Spatial multi-criteria evaluation to enhance governance: changes in Malaysian planning

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Introduction

Spatial planning and decision support methods are to make the process of planning and decision making more transparent. In this paper we would like to present an ongoing change process observed in Malaysia, where multi-criteria decision-making is currently being introduced in a strategic public transport study in two different forms. The study is about the selection of one of three light network expansions around the city of Kuala Lumpur. The options are a grid, a radial and a concentric system. This study follows one of two pathways of spatial multi-criteria analysis. The other study is about the identification of possible transit zones in this network. This study takes the other of the two pathways.

To discuss these experiences we first define governance and good governance or 'democratic' governance. Then we propose a model of the planning and decision making process and define in detail what spatial multi-criteria analysis means to this process. Only over the last few years software and methodology has become available to spatially perform multi-criteria analysis. We discuss the newly released ILWIS-SMCE as an example of such software. The main advantage of having such software and methodology is to structure the evaluation problem, which we will demonstrate with the transit zone study. Then we will look at the procedural changes in the planning process and the consequences for governance.

Interestingly this change process is based on several key-individuals in academia, government and private sector. We believe that many lessons are still to be learned from the changes ongoing in Malaysia.

Democratic governance

The authors of the UNDP Human Development Report 2002, Sakiko Fukuda-Parr and Richard Ponzio, provide an interesting personal paper about that report (2003). They review definitions of governance by Worldbank, UNDP, OECD, and the Institute of Governance. They conclude that "governance is about processes, not about ends. It is about the process by which power and authority is exercised in a society by which government, the private sector, citizens' groups articulate their interests, mediate their differences, and exercise their legal rights and obligations."

The question of what is good governance is answered by the definition of democratic governance. In the Human Development Report 2002 (UNDP) it is elaborated on the concept of 'democratic governance' that is governance that would promote human development. Like the concept of 'good governance', democratic governance seeks efficient institutions, and a predictable economic and political environment necessary for economic growth and effective functioning of public services. But in addition it is concerned with political freedom and human rights, and removal of discrimination as central objectives.

If we then follow UNDP's definition of good governance as ensuring (a) participation of citizens in the stare affairs; (b) empowerment especially of women; (c) accountability of duty bearers; (d) transparency in systems of decision making; (e) maintenance of peaceful conditions, and (f) efficient and equitable allocation as well as effective utilization of the country's resources, the relation between good governance and the procedural and methodological transparency provided by planning and decision support methods emerges.

However, in such abstract terms, nothing more than an emergence occurs. Let us therefore look at the particular changes taking place in Malaysia. First we need to introduce a concept of planning and the decision making process, followed by an example of a planning and decision support methodology, spatial multi-criteria evaluation (SMCE), which is currently being introduced by several organizations in Malaysia. We do so, by discussing ILWIS-SMCE, which is built on this concept.

Introducing ILWIS-SMCE

ILWIS stands for the Integrated Land and Water Information System. It is a Windows-based, integrated GIS and remote sensing application. Release 3.2 (January 1st 2004) contains a new spatial multi-criteria analysis (SMCE) module, which is an extension of the raster operations. What turns the GIS into a spatial planning and decision support module is the addition of methods to subjectively interpret data and the importance of various data sources. We will discuss the concepts supporting the module and its functionality. A trial version can be obtained from http://www.itc.nl/.

Comment [I1]: consisting of the following functionalities.
- Display of raster and multiple vector maps in map windows
- Display of tables in table windows
- Interactive retrieval of attribute information
- Image processing facilities
- Manipulation of maps in a Map Calculator
- Manipulation of tables in a Table Calculator
- GIS analysis tools

Script language to perform 'batch' jobs

Comment [I2]: What turns the GIS into a spatial planning and decision support module is the addition of methods to subjectively interpret data and the importance of various data sources.

Concepts supporting ILWIS-SMCE

ILWIS-SMCE follows the framework for planning and decision making processes (fig. 1) as defined by Sharifi & Rodriguez (2002). In this framework we see the planning and decision-making process as an iterative and recursive activity going through the phases of understanding the problem or opportunity (intelligence), finding or developing alternative solutions (design solutions) and arriving at a preferred solution. The intelligence phase amounts to building a concept or model (qualitative or quantitative) of the processes at play, where one first describes the phenomenon, tries to understand its behaviour, assesses the current situation, and derives objectives, which are to guide further steps. The design phase may require different models (again either qualitative or quantitative) to generate alternative solutions. Finally, a preferred alternative has to be agreed upon, through some assessment of factual impacts, evaluation (i.e. judgment) of these impacts and communication explaining the rationale of the decisions. All these phases are supported by various sources of factual and subjective (expertise/judgement) evidence.

Planning and decision support methods assist in the different steps of the framework of the planning and decision making process. They provide assistance in interpretation of factual information in the sense that factual information is subjectively valued or appreciated. They allow for assessment of trade-offs in complex environments with many stakeholders and a multitude of objectives. They are means to express subjectivity and to communicate values. For example, Pfeffer (2003) applies several models as planning and decision support tools to identify most suitable ski-runs in the Austrian Alps, going through the three phases of the framework.

