THE APPLICATION OF MULTI CRITERIA ANALYSIS IN ASSESSING THE MASS TRANSIT SYSTEM PROPOSALS FOR JAKARTA

Rudy HERMAWAN
Secretary of Research Center of Transportation & Communication
Institute of Technology Bandung
Technology Laboratory I, 3rd Floor, Jl. Ganesha 10 Bandung 40132
Phone/Fax : + 62 – 22 – 250 2350
E-mail : Rudy@trans.si.itb.ac.id

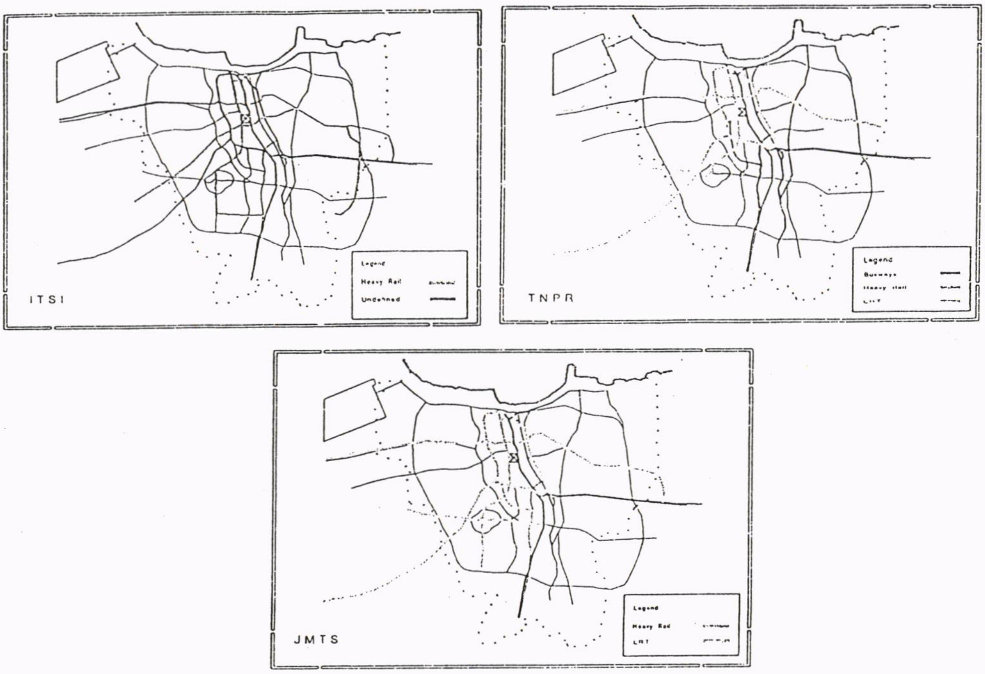
Abstract : Using three different proposals made for Jakarta during 1988-1992 as a case study, this paper evaluates and compare the alternative strategies of the mass transit system in Jakarta, assessing their strengths and weaknesses and recommending the most suitable ones. The evaluation of proposed strategies was carried out through Multi Criteria Analysis using PROMETHEE and involved a total of 12 criteria drawn from network performance (by using SATURN-SATCHMO programs for network modelling), economic and financial aspects, technology and service characteristics and project impacts. A panel of experts and Transportation Authorities was used to weight all criteria and to score the qualitative aspects through a preference survey. Finally, the results indicate that a strategy which combined Light Rail Transit (LRT) and Heavy Rail Transit (HRT) came out as the best option.

1. INTRODUCTION

1.1 Background

Jakarta, covers an area of about 650 km^2 and has a population of about 9 million people. It has been suffering for many years with similar transportation problems to other large developing cities. Principally, this problem arises from very rapid economic development and from other sectors, which increase the demand for the movement of people and goods, which then cannot be accommodated on the existing transportation system.

In order to improve conditions, the government has conducted many studies to find effective and affordable solutions. Many of those studies were commissioned by various state authorities. Their study objectives differed because of the vested interest of each institution, and thus their results often conflicted with the recommendations of other studies. Among these studies, three of them (The Integrated Transportation System Improvement (ITSI), conducted under the direction of the Railway Authorities; The Transportation Network Planning and Regulation (TNPR), conducted under the direction of the Directorate of Urban Transportation; and The Jakarta Mass Transit System (JMTS) conducted under the direction of the Ministry of Research and Technology) had similar objectives and were carried out at almost the same time. However they presented proposals that differed from each other and recommended alternative networks, corridors for development and technology to be adopted as shown in Figure 1.1. Thus, the ITSI study proposed a system that relied mainly on heavy rail technology in combination with other still undefined modes (but probably light rail transit), the TNPR study proposed a system that combined busways with both heavy and light rail, while the JMTS study proposed a combined system of light and heavy rail technologies .



