Using Multi-Criteria Analysis to Identify Suitable Light Rail Transit Route

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Abstract

Public transportation planning and development are undergoing continuous changes often prompted by both external factors and policy-directed responses. The role of public transit, particularly rail transit, becomes increasingly importance with the changing demographic and economic pattern. The trend of returning to urban living for e.g. has significantly increased the demand for efficient public transportation in urban centres. However, the design and development of Light Rail Transit (LRT) route seldom takes into consideration land use changes and demand. This paper investigates how non-spatial and spatial data can be integrated within a multi criteria decision framework to formulate and evaluate land use development corridor to determine suitable route for LRT. A raster base multi-criteria analysis model was developed base on a set and specific objectives, criteria, indicator and data requirement. The set criteria and indicator proposed are in line with the objectives to improve public transportation as stipulated in the Kuala Lumpur Structure Plan. A case study approach is undertaken within a selected LRT railroad in Kuala Lumpur, Malaysia. The model, integrating GIS and external software, shows that suitable LRT alignment can be identified that take into account social, institutional and environmental objectives. The approach will assist in the planning and development of LRT network, and thus maximizing usage of rail-based public transport to serve the community.

Keywords: Light Rail Transport, Multi-Criteria Analysis.

1.0   INTRODUCTION

Public transportation planning and development are undergoing continuous changes often prompted by both external factors and policy-directed responses.   As such, public transportation is a vital component in any urban area and often regarded as a sustainable form of urban transportation.   It serves as a promising solution to the problem of transportation demand in most urban cities.   Public transportation is also considered as a tool used by transportation planners in solving various transportation related problems, particularly which are related to traffic congestion in urban areas.

Most public transportation modes in an urban area are based on roads and rails.   Examples of road based transportation modes are buses and taxis, while rail transportation modes are Light Railway Transit (LRT), train and monorail.   It is important to note that rail-based public transportation should be fast, efficient, convenient and affordable, and able to carry a capacity which is higher than whatever that can be accommodated by buses (Parkinson, 1989).

LRT is one of the public transportation modes that are popular in most developed countries. There are more than 300 LRT systems of various types and sizes that have been successfully implemented in 33 countries all over the world, including Hong Kong, Manila, United Kingdom and Mexico (Bliss, 1989).   The capability of LRT that can carry between 15,000-20,000 passengers per day or equivalent to 3,000-20,000 passengers per hour, makes the system as an effective public transportation (Parkinson, 1989).   In Asia, poor levels of service on public transportation often lead to the vicious cycle in which the transportation system is shifted to automobile-biased motorization.   In addition, Asia also constitutes 85% of its inland surface passenger transportation (in terms of million of kilometers) to public transportation (including railway), which is almost double the world standard of around 45% (Wong & Lam, 2006).   In effect, it is increasingly important to formulate an effective policy on the planning, management and operation of the public transportation system including LRT.

It should be noted however that the main problems that are usually identified are from the aspect of integration i.e. mistakes in integrating LRT route alignment or the failure in taking into account surrounding land uses, or the linkages between other public transportation modes that are not properly planned.   The lack of integration often creates problems, such as minimum usage of the LRT services and contributes to the financial loss incurred by the rail operators.   These problems often arise from inappropriate planning at different stages of the

development and also neglecting the macro and micro issues related to public transportation and the community (Bickel, ____).

Thus, public transportation planners are often faced with a continuing challenge in refining their ability to model the interactions between land uses and transportation demand and supply. GIS as such is seen as a powerful tool to develop better public transportation analysis techniques due to its ability to manage, recall and evaluate information effectively. It is also regarded as a comprehensive approach due to its ability to consider various inter-related criteria in the decision-making process. This paper will highlight on the application of multi-criteria techniques incorporated with GIS in identifying possible LRT railroad alignment that take into consideration important and critical spatial and aspatial criteria.

