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CONTENTS

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Title

MANAGEMENT OF TRANSPORTATION SYSTEM AND PRIORITIZATION OF TRANSPORT INFRASTRUCTURE PROJECTS

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Abstract:

The increasing demand for transport services in Indian cities has been observed due to increases in population, increases in household income, and increases in economic activities. Traffic congestion problem is a serious hindrance to economic growth as transport is a basic economic infrastructure for any economy. In most of the Indian cities, congestion and delays are ever increasing and the supply of road space is becoming highly insufficient. Countries try to solve congestion problem by constructing new roads, widening of existing roads or construction of flyovers or underpasses. Such infrastructure development programs take place either to create alternate roads for particular destination or to segregate through-traffic from cross- traffic at various road intersections. In the large metropolitan cities of India, journeys along the roads are characterized by low travel speed, delays at the road intersections and infrastructural inadequacies in the road network. It is essential to judge the priority of development of transport infrastructure at different alternate locations using scarce economic resources before such construction takes place. Present study intends to discuss about the existing techniques used by the planners to evaluate investment projects and considers the applicability of Multi Criteria Analysis technique as a tool for that in the form of a case study.

Key Words: Grade separated paths, Cost Benefit Analysis, Multi Criteria Analysis, Concordance Index, Volume- Capacity Ratio.

Introduction:

Transportation network is an economic infrastructure which is highly essential for the unhindered growth of an economy. Proper management of traffic and transportation system in urban areas is a vital issue especially for developing countries like India. Since the secondary and tertiary sectors are located in urban centers only, the National Urban Transport Policy of India (2006) rightly says that 'the state of our towns and cities is crucial to India's future growth....' as these are the centers where the future growth of the country is expected to take place. Therefore well managed carriageways for motorized and non-motorized vehicles as well as good provision for pedestrian movements are essential within the transport network of a city. Urban

development centers should be strengthened through infrastructure development so that there is efficient discharging of duties by the commuters. Cities in Japan, the Netherlands, Germany, and several other European nations demonstrate that instead of aiming for total motorization, the objective of urban planning should be the appropriate integration of non-motorized transport modes with motorized transport modes (Replogle,2009).

Different countries are trying to develop transport infrastructure in the form of construction of new roads, widening of existing roads or construction of flyovers or underpasses. The objectives of such infrastructure development programs are either to create alternate roads for particular destination or to reduce the heterogeneity of traffic flows along congested routes to reduce travel time for the commuters by segregating through- traffic and cross-traffic at various road intersections. Traffic congestion problem in various metropolitan cities of India is a serious issue for all the stakeholders of transportation system. In India, construction of grade separated paths / flyovers have been taking place with the objective of tackling traffic congestion problem associated with growth of traffic in different metro cities. It is essential to have some evaluation of the existing situation before developing such grade separated / vertically apart roadway infrastructure. It is essential to judge in advance how far such construction can solve the traffic problems associated with inadequacy of transportation infrastructure at different locations in a city particularly when there are resource constraints for undertaking such development projects. Currently the planners take the decision regarding acceptance or rejection of a particular project on the basis of financial benefit-cost ratio of a project or volume-capacity ratio of a road stretch.

Literature Review:

Lebo et. al (2001) suggests use of extended version of CBA technique for appraising Rural Transport Infrastructure (RTI) investment projects as the traditional CBA technique

do not account for many of the benefits. The authors advocate for enhancing traditional CBA technique to include better assessment of the costs of interrupted access, estimating operating cost savings of Non Motorised Transport (NMT), savings due to mode changes (from NMT to motorised transport), improved valuation of time savings and valuation of social benefits from improved access to schools and health centers. The authors criticize the use of MCA technique

by planners/consultants without consultation with the concerned stakeholders / users that makes the process nontransparent.

Diez et. al (2008) compare the Cost-Benefit Analysis (CBA) with Multi Criteria Analysis (MCA) for evaluation of nature conservation policy. The authors say that although CBA technique has been used traditionally for assessment of environmental projects, the technique has its limitations. On the other hand, MCA is capable of addressing multiple objectives and multidimensional issues in complex policy-making context. According to the authors MCA is a preferred technique to address the issue of sustainable development, as sustainability is associated with multiple issues of social, economic and environmental dimensions.

Lupton (2002) explained how the Multi Criteria Analysis was used to rank two forms of Alternate Mode of Transit namely guided or unguided bus transit and light rail transit prior to a final decision on the choice of the technical option when the Ministry of Economic Development, Financial Services & Corporate Affairs, with the assistance of the Japanese Government and the World Bank, commissioned Halcrow Fox to undertake an integrated national transport strategy study for Mauritus. The author considered Multi Criteria Analysis as the suitable technique for ranking the options, as the choice can

impact a number of issues of concern to the government and any single option can not be identified as providing the best impacts in all respect.

Rocío Cascajo (2005) applies the MCA technique to compare seven European case studies of rail transport projects in order to validate the suitability of the MCA technique for evaluating projects in terms of their impact to global sustainability. There is the identification of eleven criteria under economic, social and environmental sustainability; some are measured in quantitative terms and some are measured in qualitative terms. The projects already implemented are compared in terms of their social, economic and environmental impacts as well as the aggregate impact, since the impacts are expressed in numerical terms applying the MCA technique.

The methodologies reviewed propose to apply the either CBA or MCA technique to evaluate the outcome of projects whereas the current study intends to develop a technique of ranking the alternate projects before execution, depending on the criticality of existing situation in terms of different traffic characteristics.

Objective of the study:

Objective of the present study is to discuss

- The present methods of prioritization of infrastructure projects commonly used by the urban transport planners
- The appropriateness of using such methods
- Suggesting Multi criteria Analysis (MCA) as a suitable technique for prioritization of transport infrastructure development projects.

