EVALUATING ALTERNATIVE TRANSPORT SYSTEMS IN CALI COLOMBIA

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1. ABSTRACT

The expansion of urban areas in developing countries presents many transport challenges. Many cities are rapidly expanding into the surrounding countryside and the new developments create additional traffic demand, which adds to the congestion on road networks. In developing countries, city dwellers have aspirations to acquire and use cars but the local government's objective is often to provide a good public transport system. Consequently, public transport is seen as the preferred sustainable transport mode for accommodating the increased travel demand through the provision of new public transport infrastructure or the enhancement of existing systems. However, there are a number of alternative systems available, each with their own characteristics. The challenge for public transport providers is to identify the systems that best suits their local requirements.

This note presents the findings of a study in Cali, Colombia, where alternative public transport systems were evaluated within an evaluation framework. The framework was developed in consultation with the key stakeholders in the City including the Central Government, the Municipal Authority, and Metro Cali (the local transit authority).

The evaluation framework assessed the merits of alternative public transport systems such as light rail, modern tram and articulated bus systems. An existing EMME2 multi-modal transport model was used to evaluate the benefits of the alternative systems. In addition as part of the study, stated preference tests were conducted to enhance the mode choice mechanism in EMME2 models so that the light rail, modern tram, articulated bus systems and private car users could be evaluated in a consistent way. For each public transport system option, key indicators such as accessibility, integration, economy, safety and environment were considered.

The main findings of the study was that articulated buses performed better in terms of reliability, operation and maintenance whilst fixed infrastructure systems such as light rail or modern tram offered greater benefits in terms of coverage and accessibility, integration and safety.

2. KEY WORDS

ROAD TRANSPORT/ LIVABILITY/ SUSTAINABLE DEVELOPMENT

3. INTRODUCTION

In 2002 the joint venture Schroders-Corfivalle was commissioned by the National Unity Program for Development to study the proposal for an integrated mass transport system in Santiago de Cali, Colombia. Kellogg Brown & Root (KBR) was commissioned by the joint venture to undertake the technical evaluation of alternative public transport systems.

The city of Santiago de Cali is located in the Valle region of Colombia. In recent years the city has expanded towards the south and east into agricultural areas. The growth in population has created extra demands on the existing transport system. Bus operators have responded by providing additional bus services to meet the increasing demand. At the same time, rising incomes have resulted in higher vehicle ownership, particularly for motorcycles and scooters. The combination of increased bus services and private vehicles has resulted in traffic congestion on roads within and accessing the city centre during the morning and evening peak hours.

However, for many urban city dwellers, private vehicle ownership is beyond their financial means, and access to an efficient and affordable public transport is essential for their daily travel needs. An efficient public transport system is seen by the city transport planners as the preferred transport mode for accommodating the increasing travel demand, through the provision of new public transport infrastructure or the enhancement of existing systems.

4. TRANSPORT SYSTEM

The local transit authority, Metro Cali, envisaged a two-prong public transport system consisting of high speed principal and trunk services running along the major corridors, supported by local feeder services.

The trunk services would run along the major road corridors throughout Cali, while the principal route runs along the former north-south rail line through the city. The feeder services would provide the connection between local neighbourhoods and the principal and trunk services at stopping points located on the major corridors.

The system would reduce the number of existing bus vehicles on the trunk road network, which are a major source of congestion and pollution in Cali. The new system would run on the existing roads or in segregated corridors, and also encourage a model shift towards public transport, which would generate decongestion benefits to other road users.

5. DEVELOPING THE ASSESSMENT FRAMEWORK

It was recognized that there are a number of alternative systems available, each with their own characteristics. In the current study, three different mass transit systems were considered as follows.

- Light rapid transit
- Articulated bus
- Modern tram

In addition, combined systems for light rail with modern tram were also examined.

In the assessment to determine the optimal system, it was necessary to take into account technical aspects of each alternative system. The technical assessment was undertaken to assess the demand on the principal and trunk routes. This enabled the assessment of each alternative system to be made in terms of technical aspects such as coverage, accessibility and degree of integration.

A framework to assess the performance of alternative systems and to identify the optimal system for the trunk services was required that:

- was acceptable to stakeholders; and
- gave a fair and balanced view of how each system performed.

