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Research Article / Araştırma Makalesi

IMPROVING BUS NETWORK BASED ON MULTICRITERIA ASSESSMENT

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ABSTRACT

Bus transport organisations need to conduct network reviews on periodical basis. This is meant to identify those bus routes that are weak performers as well as those that do not add significant value to the overall bus network. This research develops & adopts the slogan MISS TS which is an abbreviation for Multimodal Integrated Smart Sustainable Transport System, a transport system that is multimodal, integrated, seamless, smart and sustainable. Towards this end the research develops an innovative generic methodology that attempts to achieve an optimum bus network by taking into account all previously stated dimensions in assessing and rationalizing the performance of bus routes. The methodology starts by first categorizing the bus network into market segments i.e. CBD, Feeder, Express, Airport, Neighborhood etc. This is then followed by compiling operational and financial data on a route by route basis. Data includes operational costs, operational revenues, passengers, kilometers, passenger kilometers etc. This data is further manipulated to obtain 2 major indicators that are used to conduct an operational and financial screening of all routes, namely Load Factor (LF) and Cost Recovery Ratio (CRR). Thresholds values for these indicators are then set either based on approved manuals or on cross-sectional average network performance. A comparison is conducted with the preset threshold limits where routes with LF & CRR below threshold limits are considered weak performers while routes with LF & CRR above threshold limits are considered high performers and other routes are considered middle performers. Such screening exercise is then followed by conducting a multicriteria scoping of those weak performing routes using criteria such as coverage, connectivity, integration, social, environment & energy, politically strategic, etc. Based on scoping results recommendations can be made to decision makers whether to retain, suspend, rationalize weak performing routes and hence achieve a more efficient bus network.

Keywords: Bus, network, routes, multicriteria.

1. INTRODUCTION

Many public transport organisations need to review, analyse and assess, on a regular basis, their bus as well as other public transport networks as part of determining bus routes that are weak performers and those bus routes that are acceptable or outstanding performers. Based on the results of such assessment, recommendations can be made to decision-makers to either to continue to operate those weak performance bus routes on social grounds, or to go ahead and cancel/suspend such routes for financial & other reasons or alternatively try to work towards rationalization of poor performance routes. All in all, this is meant to achieve a bus network that

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is more efficient and dynamic. The literature reports efforts towards bus route service review, however limited literature exists on bus network review see [1] where a number of Route Design Standards criteria were identified based on a questionnaire analysis for 111 US bus operators. Transport for London conducts on regular basis bus network review, see [2] where a recent Bus Network Review was conducted at Orpington that included restructuring withdrawing routes introducing new ones. It is obvious that the scientific literature needs to reflect and develop the bus operator practices on network review into methodological practices, standards and guidelines. Towards this end, the paper presents an innovative methodology to achieve an optimum bus network.

2. MULTIMODAL INTEGRATED SMART SUSTAINABLE TRANSPORT SYSTEM

This research develops and adopts the slogan MISS TS which is an abbreviation for Multimodal Integrated Smart Sustainable Transport System, see Figure 1, a transport system that all transport planners and decision makers are aspiring to achieve. A system that provides for multimodality and integration between all modes of public and private transport where passenger journeys are seamless. A system that is smart and full of integrated ITS applications. A system that accounts for all dimensions of sustainability including economic/financial dimension, social dimension, environment and energy dimension and at the core the safety and security dimension. This research presents a generic methodology that attempts to achieve an optimum bus network by taking into account all the previously stated dimensions in reviewing, assessing and rationalizing the performance of bus routes.

