PRIORITIZING TRANSPORT INFRASTRUCTURE PROJECTS AT EARLY STAGES OF PROJECTS

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ABSTRACT

Investment on transport infrastructure is a significant component in a country's budget as it is identified as a key factor to facilitate the country's development. At the same time demand for transportation is positively correlated with the development. With this increasing demand for transport infrastructure and limited funding available, it is necessary to prioritise appropriate projects. Current appraisal practices at the early stages of projects fail to identify some important criterions and therefore, may ultimately end up not selecting the most appropriate project(s) which addresses contemporary concerns. Therefore the objective of this study is to identify a cost effective method and factors that should be considered in evaluating alternatives at the early stages of transport infrastructure projects. Both academic and grey literature was reviewed to identify current practises; methodologies and factors concerned in the recent past. Most of the time feasibility reports used descriptive format and often gave vague conclusions. Therefore the final selection of alternative(s) is implicit.

A performance matrix was developed in this study based on multi criteria analysis linear additive model. This method was primarily selected as it is easy to use in practise. In addition to the traditional criterions, this matrix contains new criterions that should be looked into with the current interests. A case study for Kandy expressway alternative selection based on this developed performance matrix is presented in this paper. In addition to the new matrix, a modified scoring system was used in the analysis to minimise the variations, as scores are given by different experts. Further, analysis was compared with the view of different experts and results of sensitivity analysis to address the possible arguments on weight given to each criterion.

Keywords: Transport infrastructure, Multi criteria analysis, Project evaluation, Performance matrix

1. INTRODUCTION

Transport infrastructure development is a key concern of authorities because it is identified as a key factor to facilitate the development and the demand for transport increases with development (Banister & Berechman, 2000; Transport Reserach Board of the National Academics, 2014). As considerable amount of limited recourses are absorbed for transport investment (Shor & Kopp, 2005) it is essential to select what projects are to be implemented first and what are the best alternatives.

This problem becomes more complex as many of the transport infrastructure developments are geographically spread, have long term, medium term and short term impacts. Incorporating all key factors in pre evaluation is essential to utilise the resources effectively, yet it is a time consuming and costly process. Current practises especially in Sri Lanka, does not pay attention to some major impacts and objectives that should be considered to achieve sustainable development. In addition current practices commonly use descriptive format and tend to give ambiguous or vague conclusion rather than being explicit (Rayner, 2004). Therefore this study focuses to find the factors that should be considered in the pre-evaluation process and a methodology to be adopted to have explicit conclusions.

At early stages of the project both time and financial recourses will be limited for proper evaluation. This will lead to poor quality data (Shor & Kopp, 2005). Therefore adopting a linear additive model based on Multi Criteria Analysis (MCA) framework incorporating the factors identified is more feasible than going for a complicated high data quality required method. Further the procedure is intended to be used widely in industry, using a complicated method will hinder that objective. Further at the early stages, external influences such as political preference may affect the project prioritisation. Considering all the practical advantages and limitation the linear additive model was selected. Academic literature and grey literature such as project reports were referred to identify current practises as well as the current objectives of development. Based on these a comprehensive performance matrix was developed to be used for evaluation.

Based on the developed performance matrix an evaluation was carried out to prioritize suitable traces for Kandy expressway. Traces provided by the project proponent were evaluated in this study. Major argument in this method is the weight given to each criterion of the matrix. To address this issues sensitivity analysis was conducted together with an analysis for weights given by each specialist in project group.

2. THEORY AND PRACTISE

Factors to be considered in transport development are the major concern. Due to its wide spread geographic and long term nature of impacts, quantifying the impacts at the early stage of a project is somewhat difficult. However, to achieve a sustainable development, it is essential to address all the critical parameters such as environmental, social and wider impacts (Grant-Muller, MacKie, Nellthorp, & Pearman, 2001; Shor & Kopp, 2005). In addition to the complexity in quantifying the wider impacts (Economic Development Research Group Inc, 2013; Graham, 2007) evaluators are faced with a great difficulty to incorporate the generational gap. This issue should be properly addressed in evaluations as the needs of tomorrow may not be same as of today (Waddell, 2007).