This framework was developed in consultation with the Technical Committee consisting of key stakeholders in the City including the Central Government, the Municipal Authority, and Metro Cali, the transit authority.

The first stage was to identify in conjunction with the stakeholders a range of criteria and attributes that could be used to evaluate each alternative system. From this initial assessment, it was found that some criteria were subordinate to others, which allowed them to be organized into a hierarchy of criteria, sub-criteria and attributes. From this KBR produced an initial draft of the assessment framework based on a three-tiered hierarchical structure:

- Criteria, closely related to the key goals of the mass transit system.
- Sub-criteria corresponding to each criterion
- Attributes corresponding to each sub-criterion.

For the assessment framework, a scoring system was developed in consultation with the Technical Committee. This allowed the various criteria, sub-criteria and attributes to be assessed and awarded factors that reflected the merits of the alternative systems relative to each other.

Factors were then assigned to each criteria, sub-criteria and attribute as follows:

- Each criterion was allocated a factor reflecting the perception of its relative importance compared to the other criteria. The sum of the criteria factors was 1.00.

- Similarly, the sub-criteria within each criterion were then assessed, and apportioned a factor that reflected their perceived relative importance among the sub-criteria within the same criterion. The sum of the sub-criteria factors within each criterion was 1.00.

- Likewise, the attributes within each sub-criterion were then assessed, and apportioned a factor that reflected their perceived relative importance among the attributes within the same sub-criterion. The sum of the attribute factors for each sub-criterion was 1.00.

For each attribute, a score was then estimated using the following formula:

Attribute score = Criteria factor * Sub-criteria factor * Attribute factor *1000

Each attribute was classified as being either quantitative or qualitative and an evaluation measure was assigned to them.

The draft assessment framework was circulated to the Technical Committee so that their views could be ascertained and their comments incorporated.

The criteria factors, sub-criteria factors, attribute factors and attribute scores are shown in Table 1.

Table 1 – Assessment framework

CRITERIA		SUB-CRITERIA		ATTRIBUTE			
Description	**Factor**	**Description**	**Factor**	**Description**	**Evaluation measure**	**Factor**	**Score**
Primary benefit to user	0.30	Coverage and accessibility	0.67	Total weekday passengers	Number	0.25	50
				Percentage of total demand	%	0.25	50
				Average journey time	Minutes	0.25	50
				Average journey length	Kilometres	0.25	50
		Integration	0.33	Average interchange time	Minutes	1.00	100
Secondary benefit to user	0.25	Level of service	0.40	Level of comfort	Excellent/ Good/ Adequate	1.00	100
		Reliability	0.30	Passengers affected by disruptions	Number	0.33	25
				Impact of incidents on operation of the system	High/ Average/ Low	0.07	5
				Impact of breakdowns on road users	High/ Average/ Low	0.20	15
				Expected variation in journey time	High/ Average/ Low	0.20	15
				Reliability of power supply	High/ Average/ Low	0.20	15
		Safety	0.30	Risk of potential accidents	High/ Average/ Low	1.00	75
Primary impact of alternative system	0.20	Reliability	0.30	Cost of increasing coverage per km	US$	0.33	20
				Cost of increasing capacity by 20%	US$	0.33	20
				Capacity of system	Number	0.33	20
		Operation of system	0.30	Availability of spares	High/ Average/ Low	0.50	30
				Ease of maintenance	High/ Average/ Low	0.50	30
		Environmental impact	0.40	Impact on townscape and noise	High/ Average/ Low	0.34	27
				Impact on air quality	High/ Average/ Low	0.33	26
				Segregation	Significant/ Not significant	0.34	27
Secondary impact of alternative system	0.15	Impact on employment	0.50	Local direct jobs during construction	High/ Average/ Low	0.33	25
				Local direct jobs in opening year	Number	0.66	50
		Impact on existing transport system	0.50	Existing bus vehicles	Number	0.33	25
				Existing bus drivers	Number	0.33	25
				Level of employee retraining	High/ Average/ Low	0.33	25
Cost related issues	0.10	Construction	0.50	Expected time for construction	Years	0.33	17
				Risks related to costs and construction timetable	High/ Average/ Low	0.67	33
		Operating costs	0.50	Risks related to operating costs	High/ Average/ Low	1.00	50

