GIS Based Integrated Planning Assessment for Sustainable Land Use Development

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Abstract

Development planning and assessment require an effective approach to achieve the desired goals and objectives, evaluate alternative as well as control development programs that are in line with the current and future prospects. The advent of information technology encouraged the integration of planning assessment and GIS approach for sustainable development. GIS technology has long been applied in planning activities which essentially include plans formulation as well as development control. The Manual for preparing the various levels of plan has provided that all plans use GIS technology in plan formulation. This paper sets out the information requirement and GIS functionalities, which are relevant to various plans especially the regional plan for Lembah Klang region. The dynamic nature of planning and monitoring of development in Klang Valley, the fastest growing region in Peninsular Malaysia, apparently requires a 'tool' for continuous evaluation and analysis of the current environment as well as the capacity for future development. As such, a new concept of evaluation model named Integrated Land use Assessment (ILA) was introduced within the prior developed "Application of Geographic Information System (GIS) for Klang Valley Region" (AGISwlk). The introduction of ILA as an integrated land use planning approach that exploits the GIS analysis capabilities, supported by the use of planning support systems is seen as a good mechanism for monitoring urban development. The ILA model developed is implemented through incorporation with the use of the *What if?* PSS which is a scenario-based, policy-oriented planning support system that uses increasingly available GIS data. Apart from that, a user interface is also developed to ease the access and preparation of data from the AGISwlk database to run the ILA model and generate alternative scenarios. This paper will discuss the approach, developed model and underlying concept of ILA and emphasise on the case study concerning the use of ILA model for generating alternative development scenarios in Klang Valley. To conclude, several issues raised in the study will be discussed.

Keyword: Geographical Information System, Integrated Land Use Assessment and Planning Support System

Introduction

Driven by the rapid changes of technology, multi-cross disciplines took the opportunity to incorporate in the information technology business. In the planning field, information technology has changed planner's view and other professionals to adapt digital world in conducting their tasks. The incorporation of multi-technology, especially Geographical Information System (GIS) had contributed tremendous effect to development planning and process which can now be done faster than ever while thorough evaluation can be made easier with less time consumption and therefore being more cost-effective.

In planning development, land use is the major concern of any activities involved. As such, to achieve sustainable living environment, the planning and management of land should be given the highest priority though economy, infrastructure, facilities and environment pressure for demanding development. The impact of development depends very much on the management of land by local government and other parties involved in development plans and planning process.

Sustainable Development

United Nations World Commission on Environment and Development defines Sustainable Development as 'meeting the needs of the present without compromising the ability of future generations to meet their own needs'. Sustainable development is not a new concept. Rather, it is the latest expression of a long-standing ethic involving peoples' relationships with the environment and the current generation's responsibilities to future generations.

Sustainable development requires us to take account of the social, environmental and economic consequences of our actions both now and for future generations. It should be noted that sustainable development is not a synonym for environmental conservation but is, rather, concerned with development that is undertaken with due regard for the protection of the environment.

The Town and Country Planning Act 1976, (Act 172), stipulates that the local government is the local planning authority for the area. As land is a State matter, thus any urban problems associated with development such as transportation, flash flood, landslides and siltation as well as lack of housing and facilities, need to be tackled at the planning authority level. As a reflection of the practice of sustainable development, and given the importance of environmental protection, it is imperative that environmental concerns be incorporated into development planning. Therefore, it can be agreed that 'the quest for sustainable development means that local authorities have to maintain comfort, convenience, efficiency, and preserve their built and natural environment' (Mohamad Saib, 2002).

GIS for Development Plan System in Malaysia

Development planning requires an effective planning approach to achieve the desired goals and objectives, evaluate alternatives as well as control development programs that are in line with the current and future prospects. GIS technology has long been applied in planning activities, which essentially include plans formulation as well as development control (Yaakup *et al.*, 2003).

The different spatial level and form of plans requires different support in term of information system. Various skills are also required for preparing development plans using GIS. They include the ability to build up and manage the database which should incorporate socio-economic attributes of the local population. Managing services at local level would also call for contiguity and proximity analysis.

The manual for preparing the various levels of plan has provided that all plans use GIS technology in plan formulation. Focusing on the case study of Klang Valley, namely the development of Application of GIS for Wilayah Lembah Klang (AGISwlk), this paper will discuss the approach of the evaluation model developed known as Integrated Land Use Assessment (ILA).

Next, the paper will discuss ILA modelling and spatial analysis techniques appropriate in Klang Valley region, which integrate GIS, and other PSS for plan generation and plan evaluation technique.

Klang Valley Region

This paper looks at the Klang Valley Region which of late shows all the evidences of going through metropolisation process. The Klang Valley Region which is made up of five districts including Gombak, Klang, Petaling, Kuala Lumpur and Hulu Langat, is experiencing the highest rate of urban growth in the country. The City of Kuala Lumpur has long been the center of economic growth activities for the Klang Valley Region. The National Physical Plan (RFN) has also stressed on the Kuala Lumpur Conurbation. Kuala Lumpur urban sprawl extends in all directions well into the surrounding state of Selangor, but particularly to the south and southwest of the Klang Valley (ESCAP Publications). Figure 1 shows the conurbation area in Peninsular Malaysia.