2.0   RESEARCH METHODOLOGY

In this case study, analyses are carried out on two new growing centers in Kuala Lumpur suburbs, the capital city of Malaysia. The selection of the research area is based on the demand of existing railroad services coverage that need to be added and extended to new populated area. In addition, the land use meets the criteria for new railroad alignment. Since the location of the case studies, Bukit Jalil-Seputeh and Bandar Tun Razak-Sungai Besi, are adjacent it will be practical to integrate the allocation of route alignment in this two areas.

There are four main stages involves in the implementation of this research (Figure 1), which are:

a)   to identify the objectives and evaluation criteria
b)   to implement the multi-criteria analysis,
c)   the generation of alternative route
d)   evaluation and selection of route

In creating the best possible route, the selection of criteria also has to be selected thoroughly in order to meet the objectives set for the rail-based public transportation. Determining an accurate and reliable criterion is crucial in the outcome of the analysis.
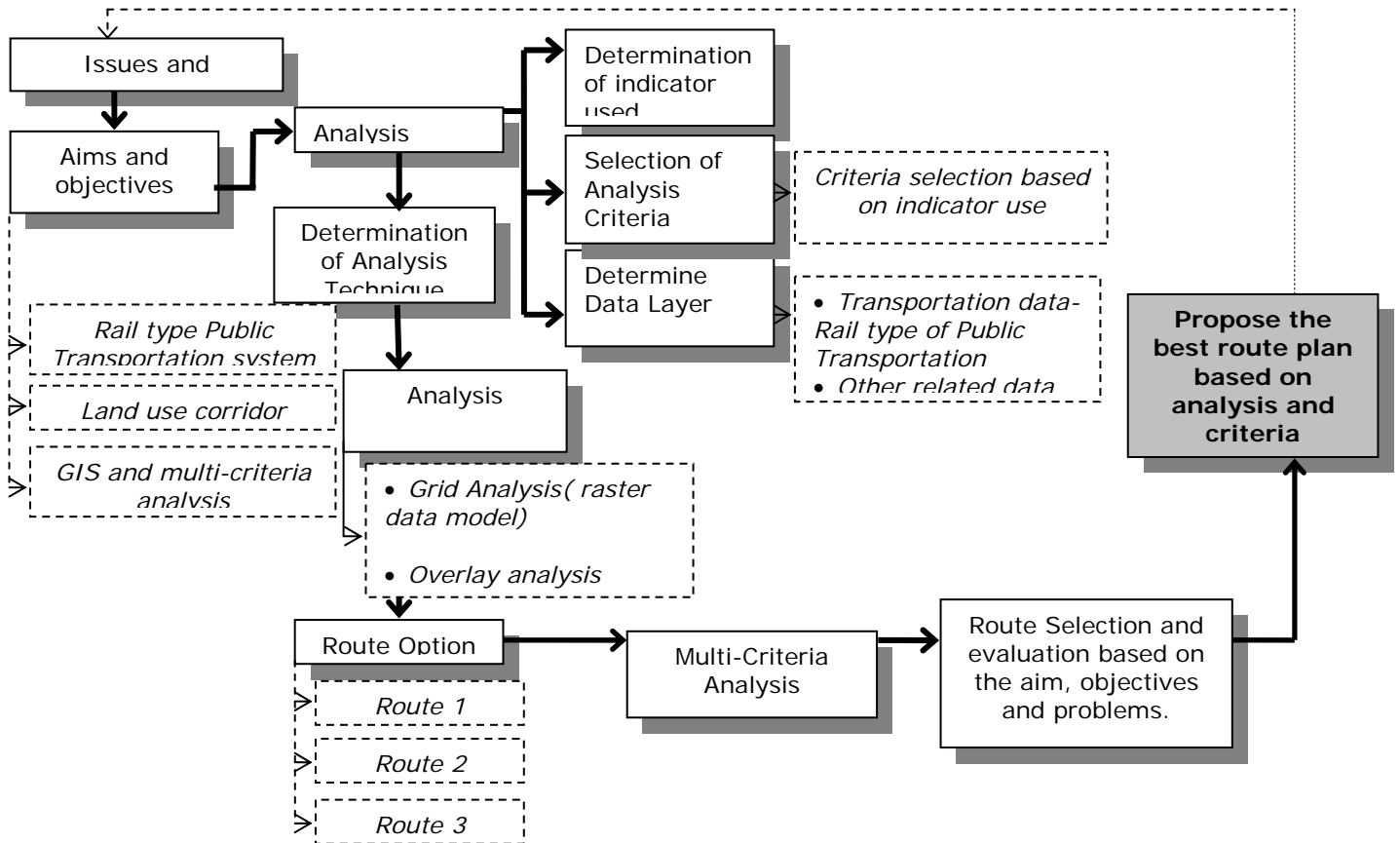
Figure 1: Research Methodology