(Source: Jakarta Mass Transit System, 1994)
Figure 1.1 Alternative network proposals

1.2 Objectives of The Research

Using this situation as a case study, this research intends to evaluate these three proposed mass transit system strategies by using multi-criteria analysis method. This evaluation just compared the recommendations put by the three studies and will be conducted without regard for the actual government decisions on the selection and implementation of the plans, which could and would have been based on many considerations including reasons of vested interests, internal political relations and sources of international finance.

1.3 Data, Scope and Limitations

Two types of data were used for this research; (derived from various sources) namely:

i. Primary data obtained from surveys or direct observation in the field.
ii Secondary data obtained from the original proposals and other relevant studies or reports, and from computer data files used in JMTS and TNPR.

Due to difficulties in obtaining all of the data required from the original studies or from the direct surveys, much of the work is based on data from just one of the studies which was then assumed to be valid for other studies as well. Therefore, the comparison and evaluation exercises will be based on just three networks, one set of trip matrices, one economic and financial appraisal scenario, and one system evaluation framework. In addition, some assumptions, modifications and simplifications had to be made in order to give a fairer basis of comparison.

2. RESEARCH METHODOLOGY

2.1 Overview of Research Methodology

An overview flow chart of the research methodology is shown in Figure 2.1 below.

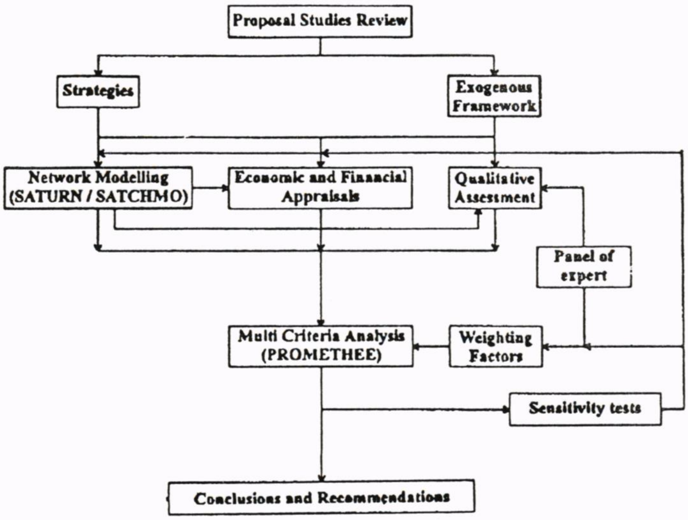


Figure 2.1 Flowchart of research methodology

The first step in this research was thus to review the strategies in the three proposal studies, as well as their planning methodologies. In parallel, network representations of the proposed strategies are set up based on information gathered from the review of the studies. The work continues by modelling the proposed strategies and assessing their performance, followed by an appraisal of the economic and financial viability of the schemes, including an investigation of those impacts which could not be measured quantitatively. The network performance and the economic and financial viability indicators are selected for analysis as they are considered to be the most important aspects of the schemes and are also common to all studies. This is followed by an evaluation using Multi-Criteria Analysis, in particular the PROMETHEE. In order to investigate the sensitivity of certain inputs, as well as to observe the critical steps and parameters, we then carry out a series of sensitivity tests. Finally the conclusions and recommendations drawn from this work is given.

2.2 Network Modelling and Analysis

Network modelling was carried out in order to measure the required network performance criteria quantitatively. This performance was assessed by applying each proposed strategy for a mass transit system (loaded by future trip demands) into a common computer model. The alternatives involve both different technologies (Heavy and Light Rail or Busway) and different corridors. The main modelling differences between alternatives including their speed, capacity, fares level, station spacing etc.

These tests used a combination of transport network modelling packages SATURN (Simulation and Assignment of Traffic to Urban Road Network) and SATCHMO (SATURN Travel Choice Model). SATURN is a transport modelling package program developed in the Institute for Transport Studies, University of Leeds, which can be used to simulate and assign traffic flow onto urban road networks (see Van Vliet and Hall, 1993), while SATCHMO is a multi-modal transport package designed to complement SATURN, developed jointly by W.S. Atkins with Steer, Davies and Gleave. Together they offer a comprehensive modelling tool capable of handling tactical and strategic transport modelling and analysis of travel choices (mode, route, time or destination) (Arezki, 1993). It was felt that the use of SATURN and SATCHMO as "external" programmes (i.e. not involved in any of the three original studies) would avoid any bias toward one particular study.

The input network and trip matrix data required to run the program were obtained from computer files derived from JMTS. Other specific data were derived from the three original studies' data files or supplied externally from other reports and literature. The outputs of the modelling consist of network performance, i.e average speed, the average volume over capacity (V/C) ratio, modal split and system capacity, which are all included in the evaluation stage.