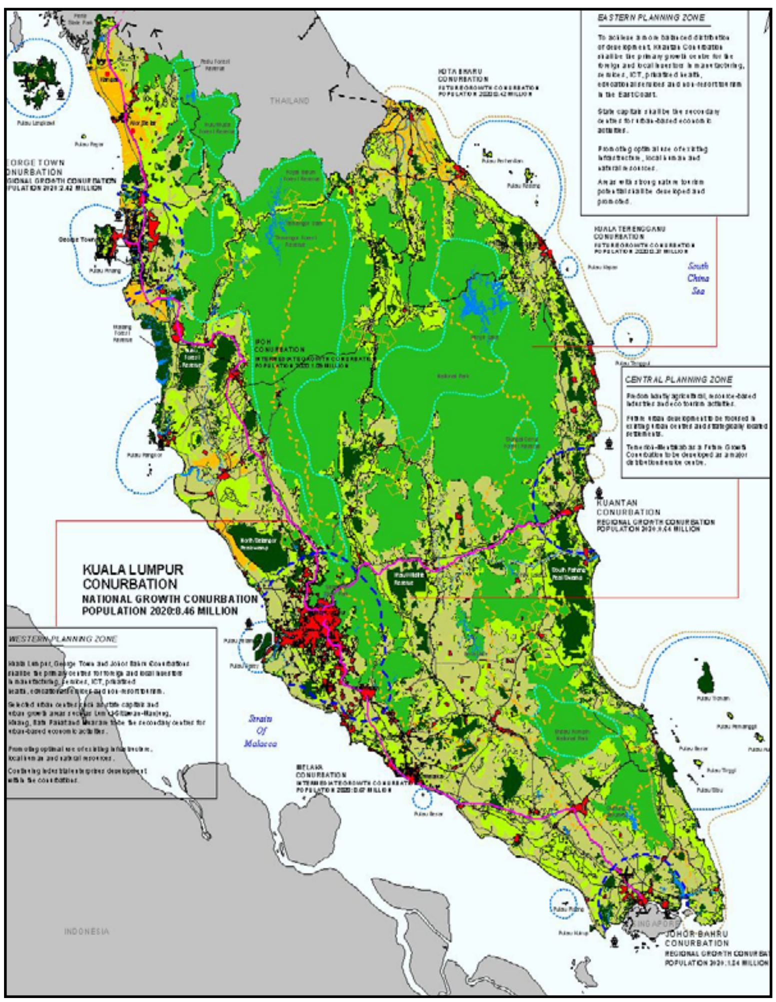

Figure 1 : National Physical Plan- Alternative Development Plan Strategy
(Source: Technical Report of National Physical Plan, FDTCP, 2003)

The Klang Valley conurbation is considered the most developed and fastest growing region in the country. The region is faced with the most serious urbanization problems such as urban sprawl and scattered development, land use conflicts, squatters and slum housing development, inadequate network facilities, land shortage, inevitable high land prices and the degradation of environmental quality. Much of the original forest cover has been replaced by urban land use, and development has now encroached into the foothills resulting in surface erosion and increased incidence of flash floods. The region is also well served by road networks whose efficiency is hampered only by traffic congestion.

The whole of Klang Valley had experience a tremendous growth rate of built up area. Analyses carried out within 1988 to 1998 (Figure 2) have indicated a four-fold increase in built-up areas. This might be influenced by the urbanisation process, which consequently led to forced and pressured development to further cater for the urban needs. Furthermore, the expansion of the city due to pressures for new development within the city and urban fringes have systematically seized the limited green area available. In effect, there is a decline in the urban eco-environment through loss of urban green in Klang Valley as shown in Figure 3 and Table 1 (BKWPPLK, 2001).