The principle of the assessment framework for the alternative systems was based upon assigning the attribute score to the alternative that optimised the evaluation measure for a particular attribute. The other systems were assigned an attribute score based on their performance relative to the optimal system for the particular attribute, as follows:

- For evaluation measures that were quantitative, the other systems were assigned a score that was proportional to their evaluation measure relative to the evaluation measure for the optimal system

- For evaluation measures that were qualitative, the other systems would be assigned the same attribute score if their performance was similar to the optimal system, or $^{2}/_{3}$ of the attribute score if their performance was relatively intermediate compared to the optimal system, or $^{1}/_{3}$ of the attribute score if their performance was it was relatively low compared to the optimal system.

This modular approach to the determination of the attribute scores allowed the assessment to focus on the individual attributes thus ensuring a more objective approach to the assessment of quantitative or qualitative evaluation measures

The attribute scores could be determined immediately once the criteria factors, sub-criteria factors and attribute factors were specified. This approach allowed greater flexibility in the performance of sensitivity analysis on the robustness of the comparison of the alternative systems by varying the criteria, sub-criteria or attribute factors.

For each criterion, the attribute scores were summed to determine the criteria evaluation score. In turn these were summed to determine the total evaluation score for each alternative system

Where appropriate the evaluation measures for quantitative attributes were taken from the EMME/2 model, or local transport industry or industry standards, and awarded a score in accordance with the attribute scoring system shown in Table 1**.** Other evaluation measures for qualitative attributes were subjective and these were assessed and awarded a score by the Technical Committee.

All alternative systems were considered to be technically viable options and the scoring system was a means of measuring the suitability of each of the alternatives relative to each other.

The results of the scoring were assessed to ascertain if one of the alternatives had a total score that was more robust than the others. This was done by performing a sensitivity analysis of the results.

During the course of the study, the criteria, sub-criteria and attributes were reviewed and updated as the technical work proceeded.

In addition, the EMME2 model was enhanced to better represent the transport system and the modal choice was revised using recently more collected stated preference data.

6. RESULTS OF THE ASSESSMENT FRAMEWORK

6.1. Primary Benefit to the User

The coverage and accessibility sub-criteria were considered to be of primary benefit to users. These sub-criteria reflected the principal technical requirement of the transport system which was to provide an efficient means of meeting the transport demands of Cali up to 2030 and beyond. These sub-criteria were considered to be the most important since they provided a relative measure of how the integrated transport system would respond to the travel demands of Cali.