Multi -criteria evaluation (MCE) can be seen as a methodology supporting the decision making phase (Voogd, 1983; Triantaphyllou, 2000). First alternatives, a hierarchy of evaluation objectives and criteria and the factual effects, also called scores, of these criteria, are established in an effect table. Then these scores are valued by means of value functions (Beinat, 1997), which transform scores to dimensionless standardized scores. Priorities are established in the hierarchy of objectives differentiating the importance of different criteria. Finally an aggregation function is applied, such as a weighted summation, which aggregates all standardized scores to a total score for each alternative. Differences in score, lead to a ranking of alternatives. Establishing a hierarchy of objectives and criteria, definition of value functions, and prioritization of objectives and criteria are highly subjective.

Comment [I3]: Example of MCE here? E.g. Rail alternatives!

The added value of the framework is that when MCE is applied to spatial planning and decision problems MCE appears to be applicable in all three phases, not only the decision phase. In MCE various alternatives are evaluated with respect to a series of attributes represented in a table of effects. The objective is to obtain a ranking of the alternatives. In SMCE these alternatives turn out to be various localities or in the terminology of geographic information systems, the various polygons or pixels in a map. Consequently, SMCE can be used in all three phases of the framework, i.e. to distinguish locations with different degrees of problems or opportunities, differentiate locations of variable suitability for feasible courses of action, and selection of best locations amongst a set of feasible locations.

ILWIS-SMCE partially implements Herwijnen’s (1999) model of spatial multi-criteria analysis (fig. 2) as applied in the decision phase of the framework for planning and decision making. Here, alternatives are the three series of maps and alternatives are the pixels or polygons in the maps. The model shows that, unlike MCE, not only an aggregation of effects (function f), but also a spatial aggregation (function g) is necessary to arrive at a ranking of alternatives. Such spatial aggregation is first applied to attribute maps, after which the aggregate effects are evaluated and ranked following regular MCE methodology, or spatial aggregation is applied to the result of an SMCE. Different paths lead to different results. The current version of ILWIS-SMCE follows the aggregation of effects of path 2. A beta version exists, which adds various spatial aggregation functions.

In addition, ILIWS-SMCE can be used in the problem analysis and design phases by considering a single column of maps (fig. 3) rather than three columns of maps. In this situation, the only alternatives evaluated are the pixels or polygons of a single series of maps representing the various criteria.

Geneletti (2002) applied path 1 analysis to environmental impact assessment of road alignments to monitor where problematic areas occur and choose the least impacting alignment. Sharifi and Retsios (2003) did an illustrative analysis path2 analysis with few criteria to generate alternative solid waste site locations (i.e. the design phase of fig. 1), and evaluated the most appropriate site (choice phase of fig. 1).

Spatial multi-criteria evaluation can be implemented in any GIS environment, provided that some of the methods which assist in expressing subjectivity (i.e. establishing a hierarchy of objectives and criteria and prioritization in this hierarchy) are implemented outside the GIS environment and results are imported to the GIS environment. These processes are tedious and error-prone. The advantage of having specialized GIS modules such as ILWIS-SMCE is that we can focus on the expression of subjectivity and the complexity of problem analysis, design of solutions, or decision-making.

Functionality of ILWIS-SMCE

In order to appreciate the transparency required in SMCE we will discuss the functionality of ILWIS-SMCE in some detail. Through several methods subjectivity is made explicit and communicable.

Compared to the non-spatial software for multi-criteria evaluation, ILWIS-SMCE still has limited functionality. The main functionality is in establishing a tree hierarchy of objectives and criteria, i.e. the criteria tree or value tree. Each criterion is measured with an indicator map. Compensatory criteria are called factors, and non-compensatory criteria, which mask out non-performing areas in the mapped area, are called constraints. The criteria tree collects all information regarding hierarchical relation of objectives, criteria and indicators, the priorities (weights) of these and the standardization settings. Therefore a change in any of this information implies a new definition of an evaluation objective by the decision maker. It provides the understanding and communication of how a decision-maker understands the objectives an evaluation, i.e. the evaluation model.

The value function operations available are the linear functions of maximum, interval and goal standardization (Voogd, 1983). They transform the values in the pixels to dimensionless values between 0 and 1, which makes the criteria of different dimensions comparable. The value functions are implemented as benefit (the higher the criterion score the higher the criterion utility or appreciation) or as cost criteria (the lower the criterion score the higher the criterion utility or appreciation). For each criterion, such a value function is to be chosen, which is then applied to all pixel scores in the whole series of maps for that particular criterion. Assume three alternatives, which each have different spatial impacts on noise levels (a cost criterion), one could compare all pixels relative to the highest noise level (maximum standardization) in the series of three effect maps, the highest and the lowest noise level (interval standardization), or relative to a goal value such as legal limit of allowable noise level (goal standardization). Apart from value maps, class (or nominal) maps can be valued too. The same weighting wizard, which is also called for prioritizing criteria, is called to standardize the classes in maps. The appreciation or utility of one class is therefore evaluated (weighted in a sense) in relation to the utility or appreciation of the other classes.