2.1 ESTABLISHING RESEARCH OBJECTIVES AND SELECTION OF CRITERIA

Planning philosophy and policy formulation are vital for the development of a public transportation system particularly in highly populated areas (Wong & Lam, 2006). Therefore, one of the key aspects of the research is to establish the critical strategic policies effecting the development of public transport in the study area. In determining the LRT railroad development corridor, the transportation strategic policies is translated into criteria to provide the basis for selecting suitable development area that take into consideration various factors. This selected criterion is also base on the strategic policies stipulated by the Kuala Lumpur Structure Plan (KLSP) which will form the basis in generating scenario development for the case study.

The objective based criteria are then further refined and detailed out into sub-criteria and indicators. This is based on a study carried out by the Federal Town and Country Planning on rail based public transportation, and agreed upon with various stake holders in Klang Valley Region where the study area is located (Figure 2).
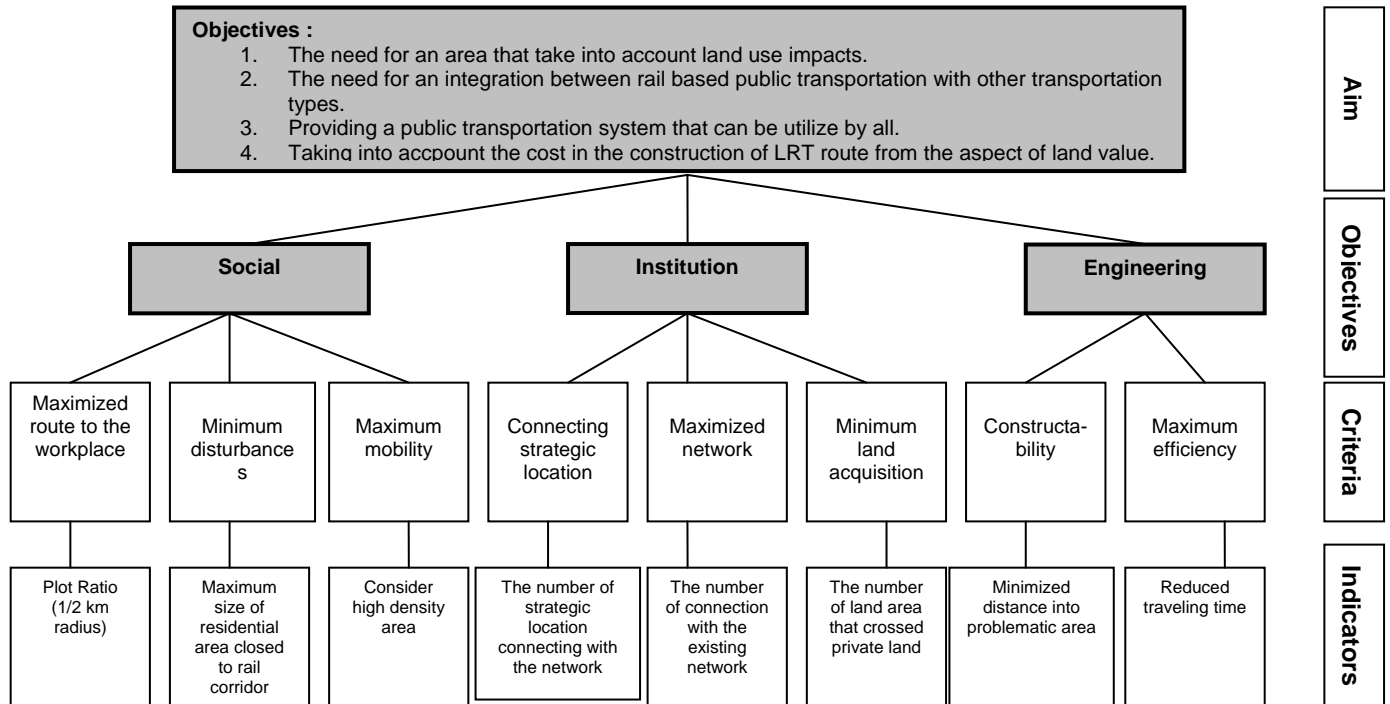