Due to the increasing evidence in climate change (Intergovernmental Panel on Climate Change, 2013), considering the climate related impacts is also critical in transport related developments as it is a major contributor in the long run (Chapman, 2007). However, it can be seen that in practice consideration on impact to environmental resources, projects contribution to climate change mitigation and adaptation strategies are ignored. Further cumulative impacts of different projects are not considered in impact assessment (Folkeson, Antonson, & Heedin, 2013).

Travel time saving, vehicle operating cost reduction, savings in road maintenance, accident cost reduction are the major impacts that have been considered in Sri Lanka in past studies (Egis beceom International, 2009; Egis beceom International, 2010; Korea International Co-operation Agency, Korea Consultants International, 2001; Korea International Co-operation Agency, Korea Consultants International, 2005; Oriental Consultants Company LTD, 2000; Oriental Consultants Company Limited, 2010). Some studies have considered additional impacts such as reduced traffic congestion, diver frustration reduction and mitigating certain external impacts in both environmental and social context (Skills International, 2013). Some times more emphasis is given to construction cost giving the cost break down with risks +15% in cost and -15% in benefit (Road Development Authority, 2009; Road Development Authority, 2010; Road Development Authority, 2013).

Review of these pre-construction evaluation reports of transport projects revealed that they tend to focus only on one major or the traditional assessment criterion. Most of the time they used descriptive formats and therefore final conclusion tend to be implicit, especially in environmental impact assessments (EIA). Further it can be seen that they lack in proper planning for post construction monitoring in these documents. This lack of preparation for post evaluation makes it difficult to conduct robust post construction evaluation. However studies show that more attention is given to environmental and social aspects in developed countries (Bristow & Nellthorp, 2000; Mackie & Worsley, 2013).

Due to lack of consensus and available data, social and environmental impacts of the development are usually not properly assessed (Geurs, Wouter, & Wee, 2009; Wijesekara, 1999; Zubair, 2001). This provides the evaluators an opportunity to neglect undesired impacts in the evaluation process (Jay, Jones, Slinn, & Wood, 2007; Lee & George, 2000) or incline them to use techniques such as least cost approach (Department of National Planning; Ministry of Finance and Planning, 2001). Further, even when the impacts are evaluated to some extent no proper weight is given in the final decision making (Gamalath, Perera, & Bandara, 2014).

Considering appraisal techniques to incorporate different impacts, literature suggests a wide range of techniques in transport project appraisal such as Cost Benefit Analysis (CBA) and Multi Criteria Analysis (MCA) methods (Bristow & Nellthorp, 2000; Gwilliam & Gommers, 1992). Among them traditional CBA can be incorporated with monetised parameters. However, lack of consensus on assigning unit prices and high quality data requirement in this methodology is unanswered (Jensen, 2012; Salling & Banister, 2009).

Due to the lack of data and resource availability, use of CBA will be limited, especially in early stages of project and in small scale projects. Further, considering only monetised impacts will not fulfil the needs of the community. Several studies have shown that result from Multi Criteria Analysis (MCA) is close to the final decision of authorities than that of CBA (Eliasson & Lundberg, 2012; Tudela, Akiki, & Cisternas, 2006). However, CBA is useful in determining the financial viability of the projects at latter stage.

To incorporate such wide range of criterions for assessment, MCA can be used (Ivanović, Grujičić, Macura, Jović, & Bojović, 2013; Keeney & Raiffa, 1993; Wolfslehner, Vacik, & Lexer, 2005). Comprehensive studies in infrastructure management show a wide usage of MCA tools not limiting to initial appraisal (Janssen, 2001; Kabir, Sadiq, & Tesfamariam, 2013).