2.3 Economic and Financial Appraisal

This step was carried out so that the economic and financial aspects of the assessment analysis could be included in the evaluation stage. The economic indicators used is The Internal Rate of Return (IRR),which is commonly considered as the preferred indicator in project evaluation, that is the discount rate at which the net present value of the costs and the benefits becomes zero. The formula to calculate this indicator is :

$$\Sigma\,(\text{Benefit}_i - \text{Cost}_i) / (1 + r)^i = 0 \qquad [2.1]$$

where: i = year (from base year to the end of project life).
r = discount rate (which becomes IRR, provided that the equation is satisfied)

Furthermore, the financial indicators used is the Cost per Passenger-Kilometres (CPKM), which was obtained from a simplified costing model, may indicate how much passengers should actually pay for using the system concerned. This value is derived by dividing total annual costs by the total annual number of passengers multiplied by the total kilometres travelled:

$$\text{CPKM} = \text{Total annual cost/ (number of passengers*kilometres travelled)} \qquad [2.2]$$

All costs used in the calculations were directly derived from the original proposals, whereas the benefits and revenues were estimated from the results of modelling exercises (e.g. from the time savings between Do-Minimum and Do-Something scenarios). Due to the different assumptions made in each proposal, e.g. the construction period, the value of time etc., for the sake of a fair comparison it was decided to use common assumptions for all proposals.

2.4 Method and Criteria for Strategy Evaluation

2.4.1 Current methods of evaluation

Evaluation techniques have been evolving for many years, from those based mainly on intuition to others which are based on more formal methods. So far, evaluation methods can usually be categorised into two groups, one which deals primarily with monetary aspects alone and another which includes non-monetary aspects as well.

In the first group, the most common methods used are Cost-Benefit Analysis (CBA) and Cost Effectiveness. CBA has been in widespread use for many years and its main advantages are that it is simple, direct and objective. Another method, Cost Effectiveness Analysis, was developed which can measure the effectiveness of that project with regard to its cost.

The second group, which includes non-monetary aspects, is commonly based on the so-called Multi Criteria Analysis (MCA) evaluation techniques (see Bana, 1990, for example). In practice, results from the monetary based methods can also be integrated into this group. Two main development streams emerged. First, one which based on descriptive analysis. These methods were relatively easy and simple to construct therefore they were more commonly used in practical applications. Secondly, the methods that were grounded more in mathematics such as the Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE) (see Brans and Mareschal, 1993), Analytic Hierarchy Process (AHP) (see Saaty and Kearns, 1985), Elimination and Choice Translating Reality (ELECTRE), etc. Due to the rather complex nature of the process, these methods were more popular for academic purposes.

2.4.2 Proposed method

Having considered the methods available, and taking into account the factors previously mentioned, the evaluation method chosen for this study is based on MCA. This choice is also based on the fact that this type of evaluation method has not been fully exploited in transportation field whilst it appears to have the potential to be used more widely in this field (see ITS *et al*, 1995).

The particular MCA method proposed to be used is the PROMETHEE. This method, as one of the more advanced evaluation tools, has already been adopted in many fields, e.g. medical, waste management and public policy decision making. This particular method were also simple, clear, stable and it can include a wide variety of criteria and include the participation of interested parties in the process through their role in assigning the criteria weights. It is also relatively easy to conduct a sensitivity analysis of the results.

This method is able to rank a set of alternative plans in accordance with a set of criteria. In comparing the score obtained for each criterion, there is a preference function which has to be chosen to represent the intensity of this preference. In evaluation, the project impact scores (multiplied by their weights) for each alternative are compared with each other, taking into account the preference function of its criterion. This method calculates (for each criterion) the extent to which each alternative was better or worse (termed as dominating or dominated) compared with the other competing plans. The scores obtained (termed as flows) for one alternative are summed up across all of the criteria, and this total becomes the basis for ranking the alternative plans.

There are many features available in this method, for instance it is possible to see a partial or a total rank between alternatives. The partial rank is based on the scores of how one alternative dominates or is dominated by other alternatives for all criteria, whereas the total rank is based on their net scores. In this research, calculations and analysis used the student version of PROMCALC-GAIA program developed at Vrije Universiteit Brussel which is capable of handling 60 actions (with a maximum of either 12 alternatives or criteria).

2.4.3 Proposed criteria adopted

Based on a literature review of which criteria were commonly adopted, the criteria selected for this research were determined by considering certain factors. First, questions of completeness, operationality, decomposability, absence of redundancy and minimum size (Keeney and Raiffa, 1976) were taken into account. Then discussions were held many informed people from which a set of appropriate criteria ultimately emerged. These criteria selected may be grouped into network performance, economic and financial outcomes, operational (technology and service) characteristics and project impact aspects as shown in Table 2.1.