Figure 2:   Hierarchy of Aims, Objectives, Criteria and Indicators

To carry out the analysis in GIS, the criteria is translated into a series of conditions that meet the objectives explained earlier. These classifications of conditions are then used in the spatial analysis using the required data, and the potential transportation nodes and services can be identified (Table 3).   The criteria are assumed to have taken account all related rail transportation problems that have been identified in the Kuala Lumpur Structure Plan and the study by the Town and Country Planning Department.

Table 3: Relationship between Objectives, Indicators and Data

OBJECTIVES	CRITERIA	INDICATORS	DATA
The need for an area that consider land use impact (accessibility, type of activities, surrounding development)	Maximizing routes to workplace	Radius 0.5km from the LRT station	Residential area Industrial Area Commercial Area Institutional
	Minimizing disturbances	To limit the number and size of residential area located closed to LRT corridor	
	Maximizing mobility	To consider high and low density residential area at suitable location (40-60 persons per acre)	Residential area Industrial Area Commercial Area Place of worships Educational area Institutional buildings
		To identify concentrations of workplace in relation to industrial, commercial, place of worships and educational area.	
The need for an integration between rail type transportation with other modes of public transportation	Maximizing network	To ensure existing network are connected with new rail network.	Public transport terminal
To provide a public transportation system that can be used by all levels of public	Connecting strategic location	The number of strategic locations linked to the rail network	Neighborhood Center Residential Area Institutional buildings
To consider the planning process and operational cost of the development corridor	To consider land value	The number of intersections with private land	Land Ownership
To consider environmental needs	Constructability	Minimized intersections with constraint areas	Land Ownership Environmental Sensitive Areas

2.2   MODEL ANALYSIS

Given reliable data and using a suitable method of analysis, Geographic Information System (GIS) is seen as an effective tool to generate alternatives in the selection and solving the problems of planning and development of a railroad. In this case study, a Decision Support System (DSS) multi-criteria approach is undertaken using a grid base GIS data layer.   The DSS using a combination of GIS data, urban model and computer presentation technique has been proven to be an effective tool to improved planning decisions (Ludin & Yaakup, 2006). By incorporating spatial data, the Spatial Decision Support System (SDSS) structure and information access make possible to visualize the world in 'reality' and support the capabilities for analyzing, prediction and making planning decisions about development (Brail & Klosterman, 2001).

In this study, a DSS software DEFINITE is used to evaluate development alternatives of the LRT railroad alignment and corridor. A 20m x 20m grid base data layers are generated from the existing raw data to support the analysis. In general, the DSS involve 4 basic steps, i.e. (1) identifying assessment criteria, (2) determining scale measurement for criteria assessment, (3) the multi criteria analysis, and (4) sensitivity analysis and uncertainties analysis. Steps (1) and (2) has been explained in 2.1, while steps (3) and (4) will be explain in 2.3 and 2.4. Figure 4 shows an example of the model in generating the predetermined alternatives.