The following weighting methods are available from the weighting wizard. The direct method assumes that the user specifies a value for the relative importance of each factor himself. Weights are automatically normalized. The qualitative pairwise comparison method (Saaty, 1980) assumes that the user compares the relative difference of importance between all unique pairs of criteria (or classes if the wizard is used for standardization). The user specifies the relative importance for each pair of factors in fixed qualitative phrases (E.g. criterion 1 is much more important than criterion 2, and little more important that criterion 3) or with a slide bar. From these phrases, normalized weights are calculated. Finally, the rank order method assumes the user to express priority by specifying the rank-order of all factors, either using the rank sum method or the expected value method. Again normalized weights are calculated from these rankings.

Comment [I4]: Reference?

Standardized scores and weights are input to a function of weighted summation, resulting in a composite index score for each pixel in the map. The composite index score ranges from 0, i.e. a poor performance in terms of objectives and criteria in the value tree, to 1, meaning a good performance. Thereby, poorly performing alternatives or pixels, are distinguished from well performing pixels.

The above summary of functionality can be applied in a context of problem analysis, design and choice (fig. 1). The distinction between the design and choice phases is particularly useful since choice criteria can be very different from design criteria for three reasons. First, and this applies particularly to spatial analysis, only after well performing and poorly performing localities (pixels or clusters of pixels) are known from the design phase, it is possible to measure other criteria such as distance criteria between the localities, or impacts resulting from these specific localities. Second, and more general, designers or planners have different considerations leading than decision makers. The first considerations lead to feasible alternatives, the latter to desirable choices. Third, in design different values trees, value functions, and weight vectors may lead to different alternatives, whereas in the choice phase, these are to be kept constant for a fair evaluation.

Next we will have a look at an example application of how ILWIS-SMCE (as path 2 analysis) can assist in design of alternative solutions for transit zone locations in the Klang Valley, which is the metropolitan area around Kuala Lumpur, the capital of the federation of Malaysian states. It will illustrate that structuring of spatial information into a criteria tree is one of the most important features of ILWIS-SMCE. After that we will have a look at the planning procedures of a path 1 SMCE analysis that was carried out in an ‘umbrella’ study on strategic light rail network development in that same Klang Valley.

SMCE as planning tool for strategic rail network planning and transit zone identification

In 2003, the Federal Territory and Klang Valley Development Authority, requested a team of consultants to undertake the Klang Valley integrated Public Transport System and Land Use Development Plan. Three strategic alternative light rail networks were evaluated, following path 1 (fig. 2).

The study was instigated by the rapid increase of modal split towards from 66% private transport in 1985 to 80% in 1997, the remainder being public transport. Over the same period the number of trips made in private and public transport together increased by 35% (Perunding Bersatu, 2003). The Klang Valley is also the hub of the Malaysian economy and generates a considerable portion of the National Gross Domestic Product. It is also the financial center of Malaysia with a large sector of the population engaged in the services sector.

As an extension of this study, we evaluated the Klang Valley for possible locations for transit zones. Transit zones are areas where transfer between different modes of public transportation occurs, e.g. taxi to train, train to bus, etc. In this study transit zones were defined by light-rail transport and the transportation systems linked to light-rail stations. At the same time they serve as an area of commercial activity.

We will use the extension to demonstrate the importance of structuring an evaluation and that the methodology contributes to transparency of the decision making process. We will use the strategic rail network study to demonstrate the importance of procedural transparency. Although one is not a prerequisite for the other, methodological and procedural transparency enhance each other.

Structuring the evaluation

The value tree that was constructed for this evaluation (fig. 4), which has as an overall objective to find suitable locations for transit zones, reflects a trade-off between on the one hand the fact that an area needs to be suitable for the transit zone. On the other hand development objectives are associated to a transit zone so that it changes an area into a desired direction. Sometimes these main objectives may coincide, sometimes less suitable zones will have to be accepted to meet development objectives, and sometimes development objectives may not be reached due to impossibility to overcome suitability constraints. In other words, development constraints are weighted (traded) against development objectives.

Without explaining this tree to the very last detail, which would make this paper too long, we would like to demonstrate the rationale behind its structure. This we will then compare to other evaluation models that were elicited from different stakeholders in the next section.

The main objective (fig. 4) of area being suitable for transit zone development is defined by sub-objectives, which pertain to transportation sub-objectives (demand and connectivity) and physical suitability and economic land acquisition objectives. High demand area is defined as those areas with large employment and employee centers, residential centers, centers for social and economic services, and tourist attraction areas.

