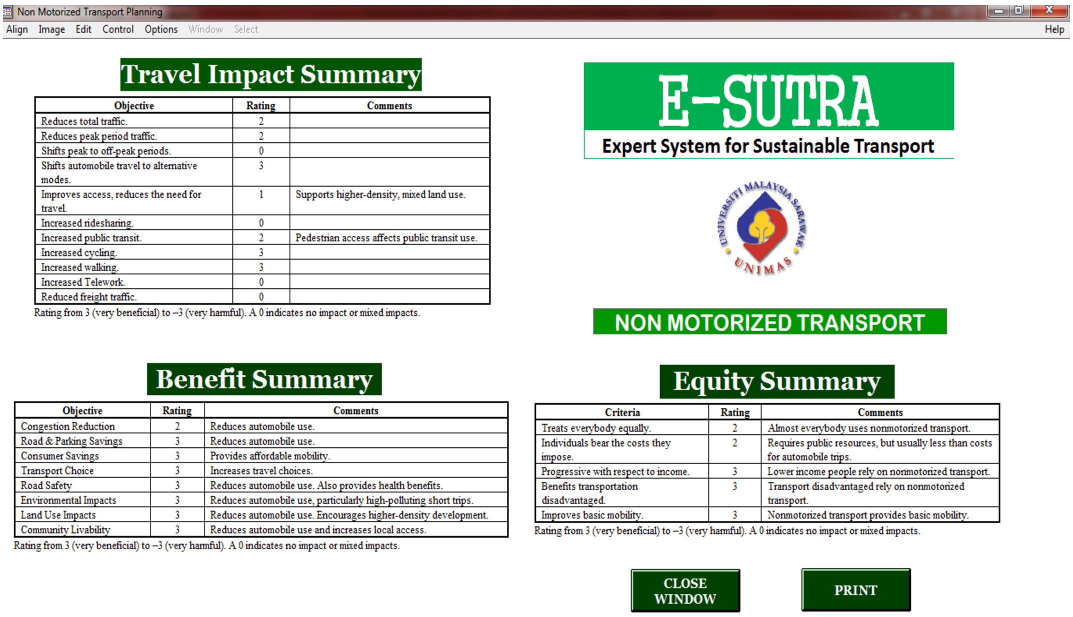

Figure 9 Impact Summary Interfaces

Validation and Evaluation (V and E)

Based on the judgment, the overall performance of E-SUTRA is comprehensive and satisfactory; the evaluator who is an expert in transportation field concurs with the author’s view. Evaluators are independent people (not domain expert) who have the same qualification as the domain expert.

Validation

Typically, according to O’Keefe (1993), the performance of an expert system can be validated by running a number of test cases through the system; the results of the system are then compared with either known results or expert opinions. Therefore, the validation process for the E-SUTRA system is carried out by testing the system and comparing the results with the views of a human expert. The performance of E-SUTRA was validated through experimental design using scenario cases of enquirers, which covered all sub-modules in the prototype system. Opinions of more than ten transportation experts were involved in this validation exercise. The purpose of this validation exercise was to gauge the accuracy of the system's knowledge base. In the validation process, the success rate of the system is calculated in terms of percentage. The final validation results demonstrate the performance of E-SUTRA is quite close to that of the experts; 72% of decisions and advices provided by the human experts match the output of the E-SUTRA system, as shown in the example given in Table 1. This is a positive indication of the accuracy of the knowledge base of the E-SUTRA system. Table 1 shows the matrix approach to measure the accuracy of the E-ASSIST system. As mentioned earlier, the results of this example are significant as 72% of the opinions of expert evaluators match the output of the E-ASSIST module in terms of advices generated.

Table 1 Example of TDM Strategy Advice: Comparison Between E-ASSIST Results and Human Expert Decision (Matrix System)–*Submodule: Congestion Reduction-Improved Transport Option*

GEOGRAPHIC AREA	E-ASSIST			EXPERT-EVALUATORS																				
	ADV1	ADV2	ADV3	ADV1							ADV2							ADV3						
				ADV 1-1	ADV 1-2	ADV 1-3	ADV 1-4	ADV 1-5	ADV 1-6	ADV 1-7	ADV 2-1	ADV 2-2	ADV 2-3	ADV 2-4	ADV 2-5	ADV 2-6	ADV 2-7	ADV 3-1	ADV 3-2	ADV 3-3	ADV 3-4	ADV 3-5	ADV 3-6	ADV 3-7
Large Urban Region	Public Transport Improvement	Non-Motorized Transport Planning	Ride Sharing	√	x	√	√	√	x	√	x	√	√	√	x	√	√	x	√	√	√	x	√	√
High-Density Urban	Public Transport Improvement	Non-Motorized Transport Planning	Ride Sharing	√	√	√	√	√	√	x	√	x	√	√	√	√	x	x	√	x	√	√	x	√
Medium-Density Urban/Sub-Urban	Guaranteed Ride Home	Ride Sharing	Alternative Work Schedule	√	x	√	√	x	√	√	√	√	√	√	√	√	√	x	√	√	√	√	x	√
Town	Guaranteed Ride Home	Non-Motorized Transport Planning	Ride Sharing	√	√	x	√	√	√	√	√	x	√	√	√	√	√	√	√	x	√	x	√	x
Low-Density Urban/Rural	Guaranteed Ride Home	Ride Sharing	Public Transit Improvement	√	√	x	√	√	x	√	√	√	x	√	x	√	x	√	√	x	x	√	√	√
Commercial Center	Guaranteed Ride Home	Non-Motorized Transport Planning	Ride Sharing	√	√	√	√	√	x	√	x	√	x	√	√	√	x	√	x	x	√	√	√	√
Residential Neighborhood	Guaranteed Ride Home	Non-Motorized Transport Planning	Traffic Calming	x	√	√	√	x	√	√	x	x	√	√	x	√	√	x	√	x	√	√	√	√
Resort/Recreation Area	Ride Sharing	Public Transit Improvement	Traffic Calming	√	√	√	x	√	√	√	√	x	√	√	√	x	√	x	√	√	x	√	√	x
				SCORE : 121/168				72%																