Table 1: Factors Considered in Appraisal in EU Countries

		AUS	BEL Road	DEN Road	FIN	FRA	GER	GRE Road	IRL	ITA	NRL	POR	SPA	SWE Road	UK Road
DIRECT IMPACTS															
Capital	Construction Costs	MCA	MCA					MCA			MCA				
	Disruption Costs		MCA					MCA							
	Land and Property Costs		MCA					MCA							
Recurring	Maintenance Costs	MCA	MCA					MCA			MCA				
	Operating Costs							MCA			MCA				
	Vehicle Operating Costs	MCA	MCA					MCA			MCA				
	Revenues	MCA						MCA							
	Passenger Cost Savings							MCA							
	Time Savings	MCA	MCA					MCA			MCA				
	Safety	MCA	MCA					MCA			MCA				
	Service Level	MCA						MCA							
	Information							MCA							
	Enforcement														
	Financing / Taxation							MCA							
ENVIRONMENTAL IMPACTS															
	Noise	MCA	MCA					MCA			MCA				
	Vibration		MCA												
	Air Pollution - Local	MCA	MCA					MCA			MCA				
	Air Pollution - Global	MCA	MCA					MCA							
	Severance	MCA													
	Visual Intrusion							MCA							
	Loss of Important Sites		MCA												
	Resource Consumption							MCA							
	Landscape	MCA													
	Ground / Water Pollution	MCA						MCA							
SOCIO-ECONOMIC IMPACTS															
	Land Use	MCA						MCA			MCA				
	Economic Development	MCA	MCA					MCA			MCA				
	Employment		MCA					MCA							
	Economic & Social Cohesion							MCA							
	International Traffic							MCA							
	Interoperability							MCA							
	Regional Policy		MCA					MCA			MCA				
	Conformity to Sector Plans		MCA												
	Peripherality/Distribution							MCA							

Key: CBA (Monetised Impacts) Measured Impacts Qualitative Assessment MCA - included in Multi-Criteria Analysis

Source: (Nellthorp, Mackie, & Bristow, 1998)

There is a wide range of MCA tools that can be used for project evaluation. Several of them are direct performance matrix analysis, multi-attribute utility theory, fussy set analysis and out ranking methods (Dodgson, 2009; Teng & Tzeng, 1996; Teodorović, 1999; Tsamboulas, Yiotis, & Panou, 1999). Feasible method to be used can be selected based on the data and time availability, risks involved and external factors such as political preference. Having strong constraints in these could lead to simple models. However, if all the factors are paid attention in evalauting projcts, even a simple model can produce useful results.

3. METHODOLOGY

Based on the literature review, factors that are currently considered in infrastructure development and that should be paid further attention due to current trends were selected as criterions for the new performance matrix.

Assigning weights to each category should be based not only the magnitude of impact but also the duration of the impact. Therefore the product of those two factors should be considered in assigning weights (Gamalath, Perera, & Bandara, 2014). Based on this logic each evaluator may use Analytical Hierarchy Process (AHP) to assign weights. Using AHP will allow the evaluator to compare each criterion pair wise (Caliskan, 2006; Tzeng, Lin, & Opricovic, 2005). Since large numbers of criterions exist, it is effective to use the decision tree concept to reduce the number of pair wise combinations. The evaluator may use assign scores to the alternatives in a scale (0-10/0-100) rather than ranking them or using AHP. This will facilitate the easy add or drop of alternatives. Negative scores could be assigned to negative impacts to achieve net impact value.

Further if several experts are giving scores to the same criterion it could be recommended to use the standardised scores with respect to the minimum. Further based on the nature of the criterion linear relationship, inverse relationship or polynomial relationship between impact and scoring should be practised.

However, the main argument that arises with this methodology is on the weight given for each criterion. Scores given for each criterion is given by the specialist of the subject and there was little argument against this. To address these issues different weights given by each specialist were separately analysed together with a sensitivity analysis, for each criterion to see the effect of weight on each factor (Dodgson, 2009).

4. RESULTS

Based on review of academic literature and project reports, factors that should be considered in evaluating transport projects were identified. Table 2 shows the complete performance matrix that is developed to evaluate different alternatives.