Table 2.1 Proposed criteria

Criteria	Objective	Description	Unit	Catagory
1. Average speed	max.	Average speed of road traffic	km/h	Network
2. Average V/C	min.	Average Volume/Capacity of road	ratio	performance
3. Modal split (PT : PC)	max.	Split of Public transport: Private	%	
4. System capacity	max.	Number of passenger/h in the system	pass/h/d	
5. IRR	max.	Internal rate of return	%	Economic
6. Cost/ pass.km	min.	Cost per passenger-kilometres	US$	Financial
7. Flexibility and adaptability	max.	Ability to adapt & suit the changes (demand etc	rating	Technology
8. Durability	max.	Durability of infrastructure, rolling stock etc.	rating	Characteristic
9. Access., comfort and convenience	max.	Ease to reach, comfort & convenience	rating	Service
10. Reliability, safety and security	max.	Dependable in terms of time, safety and security	rating	Characteristic
11. L U/City develop. & equity dist.	max.	Impact on land-use/city development and equity	rating	Project
12. Envir. impact & energy consump.	min.	Impact on environment & energy consumption	rating	Impact

2.4.4 Selection of judges

Aside from getting results from the modelling exercises, the assessment and analysis also involved a panel of "judges" to make judgements on both the intangible aspects and the required weighting factors for each criterion. There are various possible ways of selecting judges, e.g. by using judges directly from various community groups, or by using representatives selected from the government, elected people and so on. For this research, the second approach was chosen and the parties involved consisted of :

(i) Officers from the government authorities who are responsible, or will be affected by the plans, and prospective investors in the projects.

(ii) Neutral persons obtained from Universities and consultants who could be considered to have adequate knowledge about transportation science as well as the problems in Jakarta itself, so that they could act as a panel of experts.

3. APPLICATION MULTI CRITERIA ANALYSIS

3.1 Survey Procedures and Technique

As mentioned previously, some impacts can be measured or calculated directly from the network model tests and/or from the economic and financial appraisals. However, the other impacts are not quantifiable and can only be determined qualitatively. To overcome the difficulties in determining these intangible impacts and the relative importance of one criterion to the others, this was carried out by using a preference survey. This survey was carried out in two steps as follows. Firstly, in the initial visit, there was a round of in-depth interviews regarding the issues around the requirement of a mass transit system in Jakarta. This was followed by giving out the questionnaire and describing its content and the methods of assessment. These questionnaires were later collected and discussed again in a second visit. The surveys were carried out twice. The first in August 1993, just covered the weighting factors and was treated as a pilot survey. The second survey was carried out in January 1995.

3.2 Project Impact Assessment

The project impact assessment form to be filled in, which contains a complete list of criteria, is shown in Table 3.1. The assessment was made by comparing the alternative strategies against each other, taking each particular criterion in turn, and scoring each of them on a scale from 1 to 9. Each judge was also asked to give comments (if any) about the adoption of the criteria used and the assessment methods.

Table 3.1 Form for determination of project impact scores

Criteria	Type	Alternative A	Alternative B	Alternative C	Remarks
1. Average speed	max.	-	-	-	Do not fill
2. Average V/C	min.	-	-	-	"
3. Modal split (PT:PC)	max.	-	-	-	"
4. System capacity	max.	-	-	-	"
5. IRR	max.	-	-	-	"
6. Cost/pass.km	min.	-	-	-	"
7. Flexibility and adaptability	max.				
8. Durability	max.				
9. Accessibility, comfort & convenience	max.				
10. Reliability, safety and security	max.				
11. LU/ City develop. & equity distrib.	max.				
12. Environ. impact & energy consump.	min.				

3.3 Weighting Criteria

The weighting factors are applied to all criteria. There are various way to get these weights, for example by the judges agreeing a consensus weight in a special meeting. However, for practical reasons, in this research this weight was left solely to each individual judge to decide on the basis of the assessment guidance given. The assessment method was based on rank (on an ordinal scale), rating (on a cardinal scale 1 to 9) and pair-wise comparisons. The use of different methods of assessment above was an attempt to select and obtain more reliable results and to check the consistency of the assessment. These methods are briefly reviewed here as follows:

1. Ranking technique:
   Each judge was asked to give a numerical rank for each criterion, indicating the most important criterion by 1 up to the highest number (say 12) for the least important

2. Rating technique:
   Each judge was asked to give a score for each criterion, based on 1 for the least important up to 9 for the most important

3. Pair-wise comparison technique:
   This method was performed by comparing pairs of criteria. The criteria (listed on the ordinate and abscissa, see Table 3.3) are compared, one at a time, selecting the more important criterion of the two. Each cell of the matrix was filled by a score to indicate the relative importance of the left criterion (the ordinate) against the upper criterion (the abscissa), and, as a consequence, the reciprocal value had to be applied to the other pairing of the criteria in the matrix. (e.g. A compared to B and vice versa).

An example of the filled form is given in Tables 3.2 (for rank and rating) and 3.3 (for pair-wise comparison).