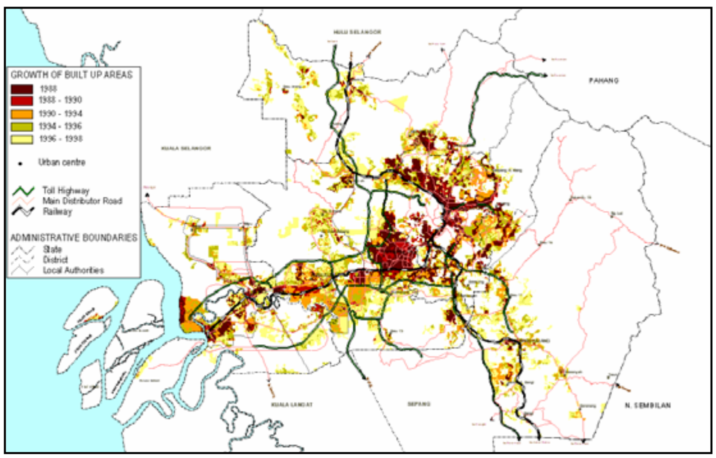

Figure 2 : The Growth of Built-Up areas in Klang Valley 1988-1998

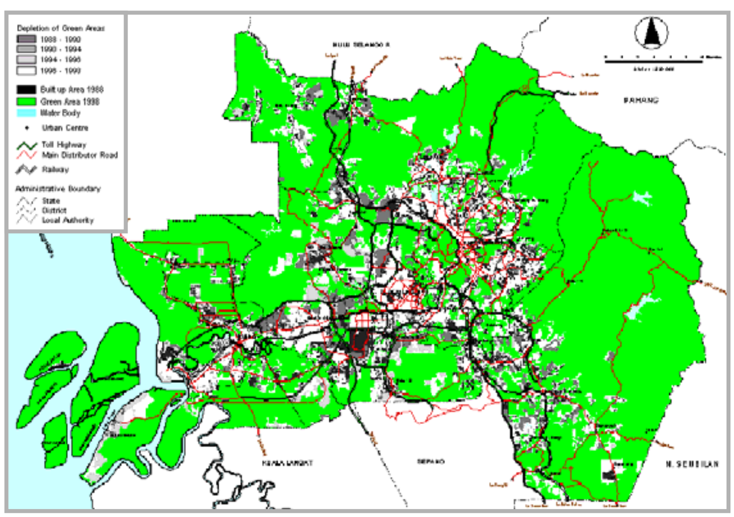

Figure 3 : Urban Green Changes in Klang Valley Region (1988-1998)

Table 1: The Loss of Green 1988-1998

DISTRICT	**GREEN AREAS (Hectares)**				**LOSS OF GREEN 1988 - 1998**	
	1988	**1990**	**1996**	**1998**	**Hectares**	**Percentage (%)**
Gombak	5,099.3725	1,981.2964	2,448.4904	6,966.6644	16,445.8237	28.98
Hulu Langat	3,666.9774	2,238.4947	4,490.4468	2,694.5615	13,090.4804	16.70
WPKL	368.6260	280.9134	2,565.1901	533.4750	3,748.2045	48.46
Petaling	9,673.3324	2,020.6212	8,164.9057	1,785.1085	21,643.9678	55.53
Klang	4,979.5235	890.8447	4,512.7240	14,262.6627	24,645.7549	42.51
TOTAL	**23,787.8318**	**7,412.1704**	**22,181.7570**	**26,242.4721**	**79,574.2313**	**33.18**

Source: BKWPPLK, 2001

One of the main factors contributing to the existence of these problems is the lack of information in supporting the monitoring processes. Due to huge/massive data and information to be gathered and managed, this has set the need for an integrated and efficient information system particularly to assist in environmental control. Essentially, an integrated approach of land use assessment using GIS (ILA) is important to further strengthen the effort in achieving sustainable land use development. The purpose of ILA implementation in AGISwlk is to act as development planning mechanism, be used as guidelines and reference for future development and support the land development control as well as provide alternative directions for development of Klang Valley.

GIS based Integrated Planning Assessment

The Geographic Information Systems (GIS) has long been accepted as the most appropriate solution to address spatially referenced data. The essence of GIS in the plan making process, quoting Calkins (1972), suggested that 'better planning will be achieved through better information, and better information will necessarily flow from an information system'. The Planning Support System (PSS) which is a combination of GIS data, urban model and presentation technique using computer for planning support has also been increasing in use for more enhanced end products.

Integrated Land Use Assessment (ILA)

Evaluation is an essential step in the planning process especially in selecting the appropriate development scenario alternative to be implemented. It is necessary for decision-makers to define the suitable planning evaluation model so that the development scenario chosen could cater for future planning and its implementation is beneficial to the public. As such, the ILA model developed is implemented through incorporation with the use of the *What if?* PSS which is a scenario-based, policy-oriented planning support system that uses increasingly available GIS data.

The introduction of ILA as an integrated land use planning approach that applies the GIS analysis capabilities while supported by the use of planning support system (*What if?*) is seen as a good alternative for achieving better and more rational decisions. The developed model is expected to dynamically support the preparation of the Klang Valley Regional Master Plan (PELAWI). Figure 4 shows the developed and implemented model for integrated land use assessment of Klang Valley. ILA is also expected to accommodate the main tasks of the Ministry of Federal

Territory (KWP) concerning the development of Klang Valley which are regional planning, facility management as well as problem solving.