2.3   GENERATION OF ALTERNATIVES

This study has selected three types of railroad layout which are 'branch', 'loop' and 'radial' in generating development alternatives. Using spatial analysis model, all three types of routes will be tested on its effectiveness and sensitivity towards the environment and other physical criteria in providing the necessary urban LRT railroad services. The non-spatial analysis component will be analyzed in an external environment. It is important to note however, that the analysis need to provide the capability to maximized the output such as maximizing route to workplace, connecting strategic locations and maximizing network. As such, all the three routes; 'branch', 'loop' and 'radial' will be evaluated against the set criteria that has been selected. Constraint areas identified will also be analyzed with the criteria. An optimal route will then be selected after rigorous and iterative analysis done on the three railroads layout.

2.4   EVALUATION AND SELECTION OF ALTERNATIVES

To facilitate in the evaluation and selection for an optimal rail route, as explained earlier this research used DEFINITE 2.0, whereby it will be carried out in a non-spatial analysis environment. Although ARCGIS application could not be used interactively with DEFINITE software, it is capable to interpret the output of the analysis (spatial data) to non-spatial data accurately to be interpreted into a table format required for evaluation.
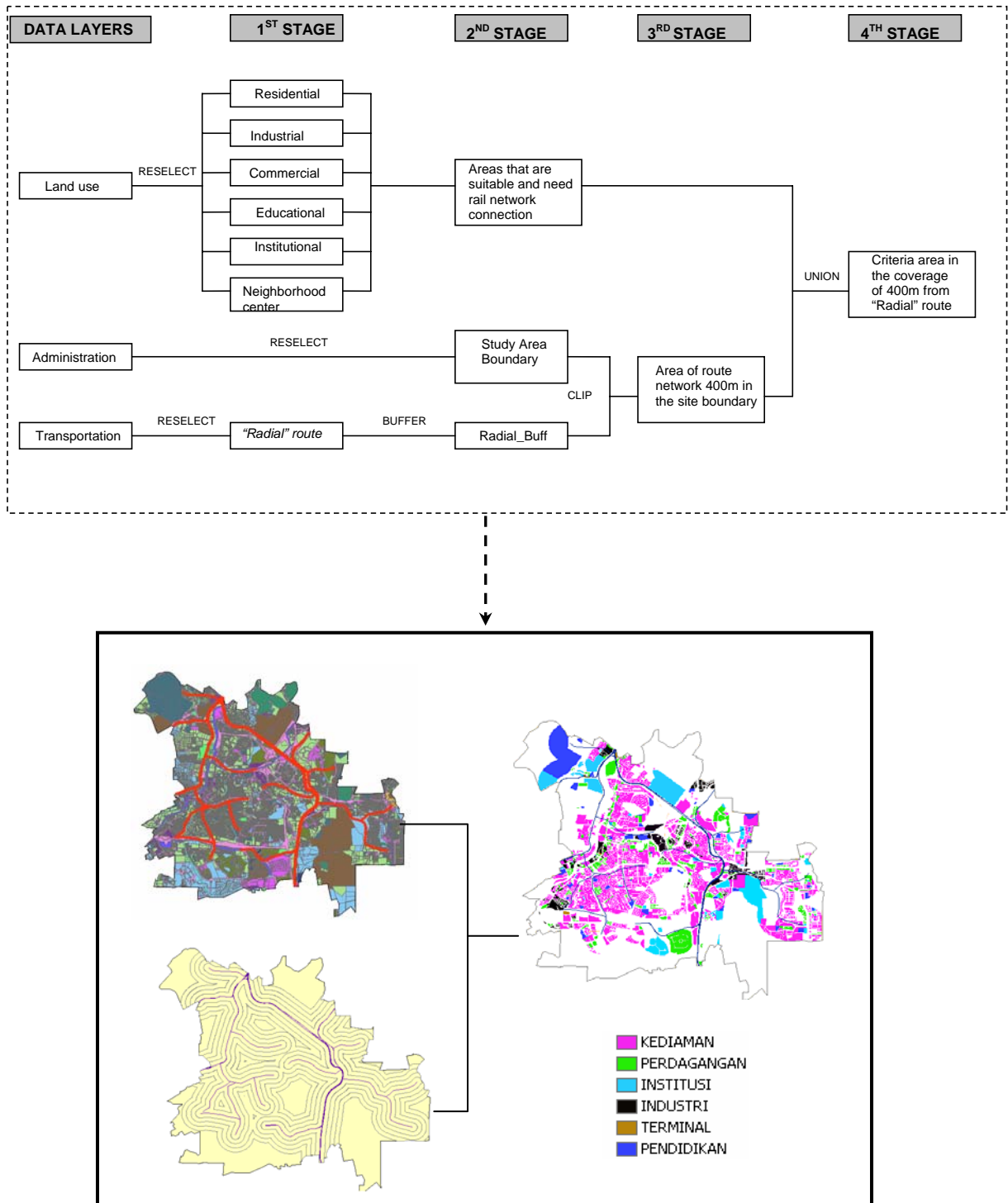
Figure 4 :   Example of a Model and Grid Analysis for 'Radial' Route.