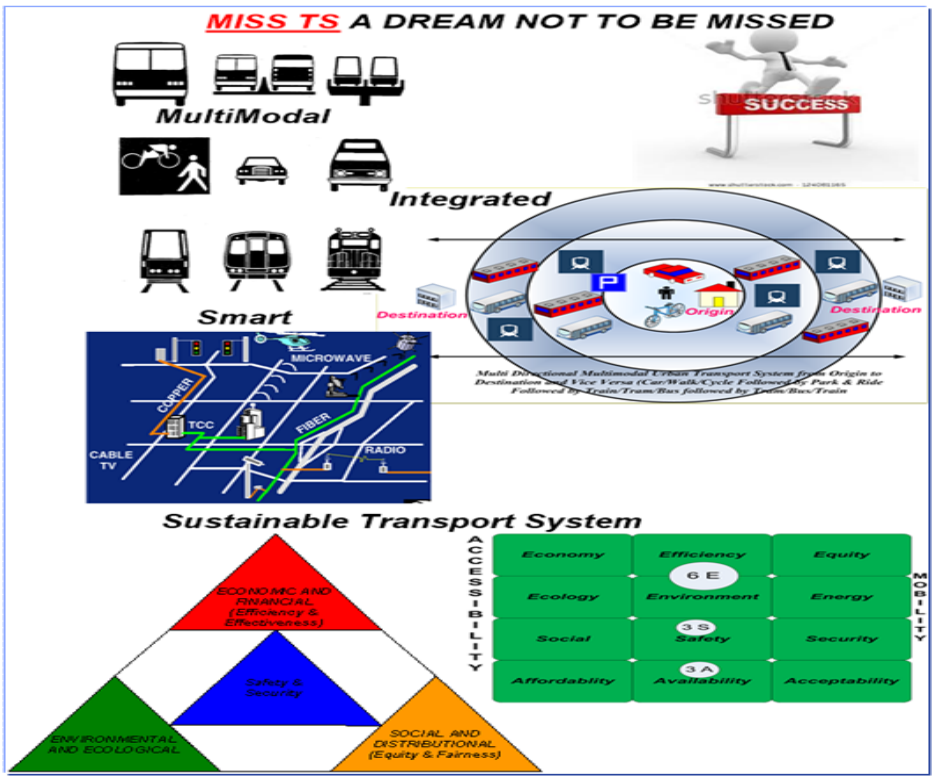

Figure 1. Components of Multimodal Integerated Smart Sustainable Transport System

3. MULTICRITERIA ASSESSMENT: A BASIS FOR BUS NETWORK REVIEW

The research developed an innovative comprehensive methodology to assess public transport networks such as bus network via a two stage assessment hierarchy namely the first stage involves a financial and operational based route by route screening assessment followed by the second stage involving multicriteria assessment for each route. The methodology is as shown in Figure 2. The following details the steps involved in the two assessment stages.

Stage 1: Financial & Operational Screening (Route By Route)

Stage 1 involves 8 steps that can be described as follows:

1. Identification of bus network & categorisation of routes into different market segments for example CBD routes, feeder routes, express services, shuttle airport services, neighbourhood services, special services, etc…
2. Compilation of required operational, financial and other data for each respective route. Data to be compiled/computed over a minimum of month duration and to include: number of revenue kilometers, number of passengers, operational costs, operational revenue, operational cost per driven kilometer, operational revenue per driven kilometer, operational cost per passenger and operational revenue per passenger.
3. For each respective route, this data is further manipulated to obtain 2 major indicators that are used to conduct operational and financial screening of all routes, namely Load Factor (LF) & Cost Recovery Ratio (CRR).
4. In an effort to determine thresholds (cut off) values for 2 of these indicators, namely LF & CRR it is advisable to either rely on internationally published manuals such as the Urban Bus Tool Kit by the World Bank see [3] or to compute cross-sectional averages of routes involved – hence providing self cross-sectional based bench markings.
5. Display route by route histograms of indicators in comparison to bench marks.
6. Conduct a screening comparison for each route where route values are compared with the cut off values and those routes with LF & CRR below threshold limits are considered as weak performers while routes with LF & CRR above threshold limits are considered high performers and other routes are considered middle or average performers.
7. Develop a 2*2 classification matrix of CRR and LF to assist in making recommendations for the second stage of multicriteria scoping.
8. Decide on routes potential for cancellation/suspension/rationalization & further scoping.

Stage 2: Multicriteria Scoping (Route by Route)

Stage 2 involves a number of steps in conducting the multicriteria scoping. All of these steps are based on the Delphi approach. The Delphi approach, see [4] is known as a structured systematic, interactive judgment/assessment method which relies on a panel of experts. The experts answer questionnaires or make judgments/assessments in two or more rounds. After each round, a facilitator provides an anonymous summary of the experts' judgment/ assessment from the previous round as well as the reasons they provided for their judgments. Thus, experts are encouraged to revise their earlier answers in light of the replies of other members of their panel. It is believed that during this process the range of answers will decrease and group will converge towards an optimum answer. Finally, the process is stopped after achievement of consensus, stability of results where the mean or median scores of final rounds determine results.