The results of the assessment are shown in Figure 1

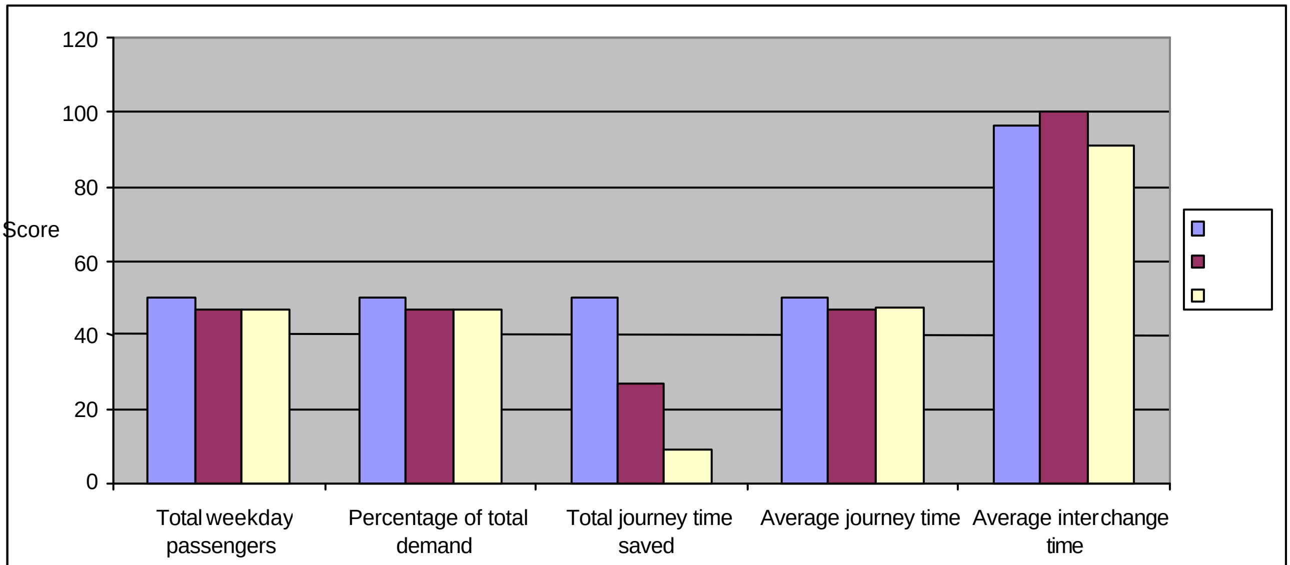


Figure 1 - Attribute scores for the primary benefit to user criteria

The total weekday passengers and average journey time attributes are an indirect measure of the decongestion benefits to other road users. If more travellers use the new system, there would be more road-space released to other road users.

6.2. Secondary Benefit to the User

The level of service, reliability and safety sub-criteria were considered to be of secondary benefit to users. These sub-criteria were considered to be of secondary benefit to the user compared to the coverage and accessibility sub-criteria and related to the travelling experience that users may expect from each alternative system.

The results of this assessment are shown in Figure 2.

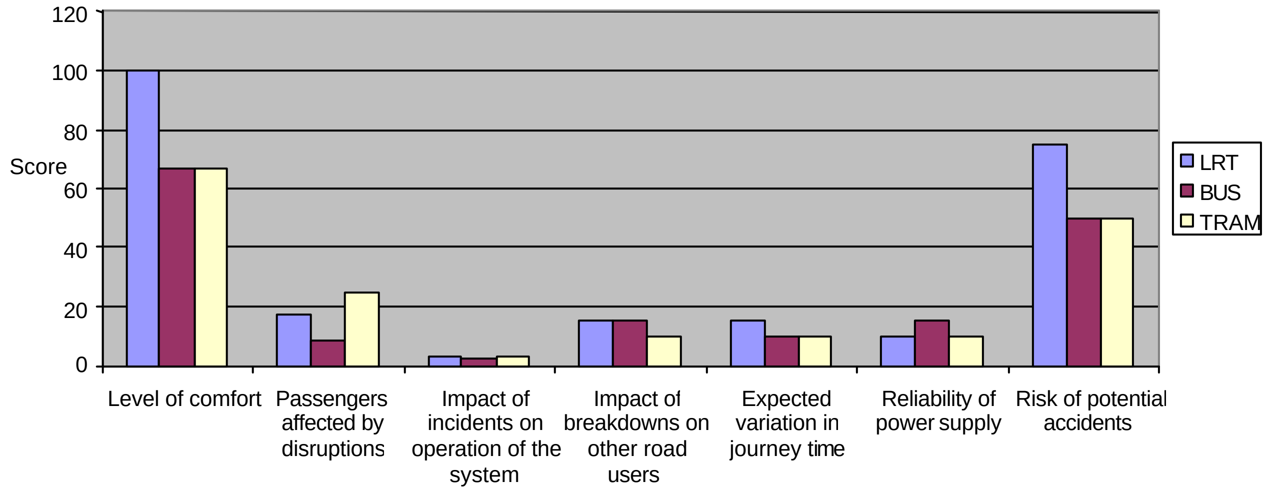


Figure 2 - Attribute scores for the secondary benefit to user criteria

The safety sub-criterion is an indirect measure of the decongestion benefits for other road users. The alternative systems attract more passengers, which results in fewer accidents on the road network, thus benefiting other road users.

6.3. Primary Impact of Alternative System

The reliability, operation of system, and environmental impact sub-criteria were considered to be the primary impact of each alternative system. These sub-criteria were intended to assess the direct impact of each system in terms of how it can be operated and maintained, and its impact on the environment.

The results of this assessment are shown in Figure 3.