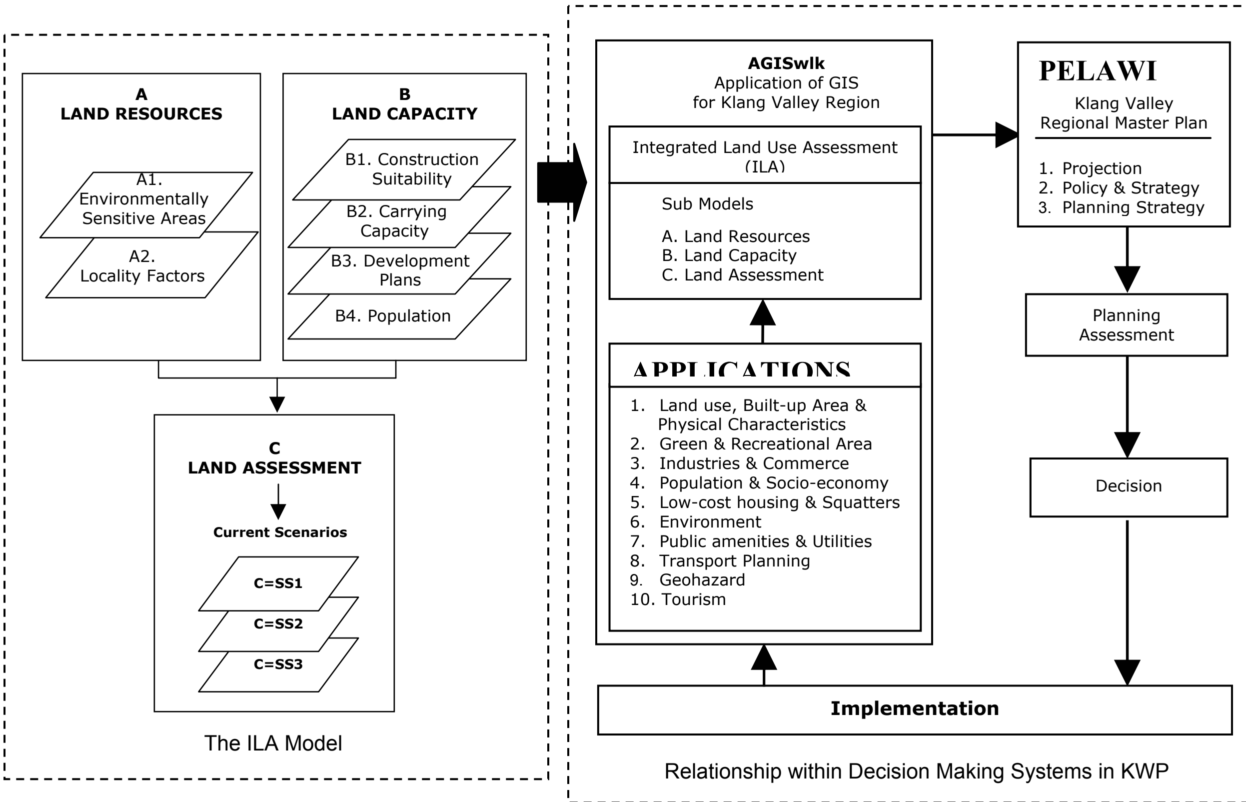

Figure 4: The model developed and implemented for Integrated Land Use Assessment of Klang Valley

The application modules of AGISwlk were initially developed base on relevant sectors associated with development planning and monitoring of the region. Various analyses were carried out under each module through adoption of the spatial modelling techniques using various GIS spatial analysis functions. They were used to generate scenarios and predict "What-if" situation base on the various sets of predetermined criteria. The database previously developed based on macro data approach was subsequently updated to provide comprehensive lot-based data especially for supporting analyses needed for deriving solutions to specific problems at micro level. The overall system is further enhanced through development of user interface to simplify data access and management as well as web based GIS for public participation and data sharing.

The Approach and Concept of ILA

The concept of integrated approach in ILA is focused on the aspect of integration of the applications previously developed in AGISwlk which are more sector-based (Figure 5). ILA emphasizes on the concept of integration whereby relationship exists between the database developed and implementation of application-based analyses in AGISwlk, with the use of planning support systems.