Table 2: Performance Matrix

Impact Category	Criterion	
Economic	Community/ economic development	
	Cost (construction, maintenance and operational)	
	Cost (disruption)	
	Land use objectives (strategic development)	
Engineering	Construction	Availability of local resources
		Constructability issues(only technology issues and disruptions)
	Geotechnical	Geologically sensitive areas

		Topography
	Hydrological	Hydrological sensitive areas
		Impact to drainage
Environmental	Effect to natural resources	
	Impact from construction waste disposal	
	Impact from land use change	
	Loss of important sites (reservations)	
	Ecological impacts	
	Pollution	Air
		Noise
		Water
Social	Access to welfare	
	Houses to be demolished	
	Impact from construction workers to the existing community	
	Commercial development to be demolished	
	Effect to agriculture	
	Increase climate change resilience of community	
	Socially sensitive areas	
	Social Separation	
	Visual intrusion	
Transport	Accessibility	
	Effect to existing road network	
	Vehicle operating cost	
	Intermodal connectivity and modal shift	
	Safety enhancement/ accident savings	
	Travel time saving	
	Travel time reliability	

This performance matrix was adopted in alternative evaluation for the Kandy expressway at pre-feasibility stage. Due to time constraints of the assignment some criterions were not considered in this study (See Table 3). Members of the evaluation team submitted their weight for each category and criterion (column 2 and 4). Weights given in the following table (column 2 and 4) are the average weight, calculated from each evaluator's individual preference.

Table 3: Weights Assigned in the Kandy Expressway Study

Category	Weight	Criterion	Weight
Economic Development	12.6	Community development	6.7
		Land use objectives (strategic development)	6.4
Engineering	15.5	Availability of local resources	3.3
		Constructability issues	4.9
		Cost	7.4
Environmental	14.2	Effect to natural resources	3.3

		Ecological impacts		3.0
		Pollution	Air	1.9
			Noise	1.3
			Water	1.9
		Protected areas(reservations)		2.9
Geotechnical	14.9	Sensitive areas		6.9
		Topography		8.0
Hydrological	11.0	Impact to drainage		5.8
		Sensitive areas		6.1
Social	12.4	Houses to be demolished		2.2
		Commercial development to be demolished		1.7
		Community development		1.3
		Effect to agriculture		3.2
		Sensitive areas		1.6
		Social Separation		1.2
		Visual intrusion		1.2
Transport	19.4	Accessibility (Origin destination)		4.4
		Accessibility to intermediate communities		2.6
		Effect to existing road network		2.2
		Vehicle operating cost		3.3
		Travel time saving		6.0

Table 4 and figure 1 shows the alternatives considered in the study. The roads links were selected by the project proponent. All possible combinations of the given road links were considered for evaluation.

Table 4: Alternatives Considered in the Evaluation

Alternative	A	B	C	D	E	F	G	H
Road links	1-8-10-11	1-8-9-11	1-4-5-7	1-4-5-6	2-5-6	2-5-7	3-6	3-7