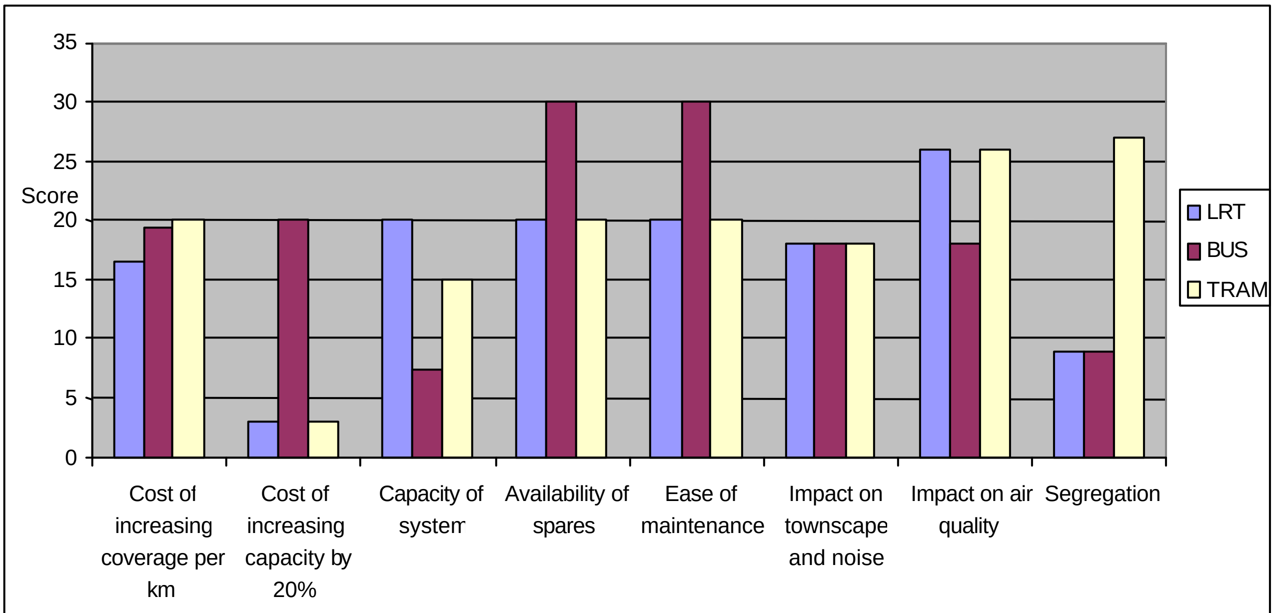


Figure 3 - Attribute scores for primary impact of alternative system criteria

The impact on noise and air quality criteria are indirect measures of decongestion benefits for other road users. The modal shift to the various systems will reduce the noise and improve air quality, which will benefit other road users.

6.4. Secondary Impact of Alternative System

The impact on employment and the impact on the existing transport system sub-criteria were considered to be the secondary impact of each alternative system. These sub-criteria were intended to assess how each of the alternative systems would impact upon the current employment situation in Cali.

The results of this assessment are shown in Figure 4.