The other main objective (transit zone should contribute to development) (fig. 4), is defined by strategic plans indicating future development areas. A transit zone could assist in such development, since it serves as a magnet for commercial and service activities. Contribution to development is also seen as providing transport to areas which currently or in the future have little access.

Note that fig. 4 only shows the output maps that are being generated, except for the constraint of ecologically reserved areas, and, as an example, some of the indicator input maps and columns in attribute tables pertaining to environmental suitability. This analysis consists of 28 input maps, i.e. indicators, and 14 output maps for the various objectives and criteria.

The output maps provide intermediate performance scores (composite indices) for each of the sub-objectives (fig. 5). Such maps are crucial to gain understanding of the problem to be able to explain why certain areas perform well and others do not and to explain what is the reason of equal overall performance in different locations. After all, the different locations can be evaluated to perform equally well but different reasons, i.e. performance of sub-objectives.

Assuming three different scenarios (fig. 6) whereby equal importance is attributed to the two main objectives (scenario1), 67% of weight is attributed to the constraint objective (scenario 2), and 33% of weight is attributed to the constraint objective (scenario 3), different areas will result as possible locations from the planning phase. In the decision phase, depending on the good performance of decision objectives, decision makers may decide it is worth to overcome constraints. Indeed scenario 2 alternatives are located at the urban fringe, whereas scenario 3 alternatives are located towards current uban centers.

Valuation of data and criteria

Between input and output the various standardization and weighting methods were used. The standardization methods were often goal value functions. They differentiated acceptable distances, obtaining standardized score of 1, from unacceptable distances, obtaining standardized score of 0, with a linear interpolation of performance in between. Other value maps were standardize with maximum standardization. Class maps were standardized with the weighting wizard where different classes were ranked. Ranks were then transformed to standardized values.

Weights were established by ranking, after discussions with a total of 10 key informants, half of which worked for transportation and land use planning consulting firms (each with 15-30 years experience), the other half were from the Federal Department of Town and Country Planning, The Economic Planning Unit, The Federal Territory Development and Klang Valley Planning Division in the Prime Minister's office, and the Special Task Force for Public Transport Restructuring in the Klang Valley. The results do therefore not represent the positions these organizations take and are only indicative. However, it provides excellent illustration of the difference between the stakeholders with respect to their evaluation models.

Transparency in structuring an evaluation

From discussions of the 10 key informants four different value trees were derived (table. 1). Since SMCE software takes much of the GIS operations and error prone valuation operations (weighting and standardization) out of our hands, we can focus on the structuring of value trees.

Commonly, value trees are developed as impact assessors. They evaluate disciplinary classes of impacts, such as economic impacts, environmental impacts, social impacts or institutional impacts. These types of value trees seem instigated by sustainability thinking. In poor applications of MCE they merely reflect groupings of data rather than objectives to be achieved. In good applications these classes of impacts are formulated as genuine objectives. Our experience though is that novices to this field of MCE find it difficult to think beyond this classification of impacts. Let us have a look at the value trees encountered and try to identify other general formats of value trees. They are based on semi-structured interviews with individuals in the various departments. They therefore do not constitute the opinion of the various agencies.

Transportation and land use planning experts look at this planning problem in what in the context of multi-objective decision making is called a lexicographic way. They would first satisfy macro scale objectives. These would then lead to areas constraining micro scale objectives. Government organizations have a particular concern about implementation, i.e. particularly compliance with regional plans or plans for highway, railway projects, etc. and political commitments. Also these objectives are not (necessarily) spatial. What binds municipalities is their concern about compatibility with current and future land use. What differentiates them is their motivation for transit zones, dependent on their location. Some municipalities in the centre of Klang Valley are interested to relief traffic on the road system and choose for high demand areas, whereas the urban fringe municipalities might rather be interested in opening up deprived areas. Private company operators are more concerned with operability and connectivity of the transit zone, and its contribution to profitability as function of investment cost and demand. Except for some of the criteria defined for government officials, most criteria can be recognized in the criteria tree that was presented earlier.

Comment [I5]: (Steuer, 1996?)

Table 1. Transit zone location decision model of four different stakeholders

Transportation and land use planning experts			
Steps	Objectives	Criteria	Weight (rank)
1	Suitable location at macro scale	High demand / ridership	1
		Environmental suitability	2
		Be close to urban development projects	3
		Low acquisition and construction cost	4
2	Suitability at micro scale	Accessibility provisions	1
		Coverage / catchments	2
		Future expansion	3

	Spacing with other transit zone	4
Government organizations		
Criteria		Weight (rank)
Role in national economic plan		1
Political motivation and promise		2
High demand		3
Cost / environmental suitability		4
Municipalities		
Objectives	Criteria	Weight (rank)
How suitable the location for present Situation	Adaptability with local land use	1
	High demand	1
How adaptable for future plans	Future development projects	2
	Deprived area	3
Private companies		
Objectives	Criteria	Weight (rank)
Ensure higher ridership	High demand area	1
Connected with other transportation modes	Connectivity	2
Capturing future ridership	Future development projects	4
Cheap installation	Environmental suitability	3
	Land ownership	4