Table 3.2 Form of weighting criteria (rank and rating)

Criteria	Type	Description	Rank	Rating
1. Average speed	max.	Average speed of road traffic	6	5
2. Average V/C	min.	Average Volume/Capacity of road	1	9
3. Modal split (PT:PC)	max.	Split of Public transport : Private	10	3
4. System capacity	max.	Number of passenger/h in the system	9	4
5. IRR	max.	Internal rate of return	4	7
6. Cost/pass.km	min.	Cost per passenger-kilometres	2	8
7. Flexibility & adaptability	max.	Ability to adapt & suit the changes (demand, technology etc)	6	5
8. Durability	max.	Durability of infrastructure, rolling stock, technology and operation duration	10	3
9. Accessibility, comfort & convenience	max.	Ease to reach, comfort & convenience	2	8
10. Reliability, safety & security	max.	Dependable in terms of time safety and security	6	5
11. L U/City develop. & equity distribution	max.	Impact on land-use/city development and equity distribution	4	7
12. Environment & energy consumption	min.	Impact on environment & energy consumption	10	3

Table 3.3 Form of weighting criteria (Pair-wise comparison)

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12
C1.Average speed		1/5	5	3	1/3	1/2	1	5	1/4	1	1/3	3
C2.Average V/C			7	5	3	2	5	7	2	5	3	7
C3.Mode split				1/3	1/5	1/6	1/3	1	1/6	1/3	1/5	1
C4.System capacity					1/5	1/5	1/3	3	1/5	1/3	1/5	1
C5.IRR						1/2	4	6	1/2	4	1	6
C6.Cost/pass.km							5	7	1	5	2	7
C7.Flexibility & Adaptability								5	1/5	1	1/4	5
C8.Durability									1/6	1/4	1/5	1
C9.Access.,Comfort & Convenience										4	2	7
C10.Reliab., Safety & Security											1/4	4
C11.LU/City dev.& Equity dist.												6
C12.Environment & Energy consump.												

3.4. Results of Surveys

3.4.1 Non-quantifiable project impact scores

The non-quantifiable project impact scores, taken as the average values across judges, are shown in Table 3.4. It shows that in 5 out of 6 criteria, the JMTS strategy got the highest scores compared to the other two strategies. Also, it shows that the TNPR strategy was better than the ITSI strategy. The differences between strategies seem to be not very large.

Table 3.4 Project non-tangible impact scores

Criteria	ITSI	TNPR	JMTS	Remark
7. Flexibility & Adaptability	4.44	5.88	6.25	experts judgement
8. Durability	5.56	5.56	6.13	"
9. Accessibility, Comfort and Convenience	5.13	6.63	6.44	"
10. Reliability, Safety & Security	5.88	6.06	6.75	"
11. Land-use/City develop. & Equity distribution	5.88	6.75	6.75	"
12. Environmental impact & Energy consumption	5.88	5.50	5.00	"

3.4.2 Weighting factors

The weighting factors per criteria (based on the rating system) from the two groups of judges representing the authorities and the neutral persons are shown in Figure 3.1. The mean score and standard deviation of the importance, or weighting factors, given to each criterion relative to others from each group of judges are also plotted.

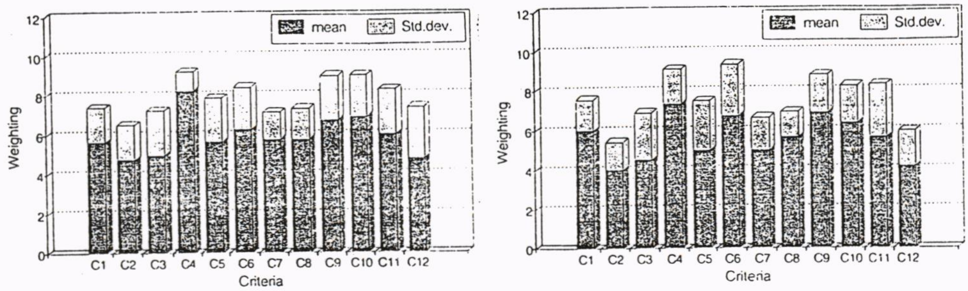


Figure 3.1 Weighting factors from authorities (left) and neutral persons (right)

Looking at these figures, there appears to be a good deal of variance in the judgements, illustrated by a quite high standard deviation. Attempts to distinguish the results between the two groups indicated that both sets of results showed similar patterns. This was confirmed by using Spearman's rank correlation test which gives $r_s = 0.899$, which is higher than the Spearman coefficient $r_s^0 = 0.504$ (for $n = 12$ and $\alpha = 0.05$), which means that both ranks are positively correlated.

A summary of the normalised results of the three methods, and also the average figures across the judges, is shown in Table 3.5.