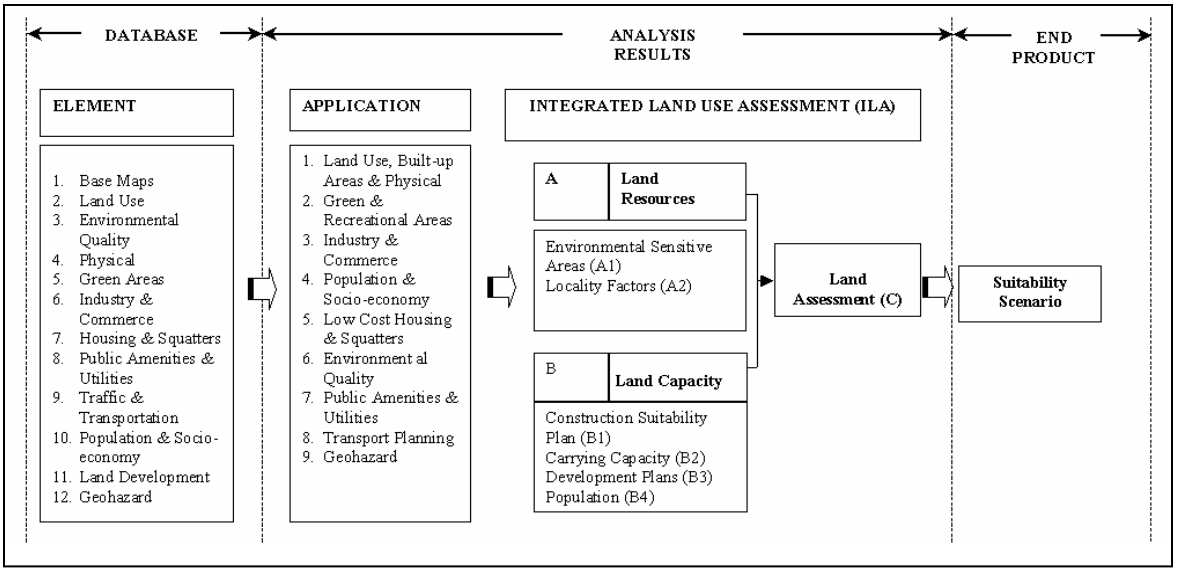

Figure 5 : The Concept of Integrated Land Use Assessment (ILA)

The assessment technique in ILA adopts the GIS spatial analysis technique combined with the weighting and sequential techniques. ILA involves two types of assessment namely Land Resources Assessment and Land Capacity Assessment. Land Resource Assessment aims at evaluating potential land resources for development in terms of suitability by considering two deriving factors, which are Environmental Sensitive Areas and Highly Accessible Area base on locality factors. Land Capacity Assessment, on the other hand, evaluates the extent of acceptable development in terms of land supply and carrying capacity toward environmental sustainability. The Land Capacity Assessment involves four deriving factors including Construction Suitability (Terrain Map); Carrying Capacity for River Basin, Transportation as well as Public Facilities; Development Plan; and Population Carrying Capacity.

Implementation of ILA

ILA study was implemented for the area of Batu and Gombak sub river basins, covering about 7,508.2 hectare of the District of Gombak in Klang Valley. In this study, both the Land Resources Assessment and Land Capacity Assessment sub models were applied to generate development scenario alternatives but due to several constraints, not all the selection factors were used.

The Land Resources Assessment was carried out by considering two deriving factors, which are Environmentally Sensitive Areas (ESAs) and Potential Areas for Development based on locality factors. While Land Capacity Assessment involved only one deriving factor which is Construction Suitability (the terrain map). This is considered the preliminary study to design a model based on an integrated approach in generating development scenario alternatives while considering the land resources and land capacity factors.

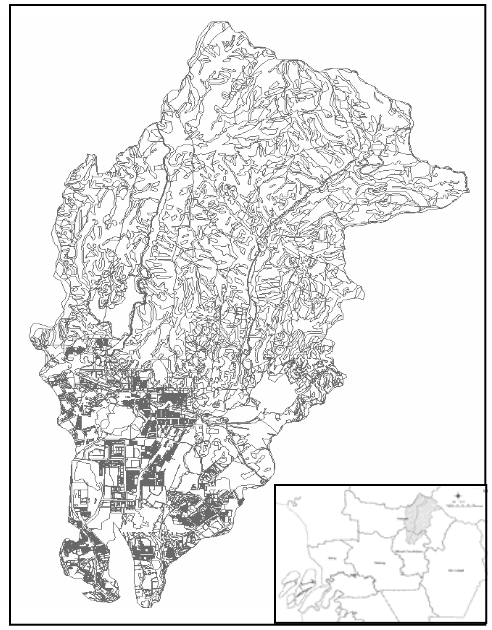

Figure 6: The Uniform Analysis Zones (UAZs) of the study area

The implementation of ILA model was divided into three main stages. The methodology was developed and organised based on the GIS spatial analysis process and planning support system framework. The first stage involved identifying of policy and strategy to be used as guideline and direction in achieving the desired output. The second stage involved identifying data in AGISwlk database to be used to create Uniform Analysis Zones (UAZs) based on predetermined selection factors (Figure 6). UAZs are GIS generated polygons, which are homogeneous in all respects considered in the model (Klosterman, 2001). The third stage which is the analysis and modeling stage involved the process of creating UAZs, designing project file and conducting suitability analysis. The process of creating the UAZ layer includes combining of GIS data layers. The GIS functions involved in the process are the overlay function, classification and measurement. Designing the project file is most important because it influences the suitability analysis and affects the resulting output. The suitability analysis involves three steps, which are selecting the suitability factors, specifying factor weights and specifying factors ratings. In this study, a mathematical formula was applied for all factors involved in generating the development scenarios.

Through the study, a table of deriving factors and selection criteria based on the ILA model was prepared (Annex: Table 2) while at the same time allowing users the choice and flexibility of redefining the factors to generate the scenario alternatives relevant to the different policies, weight and rating concerned.

The result is shown in the form of maps, graphs and tables. Basically, the maps showed the areas suitable for development based on level of suitability namely most suitable, moderately suitable, least suitable and not suitable. The generated report provides a formal documentation on the assumption used for each alternative scenario and summary of the result in the form of graph and table. The table listed the category of suitability and calculated areas in the unit of hectare (Table 3) while the graph provides comparison in term of area (hectare) between the different generated scenarios. Three scenario alternatives were generated by using the same factors but by applying different weights and ratings appropriate to three different strategies (Figure 7).