Comment [I6]: Check strange ranking

Defining a hierarchy of objectives and criteria is about defining a trade-off structure, because priority given to one objective can not be given to another. It is very difficult to recognize structure in what often is more a listing of concerns than a hierarchy of objectives and criteria. It would be relevant to structure these criteria if there is no area of pixels which is dominant over the performance of other pixels (which may not be easy to recognize), if not all criteria are considered as lexicographic by the decision-maker, or if all criteria are considered to be conjunctive (aggregated with the 'AND" operator) or disjunctive (aggregated with the 'OR' operator). Having a model of trade-off types will be useful to recognize structure. Examples are:

- Sustainability trade-off: Impacts are evaluated along the sustainability objectives of environmentally sustainable, socially acceptable, economically viable, technically achievable, and other sustainability objectives e.g. institutional may be added.
- (Spatial) intervention-intervened area trade-off: as in the example above (spatial) intervention transit zones has impact on intervened area and vice versa.
- Temporal trade-off, where short term costs and benefits are evaluated against long term effects.
- Spatial trade-off: Impacts between municipalities or urban fringe and surroundings are examples of such trade-off analysis
- Sectoral trade-off: Performance maps of transit zone locations and their cost and benefits to economic sectors.

These trade-off typologies can occur nested within the hierarchy of objectives, where within the sustainability trade-off one can identify intervention-intervened trade-off. The objective is not create an exhaustive list, if this were possible in the first place, but to offer alternatives to the classification of sustainability objectives, and to challenge practitioners to find the right trade-off structure(s) for the evaluation at hand and thereby create the desired transparency .

Procedural transparency in identification of light rail network strategy

We go back to the main study in the Klang valley on the three rail networks. The SMCE path that was used in this study is path 1. A sustainability trade-off value tree was developed by the consultants commissioned to this study. Let us have a look at the decision making procedure as it was implemented in this study and compare it with procedure that has been in use so far.

The consultants started by drafting a value tree, which was discussed with a technical committee and a steering committee. The first contained members of several federal government agencies. The latter included municipalities in the Klang Valley and the state of Selangor as well. After the value tree had been endorsed, it was used to guide the design of the alternative networks. Evaluation data (scores) were collected in the form of maps, e.g.

noise impact on schools, or non-spatial, e.g. total cost of each network. Also the consultants assessed the weights for the criteria in the value tree. Only for the highest level of objectives weights were not assessed.

When first drafts of these plans were ready, ‘road shows’ were organized to each of the members of the steering committee. Plans were presented and weights were elicited for the highest level of objectives. These were then used in path 1 multi-criteria analysis, which was carried out for each of the municipalities as well as the state. One of the municipalities could not reach consensus on the prioritization of highest level objectives so two separate analyses were done for this municipality. Although different stakeholders gave different priorities to highest level objectives the grid alternative performed best for all stakeholders, but fairly closely followed by the radial alternative. This result could shortcut the decision making process. Next the results of the analysis will be fed back to the steering committee and after endorsement be proposed to the prime minister’s office.

If we compare the procedure above with planning and decision procedures until now, we can observe that until now plan development was not ‘value driven’. That is to say that a value tree against which the plans would be evaluated was not used in the design of the plans. Plan development was very much a black box, which has become a bit moregrey now. Also, there is more involvement from other, particularly, government organizations.

Although these are substantial improvements, the discussion of the value trees with the steering committee could not go into depth. A road show would have been a good way to elicit other trade-off structures such as the ones found in the transit zone study. Also a more general experience of the use of SMCE, by repeated exposure through projects and training, would improve understanding of decision-makers on how to structure an evaluation problem.

In addition, road shows to private sector and civil society could have been crucial additions in terms of the governance discussion, exploring the checks and balances amongst government levels and organizations has been a considerable step towards transparency in the decision process. It will be interesting to see whether the efficiency of the decision process has been increased as well.

Finally, as mentioned in the beginning of the paper, governance is about power and checks and balances. Spatial planning and decision support systems such as spatial multi-criteria analysis together with procedural transparency can improve governance.