Table 3.5 Criteria weighting factors

	Criteria	Rank	Rating	Pair Comp.	Average
1.	IRR	0.07	0.08	0.06	0.07
2.	Cost/pass-km	0.11	0.09	0.11	0.10
3.	Average speed	0.08	0.08	0.08	0.08
4.	Average V/C	0.05	0.06	0.05	0.05
5.	Modal split	0.07	0.07	0.07	0.07
6.	System capacity	0.13	0.11	0.13	0.12
7.	Flexibility & Adaptability	0.07	0.08	0.07	0.07
8.	Durability	0.07	0.08	0.08	0.08
9.	Accessibility, Comfort & Convenience	0.10	0.10	0.11	0.10
10.	Reliability, Safety & Security	0.10	0.10	0.11	0.10
11.	LU/city develop.& Equity distribution.	0.09	0.08	0.09	0.09
12.	Environ. impact & Energy consumption	0.06	0.06	0.06	0.06

Looking at Table 3.5 there appears to be some consistency in the results from the three different assessment methods. It was revealed that the judges thought that the most important feature in a proposed system was the system capacity. This perhaps illustrates the perception that the most urgent problem in tackling the public transport problem in

Jakarta is the provision of adequate capacity. This might also be influenced by the current normal overcrowding.

The quite high weights assigned to service characteristics (accessibility, comfort and convenience; and reliability, safety and security) also reflect the preference of most people living in the area, where the contrasting current condition of public transport makes them reluctant to use it. Whereas the quite low weight for IRR and the high weight for Cost per passenger kilometre illustrate a general tendency in people to neglect the economic consequences of building new transport infrastructure on the one hand, whilst desiring the cheapest out-of-pocket expenditure on the other. The low weights assigned to land use or city development and equity distribution, and to the environmental impact and energy consumption criteria, also illustrate different interests between developed and developing countries. Developed countries are more concerned with preserving these issues, whilst developing countries are still struggling with issues of providing an adequate system.

To check the repeatability between the first and second surveys, the results of all methods combined can be compared and shown in Tables 3.6. It can be seen that, 10 out of 12 criteria were the same or just slightly different, apart from IRR and Average V/C criteria. The differences might illustrate the effect of the additional judges in the second survey.

Table 3.6 Weighting factors from the 1st and 2nd surveys as a group

Category	Criteria	1st Weight	2nd Weight
Network performance	-Average speed	0.09	0.08
	-Average V/C	0.09	0.05
	-Mode split	0.06	0.07
	-System capacity	0.11	0.12
Economic and Financial	-IRR	0.13	0.07
	-Cost/pass.km	0.10	0.10
System / technology characteristics	-Flexibility & Adaptability	0.08	0.07
	-Durability	0.06	0.08
Services characteristics	-Accessibility, Comfort & Convenience	0.09	0.10
	-Reliability, Safety and Security	0.08	0.10
System Impacts	-LU / City dev. & Equity distribution	0.07	0.09
	-Envir. impact & Energy consumption	0.05	0.06

3.4.3 Relation of weighting factors and project impact scores

In order to test for correlation between the weighting factors and the qualitative project impact scores, a sample of the scores given by one judge is shown in Table 3.7. It shows that the weights seem to have been given independently of the scores, e.g. that high scores are just as likely to be given for criteria with low weights as with high weights. Also, the scores given were in a rather similar range. A null hypothesis test by using the Spearman rank correlation index between the weight and the average scores given to the strategies by the judges resulted in r_s between 0.228 to 0.743, which are all less than $r_s^{0}=$ 0.829 (for $n = 6$ and $\alpha = 0.05$), which confirms this non-correlation.

Table 3.7 Example of weight factors and qualitative project impact scores

Criteria	Weight	Objective	Score			
			ITSI	TNPR	JM'TS	Average
7. Flexibility & Adaptability	7	max.	6	8	9	7.7
8. Durability	6	max.	8	6	7	7.0
9. Accessibility, Comfort & Convenience	9	max.	7	8	9	8.0
10. Reliability, Safety & Security	8	max.	7	7	9	7.7
11. Land-use/ City dev.& equity distrib.	6	max.	7	8	9	8.0
12. Environ. impact.& Energy consump.	6	min.	9	8	8	8.3

3.5 Comparison of Strategies and Outranking Analysis

In order to determine the best strategy, the alternative plans, the project impact scores and the weighting were set up in an evaluation table and the PROMETHEE program then calculated and analysed the scores obtained for each alternative to rank (either partial or total) and selected the best strategy. The complete project evaluation table is shown in Table 3.8. This table shows the criteria used, their units and their objective (whether to maximise or minimise). The column type refers to the type of preference function. For criteria 1 to 6, a type 6 (gaussian preference) function was adopted due to the nature of the values derived for each criterion which were considered to be normally distributed. The standard deviations were selected as the thresholds. For criteria 7 to 12, a linear preference of type 3 was chosen in accordance with the scoring system used, i.e. a rating system with scale 1 to 9. The threshold used was 1 as the unit of rating. Finally, the remarks about their derivation are also given.