A panel of public transport experts, familiar with the bus network at hand, was selected to exercise their judgment and assessment via the following steps:

1. Identification and deciding on a set of criteria to be used in the multicriteria scoping exercise of those bus routes recommended from stage 1 for cancellation/ suspension/ rationalization. In this research, the panel of public transport experts adopted 7 criteria that are meant to cover integration and sustainability aspects. These include:
   - Connectivity (i.e. the relative extent of other public transport modes providing

connectivity to the bus route destinations)

- Coverage (extent to which bus route contributes to public transport network coverage)
- Intermodality (the extent of integrated trips using the bus route)
- Social (extent the bus route is providing mobility to the urban poor as well as overcoming mobility seclusion)
- Environment & Energy (extent of emissions & fuel consumption from alternative modes in case service is suspended)
- Safety & Security (the extent of safety & security provided by alternative modes)
- Strategic Importance (the bus routes being requested/mandated by politicians)

It is to be noted that for the same organisation at different times as well as for different organisations criteria and weights may be modified (changed by additions and/or deletions) to reflect current directions and strategies of the public transport organisation.

2. In this step, the panel of experts provides different weighting points for the seven criteria demonstrating the relativity of the impact of each criterion. The adopted percentage weightings are displayed in table 1 below:

Table 1. Adopted Multicriteria Weightings

CRITERIA	PERCENTAGE WEIGHT
Connectivity	14%
Coverage	18%
Intermodality	17%
Social	12%
Environment & Energy	15%
Safety & Security	11%
Strategic Importance	13%
∑ Weights	100%

3. In this step, the panel of experts through meetings and facilitation provides their criteria judgment scores (1 to 100) for each of the bus routes. These scores are then multiplied by respective weights and a final weighted score is obtained for each bus route. The following presents the equation used for performing such computations for each alternative

$$\text{Weighted Score}_{\text{Bus Route}} = \sum_{(\text{Criteria 1})}^{(\text{Criteria 7})} \text{Weight}_{\text{Criteria}} * \text{Score}_{\text{Criteria}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

4. Cut off pass values should be decided. The following presents the suggested score values for assisting in making various recommendations to decision makers:

Table 2. Weighted Scores & Respective Recommendations

WEIGHTED SCORE$_{\text{BUS ROUTE}}$	RECOMMENDATION
Weighted Score ≤ 50	Route Suspended/Cancelled
50 ≤ Weighted Score ≤ 60	Route Rationalised & Retained with no Subsidy
60 ≤ Weighted Score ≤ 75	Route Rationalised & Retained with Subsidy
Weighted Score ≥ 75	Route Retained with Subsidy

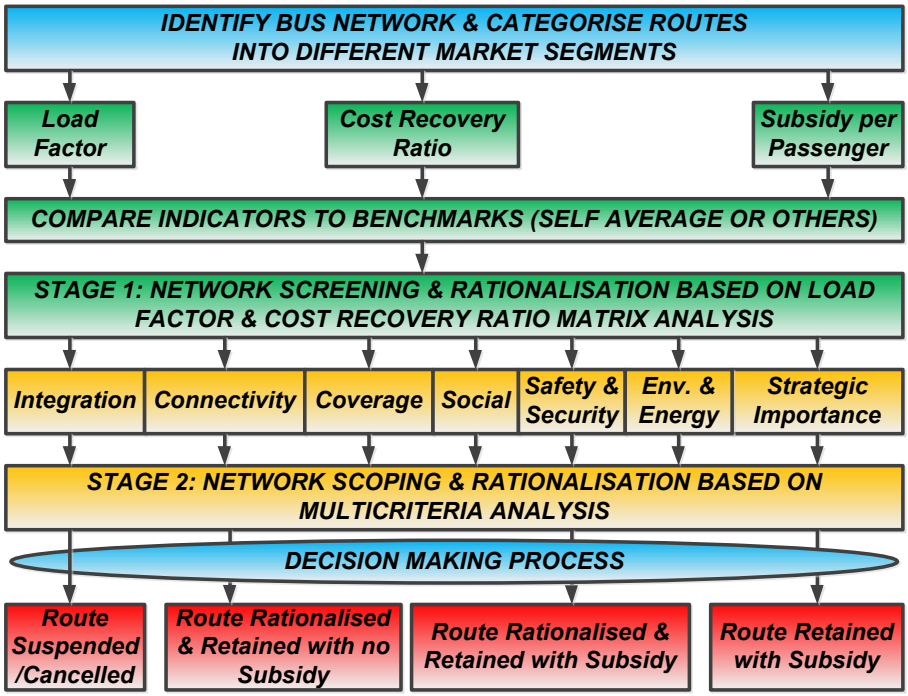

Figure 2. An Innovative Generic Methodology for Assessing Bus Network Performance

4. BUS NETWORK ASSESSMENT: A HYPOTHETICAL CASE STUDY

In this section and for the sake of demonstration, the suggested methodology for bus network assessment will be applied for a hypothetical city with 68 urban bus routes.