Acknowledgement

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Figures and tables

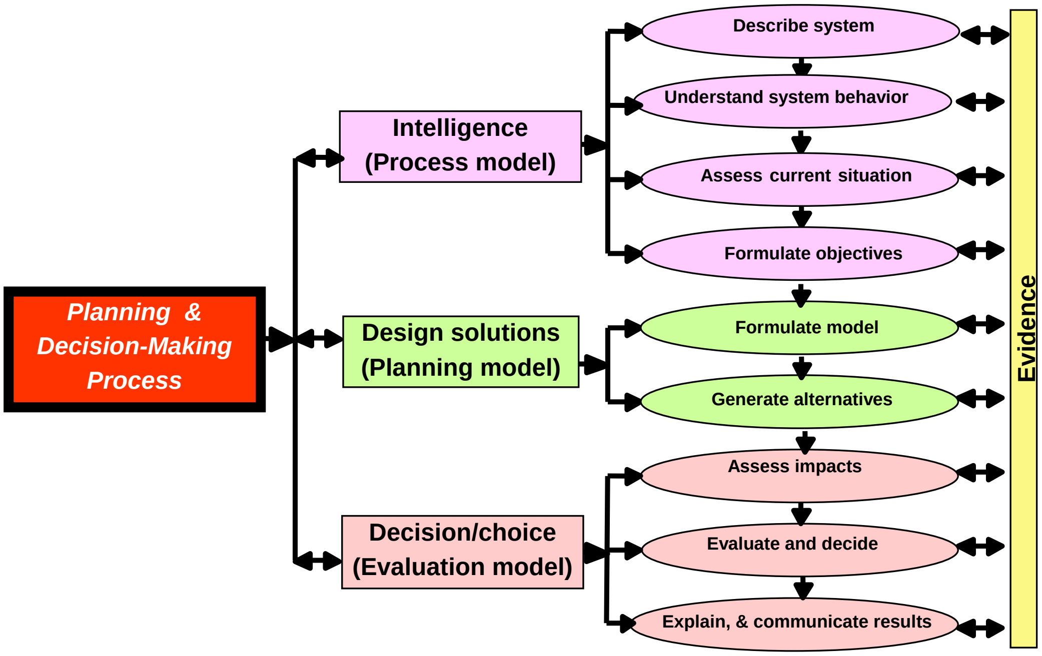


Figure 1. Framework for the planning and decision-making processes.

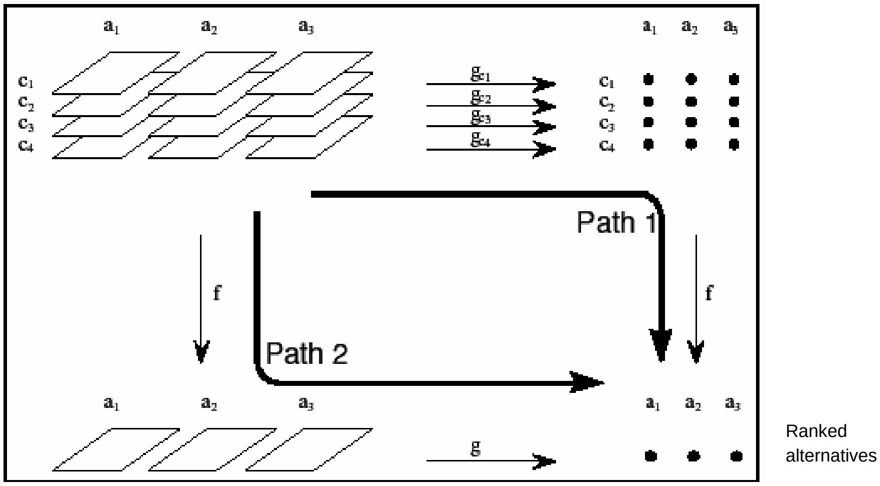


Figure 2. Two pathways for spatial multi-criteria analysis (adapted from Herwijnen, 1999). The result of both path 1 and 2 is a ranking of alternatives a1, a2, and a3, with respect to their performance in terms of the four spatial effects (criteria c1, c2, c3, and c4) for which they are evaluated (functions f) and the spatial distribution of these effects, which is aggregated in functions g.