Table 3.8 Evaluation table

Criteria	Unit	Obj.	Type	Weight	ITSI	TNPR	JMTS	Remark
1. Average speed	km/h	max	6	0.08	15.9	15.3	16.0	Results of
2. Average Vol./Cap.	ratio	min	6	0.05	0,714	0,730	0,704	modelling
3. Modal split	%	max	6	0.07	56.1	56.0	55.8	
4. System capacity	pkm	max	6	0.12	8,819	5,720	6,311	
5. IRR	%	max	6	0.07	6.4	6..6	7..2	CBA &
6. Cost/ pass.km	US$	min.	6	0.10	0.15	0.16	0.15	Cost model
7. Flexibility & Adaptability	Score	max	3	0.07	4.44	5.88	6.25	experts
8. Durability	Score	max	3	0.08	5.56	5.56	6.13	judgement
9. Accessib., Comfort & Convenience	Score	max	3	0.10	5.13	6.63	6.44	experts
10. Reliability, Safety & Security	Score	max	3	0.10	5.88	6.06	6.75	judgement
11. LU/ City dev. & Equity distrib.	Score	max	3	0.09	5.88	6.75	6.75	experts
12. Envir. impact & Energy consump.	Score	min	3	0.06	5.88	5.50	5.00	judgement

The results of the analysis is shown in Table 3.9. The positive leaving flow expresses the power of how one alternative dominates the other alternatives, and the negative (entering) flows expresses the weaknesses of how one alternative is dominated by the others. It is evident in this table that JMTS performs better than the other alternatives.

Table 3.9 The results of PROMCALC-GAIA analysis

Action	Leaving		Entering		Net	
	Flows	Rank	Flows	Rank	Flows	Rank
Al : ITSI	0.992	2	0.416	3	-0.193	3
A2: TNPR	0.188	3	0.354	2	-0.166	2
A3: JMTS	0.474	1	0.115	1	0.359	1

The result is further illustrated in Figure 3.2, which shows that in the Promethee I partial ranking JMTS performs better than the other two strategies (shown by the arrows pointing from A3 to Al and A2, representing the strategies). On the other hand, a clear conclusion cannot be reached between TNPR and ITSI (or termed as "incomparable") since these two strategies perform better than each other on some criteria and worse on other criteria. Furthermore, the Promethee II complete ranking and net flow results, shown in Figures 3.3 which gives the balance between power and weakness (called the net flow), shows that JMTS dominates the other alternatives, as it has the highest positive net flow. In this case TNPR slightly dominates ITSI in respect of the net flows phi (ϕ).

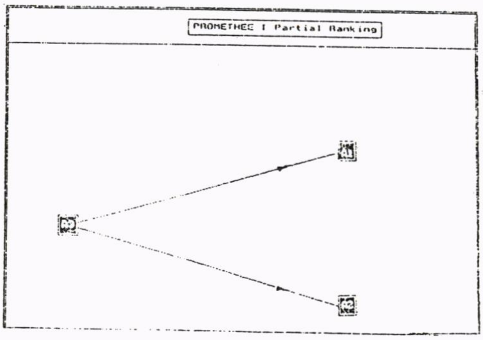


Figure 3.2 Promethee I partial ranking

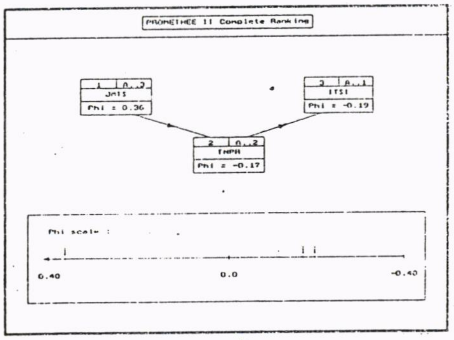


Figure 3.3 Promethee II complete ranking

Therefore, on the basis of these results, it is clear that the JMTS proposal is much better than TNPR or ITSI and represents the best option of the three proposed strategies. These results are not too surprising, since JMTS performed better than the other two alternatives in all criteria except numbers 3 and 4. On the other hand, comparing the ITSI and TNPR shows that ITSI is better in criteria 1 to 4 and 6, whereas TNPR is better in criteria 5, 7 and 9 to 12.

3.6 Sensitivity Analysis

Sensitivity analysis is required to determine which factors are crucial as well as to check the robustness of the outcome to changes that might arise in various inputs. The factors selected for sensitivity testing were based on the tests carried out by each study and on information from the literature about similar tests elsewhere. The sensitivity of the rankings of the strategies was observed by changing the weights, the network performance scores and the type of preference function used. As the results, the frequency of each alternative being ranked I, II, and III is shown in Table 3.10 below.

Table 3.10 Frequency of ranking of order

Ranking	JMTS	TNPR	ITSI	Remarks
I	33 x	1 x	4 x	Including original
II	4 x	22 x	12 x	
III	1 x	15 x	22 x	

The analysis shows that the position of JMTS as the "best' solution is relatively insensitive to the choice of weighting factors, network performance scores and type of preference functions. In addition, the ranking of TNPR and ITSI is relatively sensitive to changing the weighting factors and type of function used. ITSI is strong in quantitative aspects, in particular network performance (i.e. system capacity), whilst TNPR is good in qualitative aspects, in particular technology (i.e. flexibility) and service characteristics (i.e. accessibility).