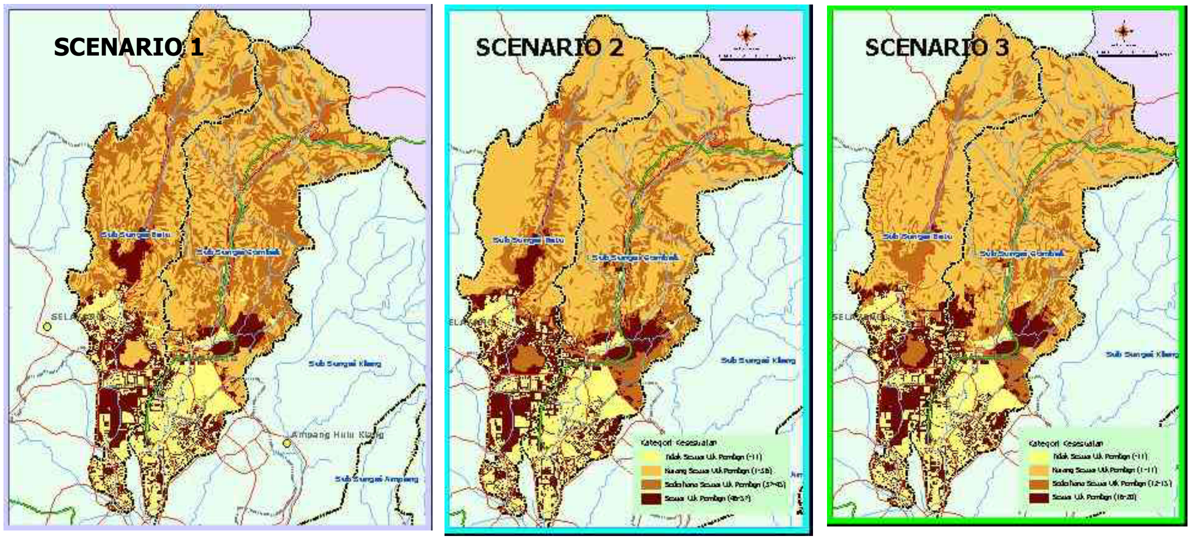

Figure 7: Integrated Land Use Assessment Development Options

Table 3: Results of Land Suitability Assessment

Development Suitability	**Scenario 1**		**Scenario 2**		**Scenario 3**	
	Area (Hectare)	**(%)**	**Area (Hectare)**	**(%)**	**Area (Hectare)**	**(%)**
Not suitable	2593	13.5	2593	13.5	2593	13.5
Least suitable	7876	40.9	9652	50.1	10203	53.0
Moderately suitable	6199	32.2	4103	21.3	3790	19.7
Most suitable	2589	13.4	2909	15.1	2671	13.9
Total area	**19256**	**100.0**	**19256**	**100.0**	**19256**	**100.0**

ILA Planning Support System User Interface

The main function of ILA PSS is to facilitate user in data organisation and preparation especially in preparing the UAZ layer based on the ILA model, which is required in generating development scenarios using the *What if?* Planning Support System. In the case of ILA, the UAZ layers are basically derived using the geoprocessing functions in ArcGIS. Initially, the functions provided in ILA PSS were developed totally through VB programming, but the introduction of ModelBuilder as a geoprocessing analysis component in ArcGIS version 9 has very much simplified the development process. The use of ModelBuilder has enabled several analyses to be executed simultaneously to obtain the end product faster. The conceptual design of ILA PSS is illustrated in Figure 8.