Stage 1: Financial & Operational Based Route By Route Screening

Compiled operational and financial data is displayed in histogram format in Figures 3 and 4. Figure 3 shows the operational cost per kilometer as well as the operational revenue per kilometer for each of the 68 routes. The figure shows that for many routes the operational cost per kilometer is higher than the operational revenue per kilometer. The cross-sectional average among the 68 routes shows an average operational cost per kilometer of 3.9 $/km and an average operational revenue per kilometer of 2.9 $/km. Also Figure 4 shows the operational cost per passenger as well as the operational revenue per passenger for each of the 68 routes. The figure shows that in most cases the operational cost per passenger is higher than the operational revenue per passenger. The cross-sectional average among the 68 routes shows an average operational cost per passenger of 4.6 $/passenger and an average operational revenue of 2.8 $/passenger, meaning that the average subsidy per passenger is around 1.8 $/passenger.

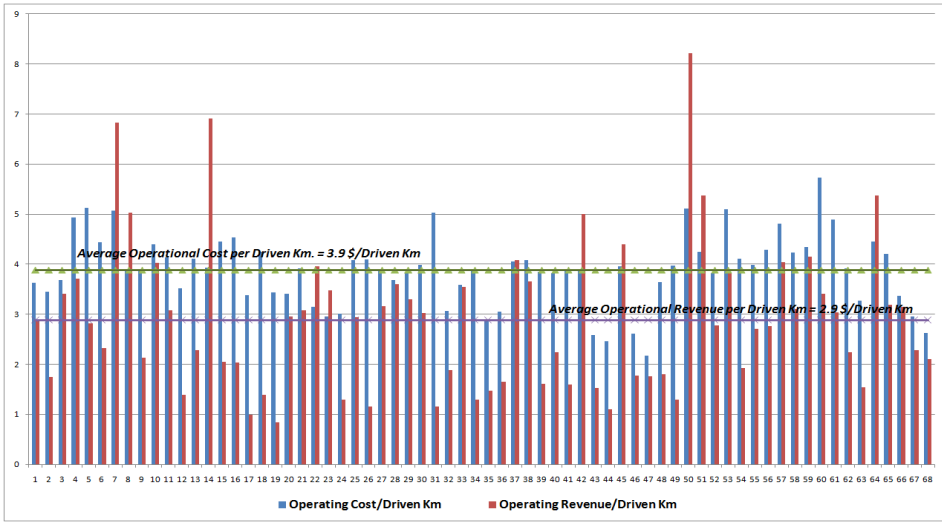

Figure 3. Operatıonal Cost & Revenue Per Driven Km Compared to Cross-Sectional Thresholds Values

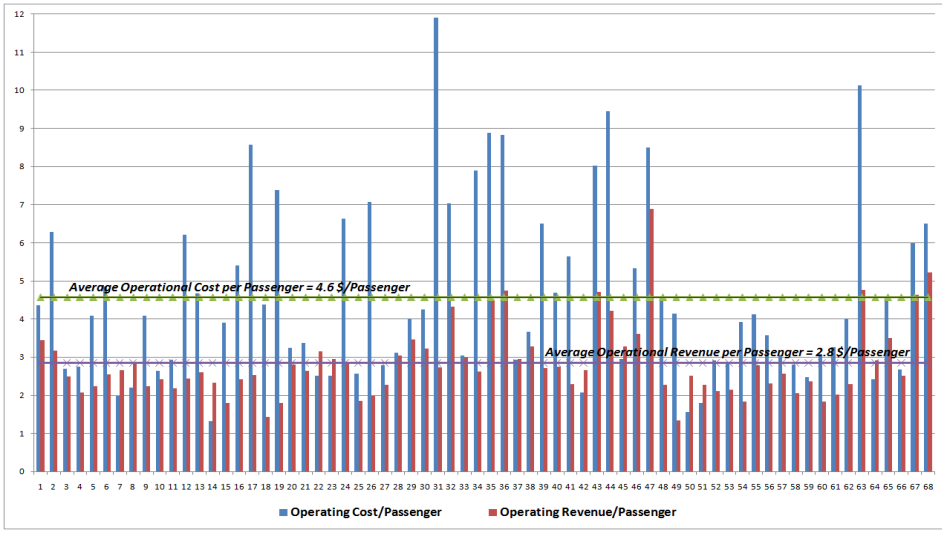

Figure 4. Operational Cost & Revenue/Passenger as Compared to Cross-Sectional Thresholds Values