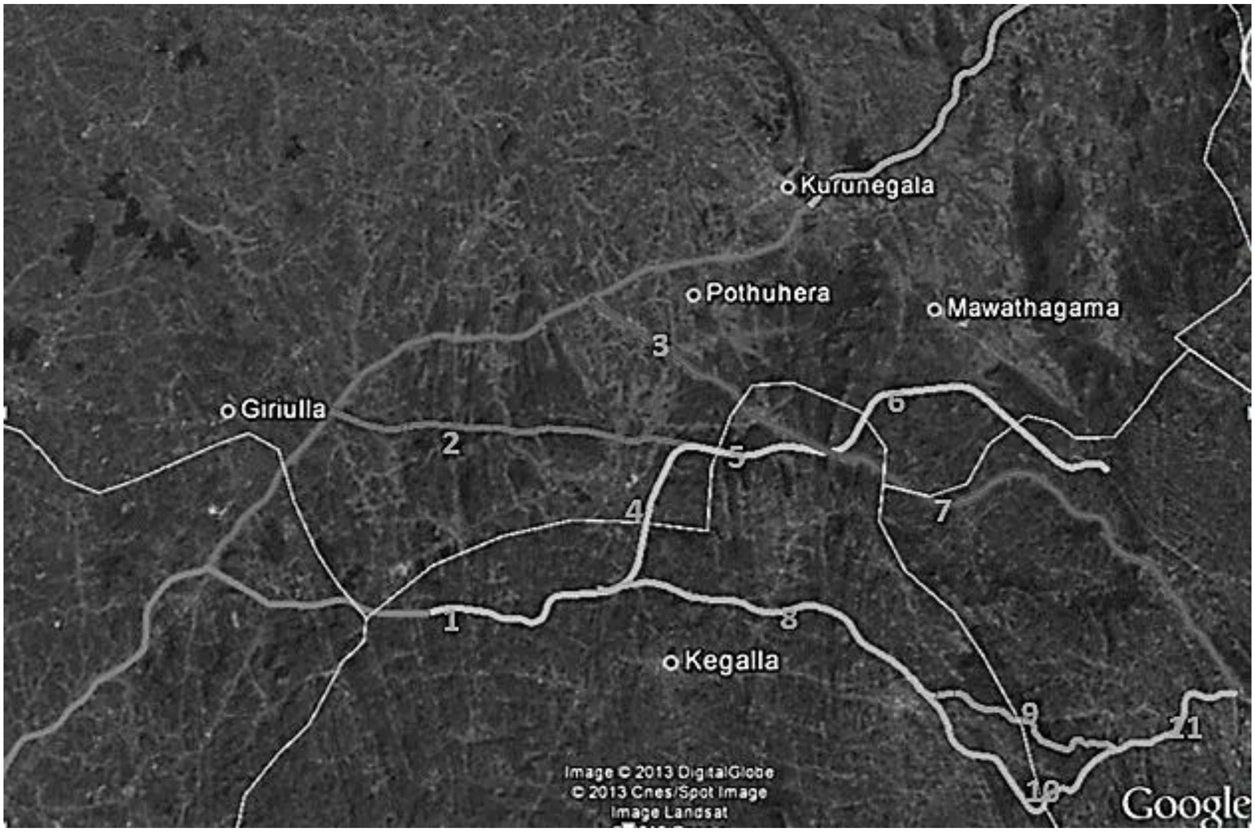

Figure 1: Road Traces Considered in the Evaluation

Scores for each criterion (not shown in table 3) was given by the expert on that field in the project group. For the analysis, each expert's score for each criterion was standardising with respect to the minimum score given by them. This was done because each individual has a biasness to give scores in a creation range and this could give unnecessary bias (double counting) for certain criterions in the analysis.

Table 5 shows the ranking of each alternative by assigning the weights of expert the indicated field only. Scores remained unchanged for every scenario. Mean weight of all was used for final recommendations of the study. Though there are small changes of ranking, irrespective of the weight combination given by each expert top alternatives remained top and least preferred alternatives remained at the bottom.

Last two rows of the table 5 shows the results if the analysis was based on least cost approach which popular in practice (Department of National Planning; Ministry of Finance and Planning, 2001) and considering only the criterions that are used in practice; cost, pollution, houses to be demolished, commercial development to be demolished, community development, effect to agriculture, accessibility (origin destination), accessibility to intermediate communities, fuel savings and travel time saving. It can be seen that ranking of those two methods vary significantly from other results in the table.

In addition to this analysis, sensitivity analysis was carried out for each criterion. Results on criterion topography are shown in the figure 2 as it was assigned the highest weight (8%) in this study. It shows that the ranking of the alternatives remained unchanged between the weight range 4%-25%. Though 4% is close to the assigned weight of 8 % only the ranking of least preferred alternatives changed at this point. Having increasing weight up to 25% does not make difference in ranking. Both these analyses show that assign weights in this study are not biased to select a particular alternative under consideration.