3.7 Comment and Discussion

Several points can be addressed from this exercise. First, the criteria and methods of measurement were limited by a number of factors, such as the maximum number of criteria which could be processed by the program (i.e 12), the time constraints. Secondly, there is still some debate about the pros and cons of MCA compared with conventional CBA. However, the application of this method should be encouraged in the future because there will be more conflicts of interest to be faced in evaluating this kind of project. The use of MCA can hopefully give a more thorough and valuable assessment than the more restricted economic or financial point of view in CBA. In practical applications, many evaluations of infrastructure projects have used simpler techniques due to, for example, time pressure in completing the studies, the amount of data input and the complexity of the analysis process. The more detailed methods, such as PROMETHEE, are still more usually limited to academic purposes.

In terms of the criteria weighting factors and qualitative project impact scores, it was almost impossible to have "similar or uniform" values between judges, due to their very different backgrounds, interests, points of view, value systems and degree of understanding about the subject being assessed. Ideally, all of the judgements should have been made in the same place and at same time, so that their decisions could be discussed between themselves, which could have led to a compromise solution. This would have been in the form of a combination of the Delphi and swing techniques. Regarding the criteria used and the methods of assessment, the judges generally accepted the criteria with regard to the stage of the infrastructure evaluated (still in network concept), although some of them proposed one or two more criteria, such as the impact of the proposed system on the image of the city, which was thought to be rather irrelevant..

It was also noticed that the values of the weights and the scores given by each judge did not vary much among criteria and alternatives (e.g. most scores were in a range of 6,7 and 8,). This phenomenon might be explained by investigating further factors such as the scaling system and the value system used or the reasons behind each judgement.

In terms of the scaling system used, some of the judges proposed using different scales (either the smaller 1 to 5 or the bigger 1 to 100 scales). In terms of the value system used, it appears that the judges rather hesitated to assign the most extreme values, and this might illustrate the traditional Indonesian value system. Also, since the values assigned were mostly based on "opinion or personal measurement" rather than "exact measurement", it is impossible to check whether their assigned values are correct.

It was realised beforehand, that some of the criteria would be cross-correlated to some extent. For example, speed affects the time saving calculated for IRR, and modal split affects both V/C and, indirectly, the cost per passenger-kilometres, as it affect the numbers of passengers for a particular mode of public transport. However, these criteria include different aspects to be assessed or considered, such as physical and economic, and they have different weights. Therefore they all are required in the assessment.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusion

Two important issues have been derived from this research. First, despite some of the weaknesses in the process, this research has demonstrated a quite fair examination of the selection process by attempting to perform an evaluation based on a more scientific methodology. Secondly, the results of this research point to the JMTS strategy as the best choice to be adopted. It might be thought that this evaluation is rather biased toward JMTS, since the work was quite heavily based on the data from that study, especially for the modelling exercise. However, the qualitative aspects of the criteria, which were independent of study data, also show the highest scores for JMTS; therefore this suspicion perhaps can be eliminated. This results is also in line with the current actual situation in Jakarta which seems to be in favour of such a strategy and demonstrated by the latest implementation plan which is based heavily on this strategy.

4.2 Recommendations

1. For applications in the real world, one can improve the evaluation methodology by using more data and by involving more people or decision- makers in the evaluation. This improvement could lead to a more objective assessment, avoiding the involvement of subjectivity, such as a narrowly defined special interest
2. Improvements in the technique of weighting the criteria and scoring the project impacts are recommended, by arranging a special meeting between all judges. From the user's point of view, judges could be recruited from elected representatives.
3. Last, there is a recent trend that, rather than using sensitivity analysis, some studies prefer to use risk or probability analysis. It is claimed that this type of analysis is more appropriate and useful for dealing with uncertainties. Therefore it might also be interesting to apply these type of analysis in this particular case.

ACKNOWLEDGEMENTS

There are so many people and institutions that I want to thank. First of all, I would like to thank my former supervisors, Dr. D. Van Vliet and Prof. P.J. Mackie. Without them this research would have never been completed. Secondly, thank to Prof. A.D. Pearman for allowing me to use PROMETHEE, Dr. Y. Arezki who taught me to use SATCHMO, Mr. M.C. Mogridge who supplied the TNPR reports, Dr.1r. Indrayati S. who allowed me to use JMTS data. Thirdly, friends and colleagues who helped me in various ways, viz: N. Marler, H. Coleman, D. Taylor, all Judges, all members of the Indonesian Student Association at the University of Leeds between 1992 to 1996 and Transportation group at ITB. Finally, thank to the Directorate General of Highways, Bina Marga, which provided the funding to pursue this study.

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