At this stage, the value set for the criteria and sub-criteria is crucial to the outcome of the analysis. The criteria and sub-criteria unit are determined in quantitative value (such as the land area and total population) or in qualitative form ('+++ () ---'). Each criterion is also established whether it is in the form of cost (-) which means the higher the value score, the lesser its contribution towards the route selection and vice versa (Figure 5). Grid analysis in ARCGIS is used to determine each of the criteria score. Each value is inserted to a map prior to the selection and evaluation analysis.

The final stage is to allocate weightage to the criteria and sub-criteria according to its strategic importance as described earlier. The results shows that 'branch' layout are sensitive to social objectives, while 'radial' are significantly sensitive to institutional objectives and environment objectives. Overall, the 'radial' design provides the highest ranking (0.81) compared to 'branch' (0.70) and 'loop' (0.70) (Figure 6). The analysis also shows that the output are sensitive to change in the value of the weightage in the main criteria and sub-criteria. Thus, the criteria are tested iteratively using the *Sensitivity Analysis* and *Uncertainties Analysis* available in the software before the result is finalized.

3.0   CONCLUSION

The research demonstrates that multi-criteria analysis can be implemented in public transportation planning to select the best railroad route plan for LRT. The research that has been carried out also present the capability of ARCGIS to be integrated with other non-spatial software applications. The databases can be extensively examined to generate alternative solutions related to public transportation. This research however can be further improved with the inclusion of more refined criteria in the analysis model. The selected criteria need to be carefully examined, prioritized and applied to the model.
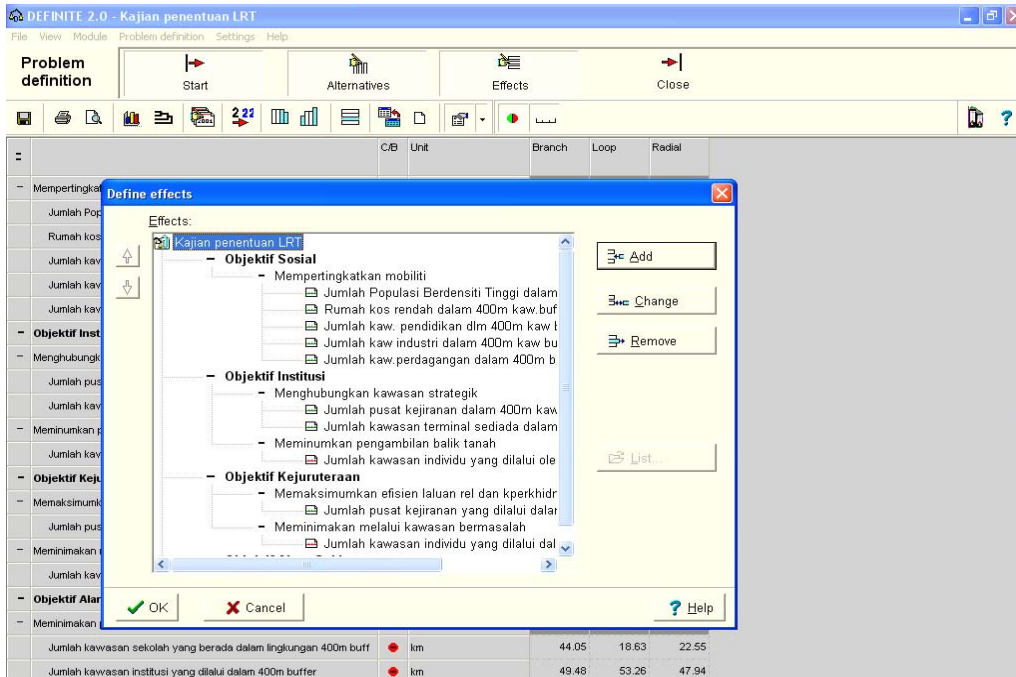
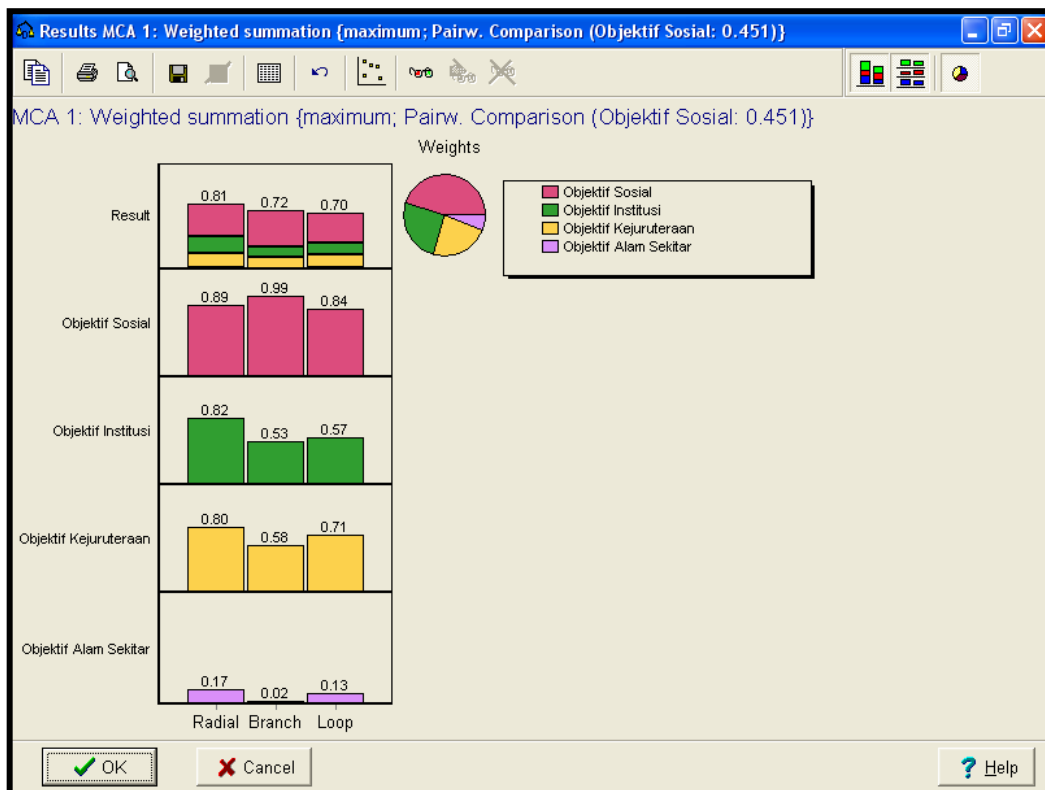**Figure 5:   Objectives, Criteria and Sub-Criteria Used in the Evaluation and Selection of Rail Route**

Figure 6 :   Results According to Assessment Criteria

It is important to note that, this technique is also applicable to other development sectors such as in the selection of suitable land use or development proposal (Ludin & Yaakup, 2006). This technique also provides a platform where spatial and non-spatial data can be analyze together and provide a desirable and significant result to the user that can be used by decision makers to locate optimal development nodes and about the best use of land. In addition, there should also be a continuous effort to search for innovative practices in the planning and development aspects of the public transit schemes to ensure that it is in line with the ever changing demand of the urban community.

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