ADV1-1 = Advice 1 by Evaluator 1, ADV1-2 = Advice 1 by Evaluator 2 ......ADVn-N = Advice n by Evaluator N

Table 2 Summary of Percentage Matched between E-SUTRA and Expert Evaluators

	ITO	UALT	LUM
Congestion reduction	72%	65%	69%
Energy conservation	67%	75%	70%
Health and fitness	67%	66%	61%
Improving equity	78%	67%	63%
Livability strategy	65%	65%	66%
Parking solutions	76%	77%	68%
Rural community	75%	64%	61%
Safety strategy	65%	73%	77%
Transport affordability	78%	80%	66%
		Average:	**69%**

ITO : Improved Transport Option
UALT: Use Alternative Modes & Reduce Driving
LU: Land Use Management

The system generated a total of 648 (9x3x8x3) strategies based on the nine objective modules, three specific aims, eight geographical areas and three TDM advice strategies; the percentages of accuracy validated based on all the outputs from the system are as shown in Table 2.

Based on all the aspects discussed in this paper, it is clear that E-SUTRA has met the conditions required for its application as an expert system for sustainable transportation through transportation demand management. It can be used as a tool for advising junior engineers in order to make decisions on appropriate TDM strategies to be implemented in Malaysia. The validation results show that more than 60% or exactly 69% of decisions and advices outputted by the E-SUTRA system match those of expert evaluators who are transport specialists. Since the E-SUTRA system is a representation or an abstraction of human expertise, perfect performance cannot be expected (O'Keefe 1993). The result of 69% accuracy has exceeded the expected level of performance of the system. From the perspective of users, the acceptable percentage accuracy of performance for a system is called the acceptable range of performance, and this should be specified at some stage of development (O'Keefe 1993). It can be certified by a third party, a government agency or the project sponsor. In this case, the acceptable range of performance has been specified by a Malaysian government authority (DBKL) with a range of 50-60% during the knowledge acquisition process. The overall result of 69% accuracy indicates the high possibility of the E-SUTRA system to be used as an advisory tool for sustainable transportation through transport demand management. Thus, we are proud and happy to say that the E-SUTRA system has accomplished the purpose for which it was designed.

Evaluation

As mentioned by Wentworth (1995), evaluation of an expert system is reflected by the acceptance of the system by its end users as well as the performance of the system in its application. Generally, the flow of the consultation sessions or advice sessions between the user and the E-SUTRA system was satisfactory. The user was able to learn every single description in the TDM strategy and could obtain recommendations given by the system.

The system allowed the user to view the impact of results before making decisions on the appropriate TDM strategies to be implemented in particular situations based on the input selected.

The user-friendliness of E-SUTRA was assessed to be satisfactory as a working prototype. Furthermore, the main screen of E-SUTRA, which consists of several buttons with text images, has been evaluated as user-friendly by most of the evaluators. The evaluation form recorded “good” in the following items assessed: “readable”, “visually pleasing” and “attention getting”. Only one parameter, “consistency of format” was evaluated as “fair” since every sub-module interface has a different pattern and layout. In addition, the evaluators concluded that the system has adequately met its objectives, it is free from bugs and the program runs properly. The most significant discovery was that the evaluators noted the system uses appropriate strategy in order to build authentic scenarios based on the input selection. Finally, the results of the evaluation form show that the features and interface of the E-SUTRA system are acceptable to the transportation experts and the end users.

CONCLUSION

The E-SUTRA system is an example of successful development of an expert system for sustainable transportation, particularly in the area of implementations of TDM. This research project demonstrates that the application of knowledge-based expert system in this domain holds a lot of potential and promises. The method of frame-based knowledge representation coupled with the power of object-oriented programming enables the knowledge to be abstracted and represented as codes; the computer can manipulate the information efficiently and the knowledge engineers can update the knowledge base with great flexibility. Since the knowledge, techniques and strategies in the transportation arena are dynamically growing, the E-SUTRA system is by no means complete at this stage. There is certainly room for future studies.

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