Table 5: Ranking of Alternatives under Various Considerations

View	Rank of Alternative							
	A	B	C	D	E	F	G	H
Environmental	8	6	1	4	5	2	7	3
Transport	8	7	2	5	4	3	6	1
Hydraulic	8	7	3	4	5	1	6	2
Economic	8	7	3	4	5	1	6	2
Mean	**8**	**7**	**3**	**5**	**4**	**2**	**6**	**1**
Least cost approach	8	7	6	2	2	2	1	2
Considering only traditional factors	5	4	2	7	6	3	8	1

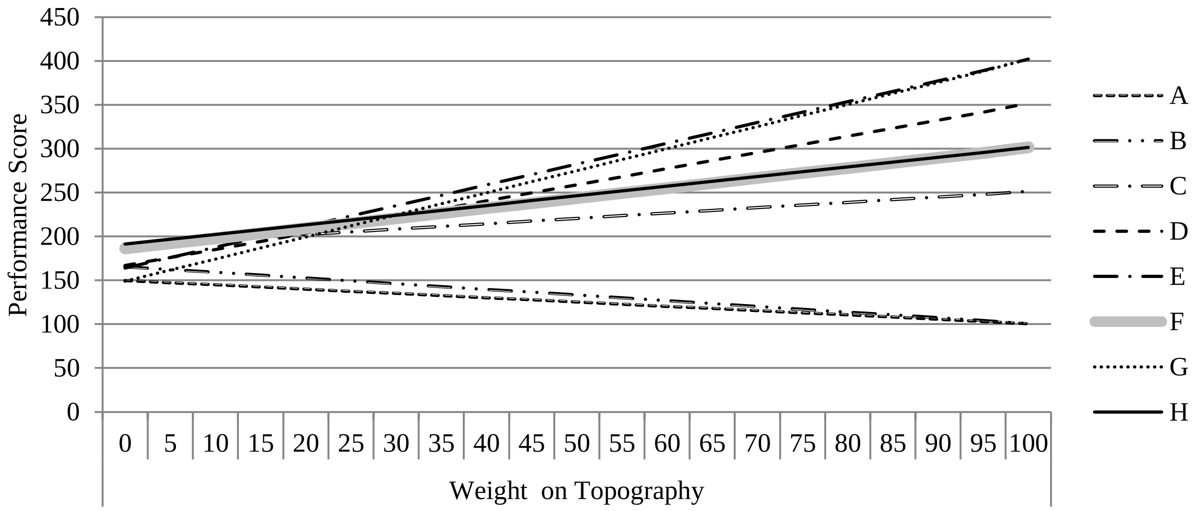

Figure 2: Sensitivity Analysis on Topography

5. DISCUSSION

Current practises in the field give vague and implicit assessments rather than being explicit. Further they neglect wider impacts. Neglecting these impacts especially in environmental and social context, which is may be for convenience, will create problems in achieving long term and sustainable development goals in the country. However, data availability, financial and time constraints and other external factors could limit the extensive evaluation and its credibility. Therefore, use of complicated and high data quality required methods will not be feasibly at the early stages of transport infrastructure projects.

Further, lack of public participation in early discussion of development is a critical issue (Caron, 2003). This would lead to misinterpretation of the objective of the people in the area of development project. So these discussion should include them including young generation to represent their needs and view on the development rather than limiting only to a group of expert.

To incorporate these wide ranges of impacts, a linear additive multi criteria model covering the key impacts that should be addressed could be useful. Therefore the suggested matrix in this study (Table 2) could be used to improve the early evaluation process. Further, these criteria could be used in more detailed analysis at the latter stages of the projects. However, this matrix considers only the impacts from land transportation. Matrix has to be modified if it is to be used for maritime and air transport projects.

Main issue with this method will be the disagreement on the weight assign to the each criterion. Sensitivity analysis and analysing alternatives based on each evaluator's weight can be used to address this issue.

In addition to the pre-construction evaluation, post construction evaluations are also essential to identify whether the anticipated objectives and targets are achieved.

6. CONCLUDING REMARKS

Review on the current methods indicates that it is essential to incorporate more comprehensive assessment in the pre-construction evaluation stages, as limiting only to the traditional criterions will not fully utilise the investment as current social, environmental and economic needs are complex. This is because otherwise at later stages of the process will be just a justification of the already selected alternative. Therefore using a comprehensive matrix form in the evaluation will be useful and practical in the early stages of the projects. This can be adopted in selecting alternatives as well as in selecting among various projects.

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