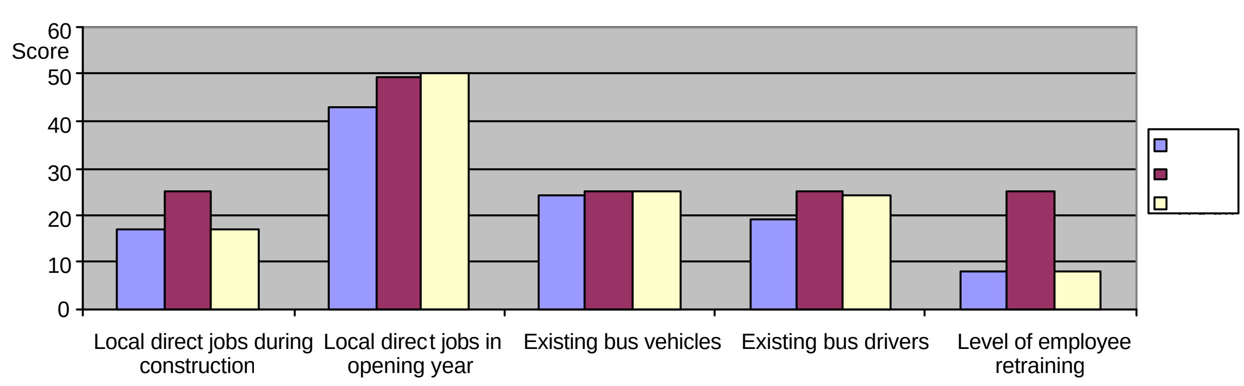


Figure 4 - Attribute scores for secondary impact of alternative system criteria

6.5. Cost Related Issues

The cost related issues are primarily dealt with in the financial model. However there are some aspects relating to costs that are not fully assessed in financial terms and these have been included in the technical assessment.

The results of this assessment are shown in Figure 5.

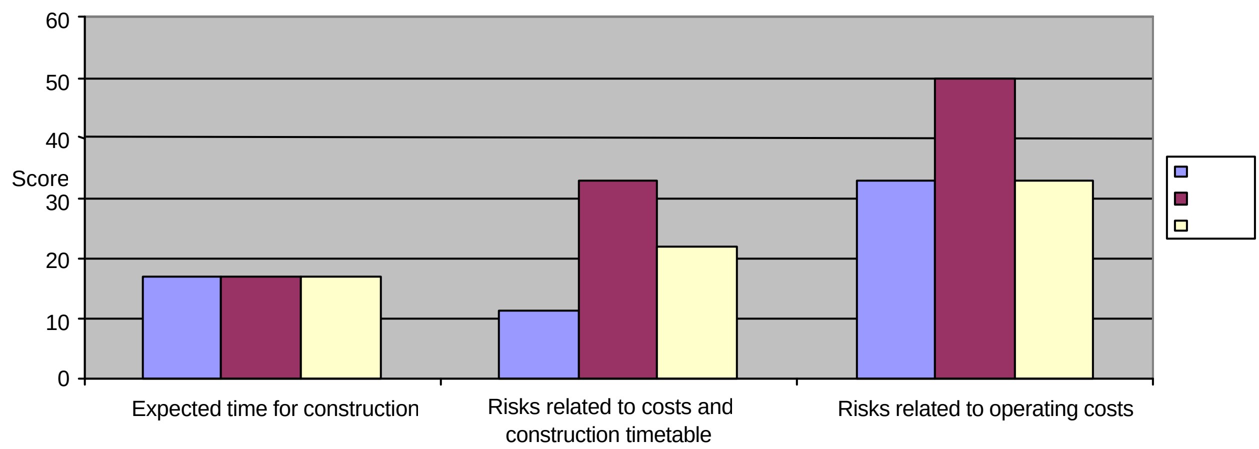


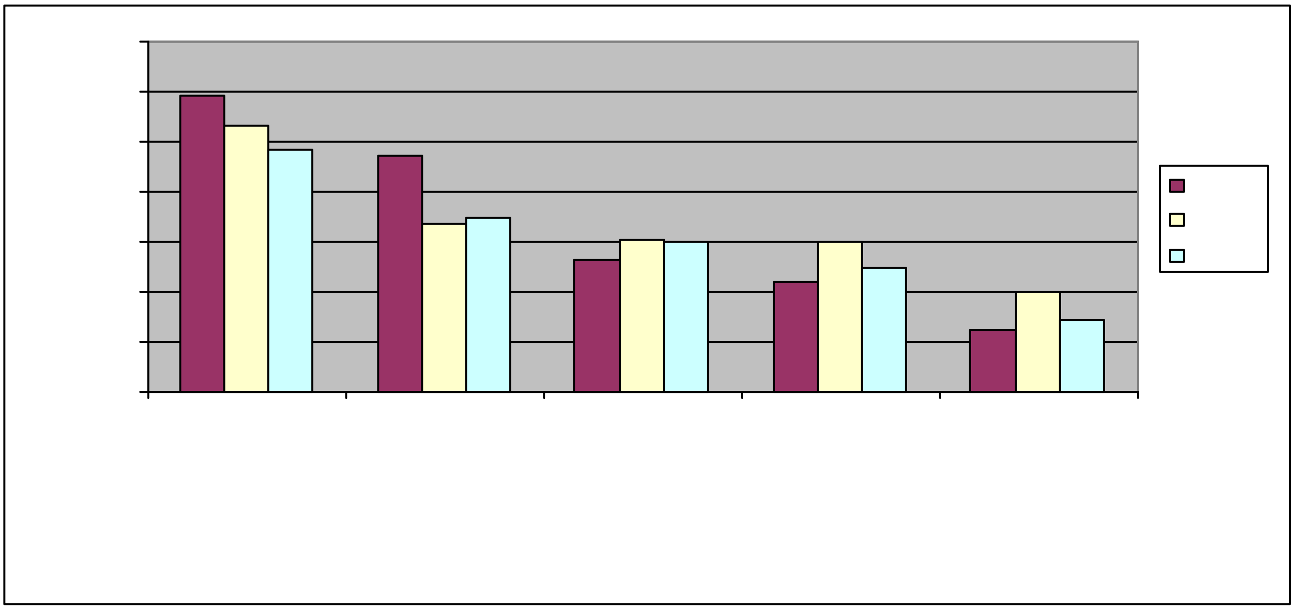
Figure 5 - Attribute scores for cost related issues criteria