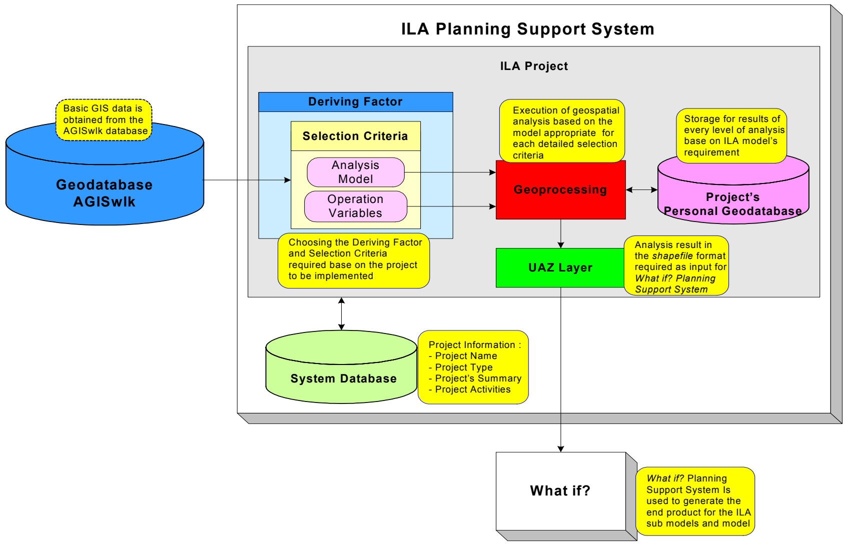

Figure 8: Conceptual design of ILA PSS

ILA PSS involves the use of the MS Visual Basic 6.0 software for its application and user interface development. MS Access is used for building the ILA PSS database which stores the parameter records and system variables. While the ArcGIS Engine Developer Kit is used as the programming component for the display and manipulation of the GIS data. The user interface was designed base on the sub models of each deriving factor in the ILA model. The interface developed (Figure 9) will allow user to change the parameter value in the model and subsequently generate the UAZ layer for the specific model.

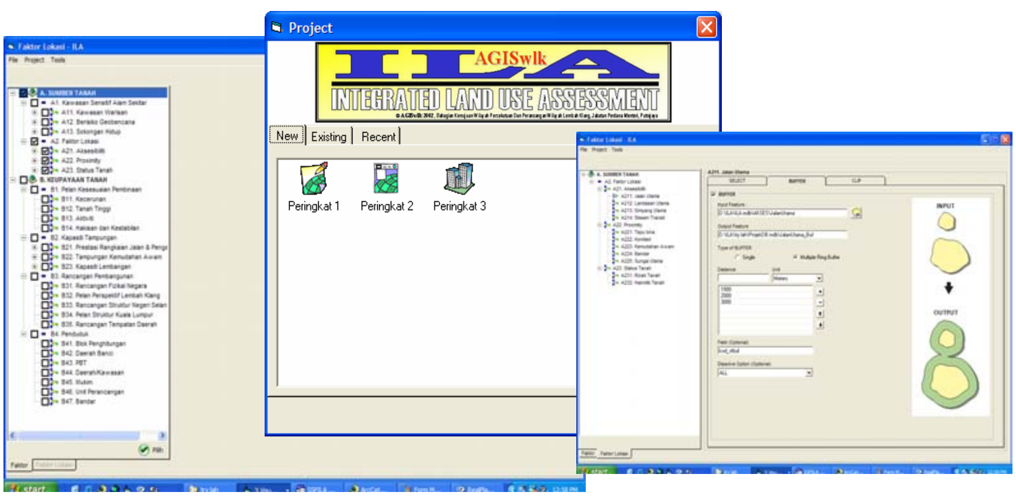

Figure 9: The Interface for managing and preparing data for ILA

Discussion and Issues

Most important in applying the GIS model is the availability of data, the accuracy and precision of the information as well as the security of the database. Whereas, the methodology in conducting the analyses must be appropriate with the right analysis techniques as it would affect the result generated. From the study conducted, it is clear that the usage of GIS and PSS can enhance development planning and monitoring. In this case for example, the environmental aspect can be well incorporated into development planning through good modeling for producing a better ESA map. However, the study had raised several issues that need to be given particular attention:

a) Defining data requirements

Data and information is an important component in ensuring the success of GIS analyses. In implementing ILA, the detailed information required needs to be defined. User should list out the factors and criteria to be used in the GIS analysis such as current land use, forest area, flood area, recreation and etc. Clarifying the use of data for analysis purpose with concern on limitation and availability of data would much help in minimising the time, cost and effort consumed in analyses implementation.

b) Number of criteria used

There are lots of criteria involved in ILA implementation. The criteria used in the study were based on the availability of data. The number of criteria used could reflect the end products. So it is important to choose and design the criteria based on discussions with the stakeholders. As a guide to choose the number of criteria to be used in the study, several questions were raised to check criteria uncertainty including i) are all the relevant criteria considered in the study ?; ii) do all the criteria's definition fulfils the objective of the study ?; and iii) are all the sub criteria equally distributed among all the categories ?

Although PSS is a useful tool to carry out sophisticated works as data can quickly be modeled and the result can be presented efficiently with high quality, it is highly dependable on the availability and quality of the data used in the model. Data availability would very much depend on the cooperation of various agencies and stakeholders involved either at the regional or local level. In brief, the application of a PSS requires collaboration, often among different professionals and disciplines, and often individuals at different locations, without which the PSS application cannot be effectively performed.

In planning, obtaining relevant information is crucial for the purpose of decision-making and good information would certainly lead to better decision. However, relevant information is usually unavailable due to factors such as lack of effectiveness in information sharing and communication between stakeholders. Nevertheless, this problem is believed to be overcome through the concept of consensus building which is further accelerated with support from the information system technology. The continuous cycle of data collection, consultation, analysis and reporting engaging planning and development programs implementation is hoped to provide a shared understanding of:

- Current development activity and trends
- The availability and allocation of land for future development
- The adequacy of land supplies to meet future needs
- The implications of projected development activity for infrastructure requirements; and
- The actions required in overcoming any potential land-supply shortfalls and infrastructure constraints.