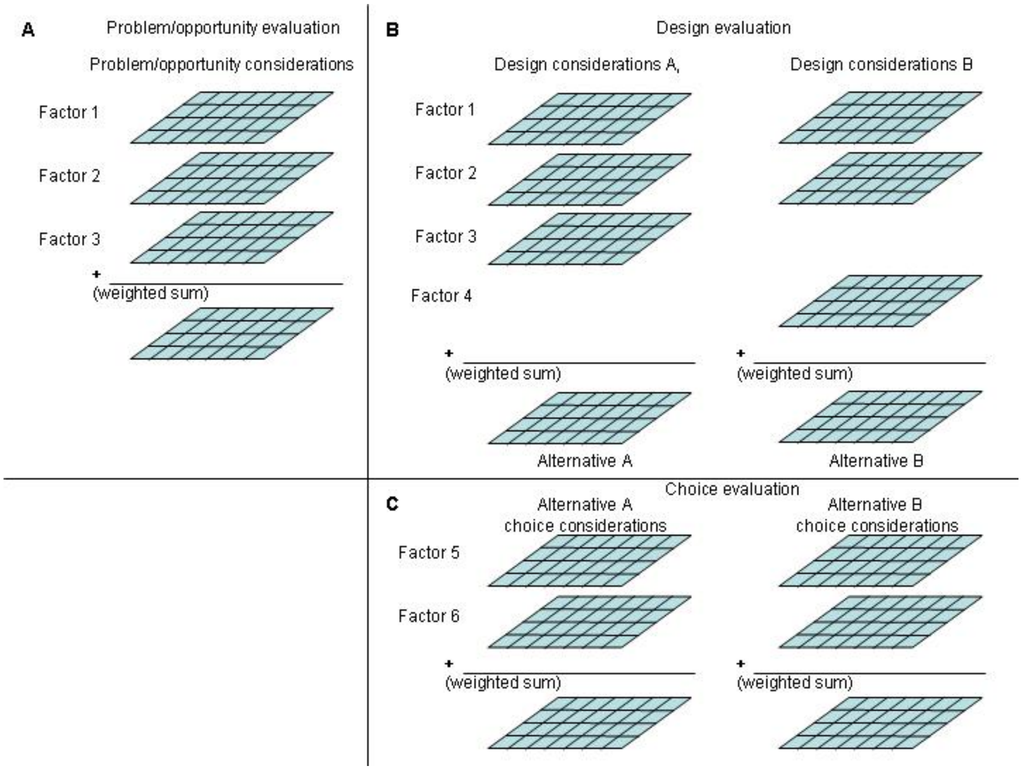
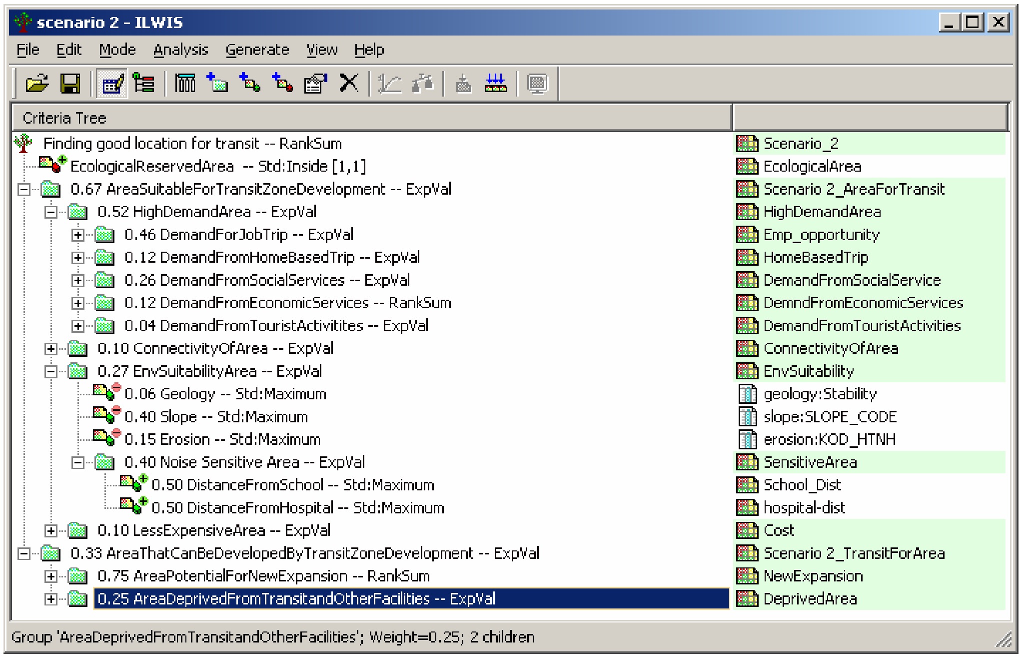


Figure 3 (**A**) Several criteria lead to an overall composite index map indicating where problems/opportunities may arise. (**B**) Different design considerations in terms of criteria structure, value functions or weights lead to different alternatives A and B. (**C**) Alternatives A and B, are evaluated with the same criteria, weights and standardization methods.



Criteria Tree	
Finding good location for transit -- RankSum	Scenario_2
EcologicalReservedArea -- Std:Inside [1,1]	EcologicalArea
0.67 AreaSuitableForTransitZoneDevelopment -- ExpVal	Scenario 2_AreaForTransit
0.52 HighDemandArea -- ExpVal	HighDemandArea
0.46 DemandForJobTrip -- ExpVal	Emp_opportunity
0.12 DemandFromHomeBasedTrip -- ExpVal	HomeBasedTrip
0.26 DemandFromSocialServices -- ExpVal	DemandFromSocialService
0.12 DemandFromEconomicServices -- RankSum	DemndFromEconomicServices
0.04 DemandFromTouristActivitites -- ExpVal	DemandFromTouristActivities
0.10 ConnectivityOfArea -- ExpVal	ConnectivityOfArea
0.27 EnvSuitabilityArea -- ExpVal	EnvSuitability
0.06 Geology -- Std:Maximum	geology:Stability
0.40 Slope -- Std:Maximum	slope:SLOPE_CODE
0.15 Erosion -- Std:Maximum	erosion:KOD_HTNH
0.40 Noise Sensitive Area -- ExpVal	SensitiveArea
0.50 DistanceFromSchool -- Std:Maximum	School_Dist
0.50 DistanceFromHospital -- Std:Maximum	hospital-dist
0.10 LessExpensiveArea -- ExpVal	Cost
0.33 AreaThatCanBeDevelopedByTransitZoneDevelopment -- ExpVal	Scenario 2_TransitForArea
0.75 AreaPotentialForNewExpansion -- RankSum	NewExpansion
0.25 AreaDeprivedFromTransitandOtherFacilities -- ExpVal	DeprivedArea