Furthermore figure 5 shows the computation of the 2 screening indicators namely the LF and the CRR. In an effort to determine thresholds (cut off) values for these 2 indicators, the cross-sectional averages of the 68 routes involved were computed. The average LF is around 29%, while the average CRR is around 73%. Both values provide self cross-sectional based bench markings. The screening comparison for each route is conducted where route values are compared with the cut off values and those routes with LF & CRR below threshold limits are considered as weak performers. The figure shows that at least 35 routes have load factors & cost recovery ratios

below average network benchmarkings. The next step is to develop a two dimensional classification 2*2 matrix of CRR & LF to assist in classification of screening recommendations, see Figure 6. The figure demonstrates that in accordance with the threshold comparison results one of four decisions will be recommended for each route. Recommendations are as follows:

- For those routes that both LF and CRR indicators are below threshold limits, further scoping assessment is recommended
- For those routes where CRR is below threshold limit while on the other hand LF is above threshold limit, the recommendation is to consider cost monitoring and cost reduction.
- For those routes where LF is below threshold limit while on the other hand CRR is above threshold limit, the recommendation is to concentrate on marketing, publicity & incentive programs to attract passengers and increase patronage.
- Finally, for those routes where both CRR and LF are above threshold values, recommendation is to sustain operation of these routes and further grow their operation.