Clearly that effective planning requires descriptive, predictive and prescriptive information inputs (Webster 1993; 1994). As planning is always oriented towards the future, forecasting becomes a necessary part of it. Following through the planning process, planners attempt to understand and define current issues, foresee future developments, and propose feasible plans based on available information. Among available approaches for meeting the forecasting requirements of planners, urban models can be efficient and effective support tools.

Concluding Remarks

The Integrated Land Use Assessment (ILA) approach serves as a pivotal means to evaluate land capacity and availability of land resources. Various scenarios, which take into account the socio-economic characteristic of urban dwellers, the constraints of physical development, availability of land and land suitability for particular type of development can be generated using ILA. The implementation of ILA as an integrated land use planning approach through the use of GIS analysis capabilities supported by a planning support system (PSS) resulted in a more integrated planning and serves as a good alternative in producing more rational decisions. Apparently, the ever-accelerating growth of the computer technology especially that involving the GIS and PSS have further simplified the method of land and environmental assessment. The use of ILA for controlling, monitoring and managing development is hoped to facilitate planning and management agencies in deriving more effective decisions towards sustainable land use development.

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Annex

Table 2: Selection Factors and Criteria in ILA

SUITABILITY FACTOR	DERIVING FACTOR	SELECTION CRITERIA	DETAILED SELECTION CRITERIA			OUTPUT
A. Land Resources	A1. Environmental Sensitive Area	A11. Heritage	A111. Historical, monument and archaeology	Buildings		1. Very Critical 2. Critical 3. High Sensitivity 4. Medium Sensitivity 5. Low sensitivity
				Hills		
				Caves		
				Villages		
				Archaeology Sites		
			A112. Biodiversity	Reserved Forest		
				Wild Life reserves		
			A113. Geology	Unique Rock	Limestone Hill	
					Sedimentary rock	
				Ex-mining area	Major Coal Mine (Batu Arang)	
					Biggest & deepest mine (Sungai Besi)	
					Major Tin mine (Perigi Tujuh Serendah)	
				Hot Spring Area		
			A114. Landscape	Public recreation Park		
		A12. Geohazard Risk	A121. Landslide	Hill Area		1. Very Critical 2. Critical 3. High Sensitivity 4. Medium Sensitivity 5. Low sensitivity
			A122. Flood	Natural retention area		
			A123. Land Subsidence	Limestone, ex-mining land		
			A124. Erosion	Beach		
				River		
				Pond		
				Island		
		A13. Life Support	A131. Fresh Water Supply	Groundwater		1. Very Critical 2. Critical 3. High Sensitivity 4. Medium Sensitivity 5. Low sensitivity
				Dam		
				Drainage System - River		
			A132. Food	Aquaculture area - Resources		
				Crops area - Resources		
				Poultry area - Resources		
				Agriculture Industry Center		
				Research Station - institution		
			A133. Energy and Building Materials Resources	Mineral Metallic	Tin	
				Industrial mineral resources area	Sand	
					Aggregate rock	
					Clay	
	A2. Locality Factors	A21. Accessibility	A211. Main road			1. High 2. Medium 3. Low
			A222. Main Railways			
			A223. Main Junction			
			A224. Transit Station			
		A22. Proximity	A221. Built up area			1. High 2. Medium 3. Low
			A222. Committed Development			
			A223. Public Amenities			
			A224. Town Centre			
			A225. Main River			
		A23. Land Status	A231. Land Reserve			
			A232. Land Ownership			
B. Land Capacity	B1. *Construction Suitability* (Terrain Map)	B11. Slope				1. Class I 2. Class II 3. Class III 4. Class IV
		B12. Elevation				
		B13. Activity				
		B14. Erosion & Stability				
	B2. Carrying Capacity	B21. Transportation	B211. Road	Main road		Level of Services (LoS) 1. Class A 2. Class B 3. Class C 4. Class D 5. Class E 6. Class F
				Traffic Volume (Traffic demand)		
				Capacity (Road capabilities to support number of vehicles)		
				Volume/ capacity ratio		
			B212. Junction	Geometry & Configuration		Service level
				Types of control		
				Volume by direction		
			B213. Public transportation	Types of public transportation		
				Usage choices		
		B22. Public Amenity Carrying Capacity	B221. Educational Centre			Carrying Capacity base on population
			B222. Religious Centre			
			B223. Recreational area			
			B224. Healthcare centre			
			B225. Police station			
			B226. Fire Station			
		B23. Basin Capacity	B231. River Basin Capacity			Carrying Capacity base on development
			B232. Drainage Capacity – River, Retention pond			
	B3. Development Plan	B31. National Physical Plan				Land use zone
		B32. Klang Valley Perspective Plan				
		B33. Selangor State Structure Plan				
		B34. KL Structure Plan				
		B35. District Local Plan				
	B4. Population	B41. Enumeration Block				Population density, distribution, etc
		B42. Census District				
		B43. Local Authority				
		B44. District/area				
		B45. County				
		B46. Planning Zone				
		B47. Town				