Group 'AreaDeprivedFromTransitandOtherFacilities'; Weight=0.25; 2 children

Figure 4. Part of value tree in ILWIS-SMCE software interface showing hierarchy of objectives and criteria, weights, and standardization functions (first column), all output maps generated (second column), as well as some of the input maps and attribute table columns.

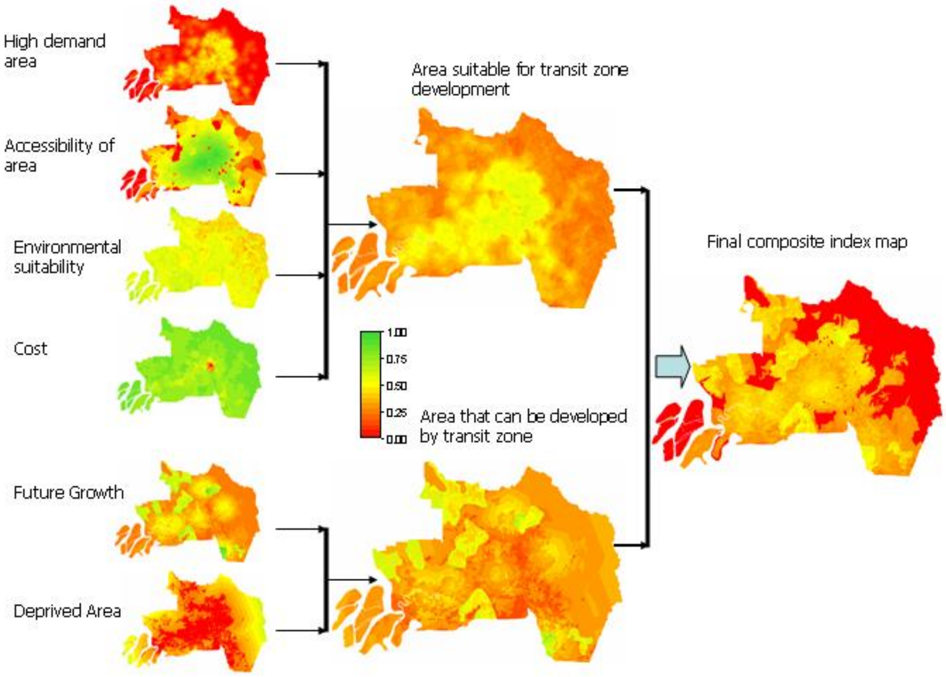
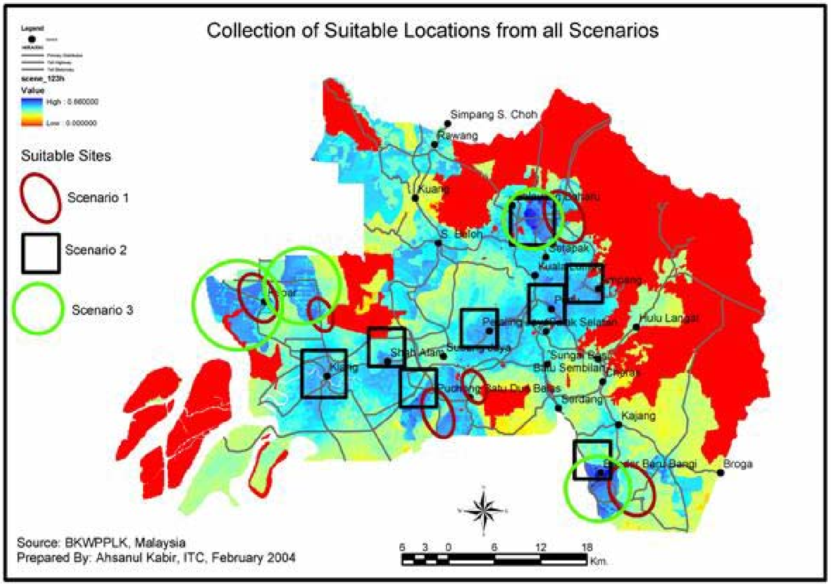


Figure 5. Aggregation of composite index maps of sub-objectives to the overall composite index map.



Source: BKWPPLK, Malaysia
Prepared By: Ahsanul Kabir, ITC, February 2004

Figure 6. Alternatives developed by varying priority of main objectives. (note: color scheme changed because this figure was prepared in Arcgis)