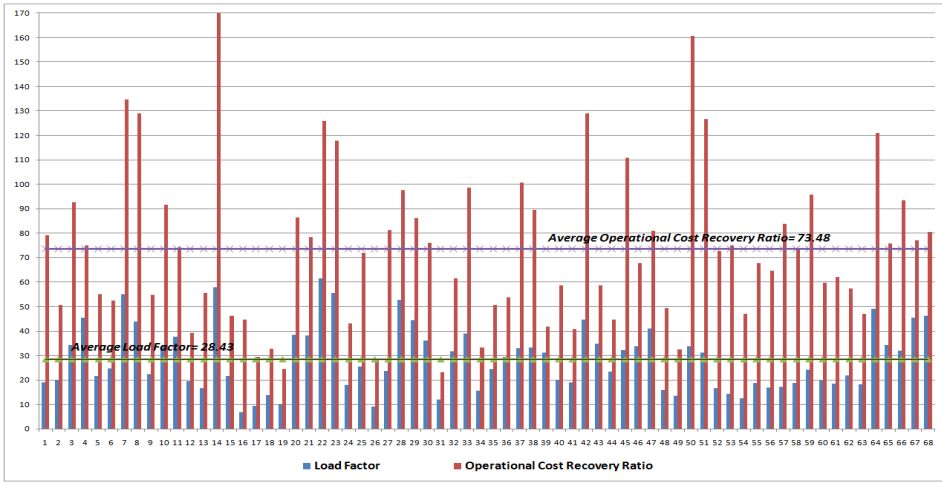

Figure 5. LF and CRR as Compared to Cross-Sectional Thresholds Values

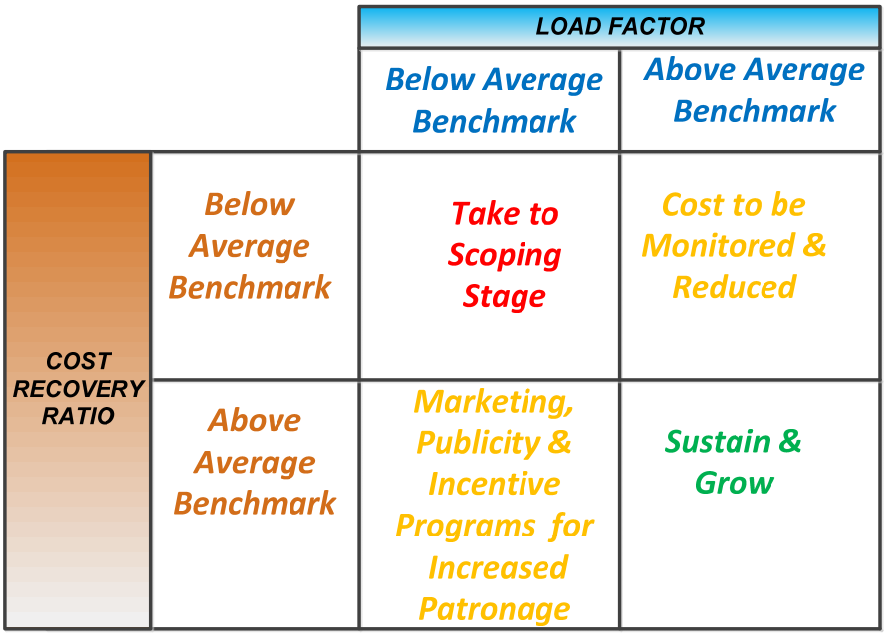

Figure 6. Screening Recommendations Based on 2 Dimensional Matrix of CRR & LF

Stage 2: Multicriteria Scoping Of Route by Route

At this stage the panel of public transport experts will convene to discuss those routes that are recommended for further scoping. The facilitator will provide maps, data and information as required. The panel will either discuss and reach consensus on the evaluation of each criteria for each route or alternatively will follow the Delphi approach and provide their anonymous assessment in a table format as the one displayed in table 3. Afterwards experts will convene another time with facilitator showing the averages and all will be discussing rational behind assessment and reaching consensus. These scores are then multiplied by respective weights and a final weighted score is obtained for each route. Recommendations are made based on cut off pass values as displayed in table 2 above. Table 3 shows framework of multicrteria scoping assessment process and 4 possible scoring ranges and respective recommendations.

Table 3. Framework of Multicriteria Scoping Assessment Process

MULTI CRITERIA SCOPING					
CRITERIA	Weight	Bus Route (1)	Bus Route (2)	Bus Route (3)	Bus Route (etc..)
Connectivity	14%	Experts Score	Experts Score	Experts Score	Experts Score
Coverage	18%	Experts Score	Experts Score	Experts Score	Experts Score
Intermodality	17%	Experts Score	Experts Score	Experts Score	Experts Score
Social	12%	Experts Score	Experts Score	Experts Score	Experts Score
Environment & Energy	15%	Experts Score	Experts Score	Experts Score	Experts Score
Safety & Security	11%	Experts Score	Experts Score	Experts Score	Experts Score
Strategic Importance	13%	Experts Score	Experts Score	Experts Score	Experts Score
Weighted Score	100%	45	58	73	80
Recommendations		***Route Suspended/ Cancelled***	***Route Rationalised & Retained with no Subsidy***	***Route Rationalised & Retained with Subsidy***	***Route Retained with Subsidy***

5. CONCLUSION

The importance of the role played by buses in the mobility of people is unquestionable. Buses are part and parcel of the integrated passenger transport chain especially in urban cities. This research developed the slogan MISS TS which is an abbreviation for Multimodal Integrated Smart Sustainable Transport System. Towards this end, the paper addressed one of the important topics as related to the bus industry, namely proposing an innovative method to review, assess and rationalize bus networks. Based on such assessment, recommendations can be made to decision-makers to either to continue to operate those weak performance bus routes on social grounds, or to go ahead and cancel/suspend such routes for financial & other reasons or alternatively try to work towards rationalization of poor performance routes. All in all, this is meant to achieve a bus network that is more efficient and dynamic. The assessment hierarchy is composed of 2 stages namely the first stage involves a financial and operational based route by route screening assessment followed by the second stage involving multicriteria assessment for each route. Details of both stages were thoroughly described. This was followed by demonstration of the applicability of the suggested methodology for a hypothetical city with 68 urban bus routes. Stage 1 involving : financial & operational based route by route screening was conducted where the 2 screening indicators namely the LF and the CRR were computed for each route and the thresholds (cut off) values for these 2 indicators were also computed. The screening comparison for each route was conducted where route values are compared with the cut off values and those routes with LF & CRR below threshold limits are considered as weak performers. A two dimensional classification matrix of CRR & LF was then developed to assist in classification of screening recommendations

Stage 2 involving the multicriteria scoping was also demonstrated where a panel of public transport experts convened to discuss those routes that are recommended for further scoping. The panel reached consensus on the evaluation of each criteria for each route. These scores were multiplied by respective weights and a final weighted score was obtained for each bus route. Recommendations were made based on cut off pass values. The presented methodology is a powerful easy to use framework to periodically assess public transport networks and to make

robust recommendations that can facilitate a well informed decision making process on whether to suspend/cancel routes, or to retain and rationalize, or to retain and grow.

It is also important to state that the main success factors for the implementation of the above methodology lies in the availability of operational, financial and other criteria related data, the existence of professional network planning staff, the ease of decision making and the periodical implementation of network changes accompanied with post monitoring and modifications if necessary.

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