6.6. Overall assessment of the alternative systems

The results of the overall assessment are summarised in Table 2 and shown in Figure 6 for the three alternative systems. Whilst the total evaluation score indicates that LRT achieved the highest score, it could only be recommended if the score was higher than the other two systems. With the original criteria, sub-criteria and attribute factors used for the assessment, LRT achieved a total evaluation score that was only 0.5% higher than the second ranked alternative, articulated bus. Furthermore the third ranked system, modern tram was only 10.7% lower, which was not excessive.

Table 2 – Total evaluation scores

Alternative system	**Total evaluation score**
LRT	837
Articulated bus	835
Modern tram	762



In order to assess the overall robustness of the result for the two leading alternative systems, the criteria factors were adjusted by the stakeholder as follows:

- The criteria factor for the primary benefit to user criteria was reduced from 0.30 to 0.25. In this group LRT had achieved the best score.
- The criteria factor for cost related issues criteria was increased from 0.10 to 0.15. For this criteria, articulated bus performed the best and had an advantage over LRT

The results of these changes for the three systems are shown in Table 3.

Table 3 - Sensitivity test

CRITERIA	Criteria factor variation	Original criteria evaluation score			Revised criteria evaluation score		
		LRT	BUS	TRAM	LRT	BUS	TRAM
Primary benefit to user	-0.05	296	266	242	276	248	230
Cost related issues	+0.05	61	100	72	73	120	76

The total evaluation scores of the three systems for the sensitivity test are shown in Table 4. With the small changes in the criteria factors, the LRT score falls slightly below that of the articulated bus. Nevertheless, the two leading systems maintain their lead over the modern tram, which remains virtually unchanged.

Table 4 – Sensitised evaluation scores

Alternative system	Total evaluation score
LRT	830
Articulated bus	836
Modern tram	756

The LRT and articulated bus achieved virtually similar total evaluation scores. However there are differences between the two systems:

- LRT performed better in the primary benefit to user and secondary benefits to user criteria, which meant that it performed better in meeting the transport demands and travelling experience for potential users.

- Articulated bus performed better in the primary impact of alternative system, secondary impacts of alternative system, and cost related issues criteria, which meant that it performed better with regards to reliability, operation, maintenance, and its impact on the environment and employment in Cali.

7. CONCLUSIONS

In technical terms, all three systems appear to be viable and none of them can be identified as being significantly better than the others.

The main findings of the study was that articulated buses provide a more flexible and adaptable system in terms of reliability, operation and maintenance whilst fixed infrastructure systems such as light rail or modern tram offer greater benefits in terms of coverage and accessibility, integration and safety.

The modal shift to the alternative system will result in increased patronage for public transport, as measured by the total weekday passengers and average journey time attributes. These sub-criteria and attributes also measure the decongestion benefits to other road users. Consequently, road safety, traffic congestion and the environment would improve together with increasing public transport usage.

8. REFERENCES

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