Current Practices of Urban Transport Project Appraisal:

In the urban cities of India, roads are used by different types of motorized and non-motorized vehicles together resulting in complex interactions among them (The Indian Roads Congress, 1990, p-9). Planners have the responsibility of measurement of the existing flow of traffic and comparing that with the existing capacity before they plan for any capacity enhancement. Passenger Car Unit (PCU) has been used as the unit of measurement of Traffic Volume and Traffic Capacity, which is the relative interference factor of one car. There is the practice of conversion of other types of vehicles according to their respective interferences as compared to a single car. It makes possible measurement of traffic volume and capacity for a specific road stretch in terms of a common unit of measurement that is PCU. The ratio of Volume and Capacity of traffic or the V/C ratio is used as a basis for understanding the acuteness of the congestion problem at any intersection. According to the transport planners, need for road capacity enhancement arises when the volume/capacity ratio of traffic approaches the value 1.00.

The green signal time is of prime importance to the commuters at a road intersection which is usually shared by the traffic vehicles towards the main road and cross road directions at that intersection. The process of providing green and red signal time for different directions is controlled by the traffic signaling system. The sum of V/C ratios of the main road and cross road helps to compare the actual volume of traffic with the theoretical capacity of any at-grade road intersection. When the sum becomes exactly equal to 1, volume and capacity become exactly equal (Japan International Cooperation Agency, 1992, p-117).

'Delay' measured in terms of vehicle hours at the intersections provides another basis for the urban planners to judge how critical the traffic situation is at any road intersection. Total delay at any intersection is estimated by the transport planners as an aggregate of delays of all vehicles of all approaches at that road intersection at any

particular point of time (Japan International Cooperation Agency, 1992, p-88). Delay for any single direction is defined as the product of volume of traffic (in terms of PCU) multiplied by the difference of actual time taken to cross that intersection and the time taken to cross the same point without any congestion (usually at a speed of 40 Km. per hour).

Use of Cost- Benefit Analysis (CBA) is very common for appraisal of transport infrastructure projects throughout the world. Under CBA, Benefit-Cost (B/C) Ratio and Net Present Value (NPV) of future returns from different projects are used frequently for appraisal of projects. If the project life time is 'n' number of years, B/C is the ratio of discounted future returns and discounted future costs of a project.

$$B/C = \sum_{t=0}^{n} Bt/(1+r)^t \Big/ \sum_{t=0}^{n} Ct/(1+r)^t ,$$

Here 'r' is the discount rate. B/C must be greater than or equal to 1 for the acceptance of a project.

NPV is calculated by adding the discounted values of net benefits of respective years, where the net benefit for a particular year is the difference of 'Benefits' (B) and 'Costs' (C) for that year.

$$NPV = \sum_{t=0}^{n} (B_t - C_t)/(1+r)^t ,$$

NPV must take a positive value for the acceptance of a project. The above two methods of CBA may not provide same preference ranking when we deal with number of

alternative projects. So it is better to consider both the methods for any project ranking (Wheatley, 2010).

Under Internal Rate of Return (IRR) method which is also used by planners, the specific value of 'r' is called the IRR for which NPV takes a zero value. Acceptance of the project will be there if IRR is greater than the market rate of interest. In this context mention should be made that there is the use of both Financial Internal Rate of Return (FIRR) and Economic Internal Rate of Return (EIRR) for evaluation of transport projects by the urban planners. FIRR takes into account only the direct benefits and direct costs associated with financial investment by the investor whereas EIRR takes into account benefits and costs experienced by the society also along with the investor. There are the problems of identification of benefits and costs as well as the quantification of the same in this context. In using all the above mentioned methods, there is the practice of taking into account quantifiable benefits or costs only.

Technique of Multi Criteria Analysis:

Different types of multi criteria analysis are used in evaluation and ranking of planning projects in general. Applications of such methods are more suitable for specific transport projects as these techniques are capable of incorporating both quantitative and qualitative socioeconomic characteristics / impacts of transportation infrastructure development. For example, there may be transport infrastructure improvement resulting in accessibility to socioeconomic opportunities. It may not be possible to incorporate such criterion to judge the priority of transport projects using CBA technique as it becomes difficult to quantify the impact of such criterion. Again when multiple criteria are to be considered to choose the most appropriate project from different alternative projects, selection may be easy in case of absolute dominance of one project over the others in respect of all criteria under consideration, but that is most unusual in the practical situation. Some project may yield better impact in terms of certain criterion but less encouraging impact in terms of some other criterion for a specific group of stakeholders. Preference ranking of alternative projects may be done on the basis of weights assigned by the stakeholders

following multi criteria techniques even if the impacts in terms of criterion under consideration can not be expressed in quantitative terms.

Application of Multi Criteria Analysis-a case study:

In Kolkata, Kolkata Metropolitan Development Authority (KMDA) has been responsible for undertaking comprehensive planning activities since 1972. Kolkata Metropolitan Area (KMA) is the area of responsibility of KMDA, which consists of areas along both sides of the river Hooghly, Kolkata towards the East bank and Howrah towards the West bank of the river. There are three municipal corporations of Howrah, Kolkata and Chandernagore and 38 municipalities under KMA. Kolkata Municipal Corporation (KMC) is commonly understood as 'Kolkata'. Kolkata with its population of 4,580,544 (2001 Census), suffers from the problem of congestion which is characterized by low travel speed, delays at the road intersections and heterogeneity of traffic composition along the road stretches. In the decade of the early nineties the Japan International Cooperation Agency (JICA) conducted a feasibility study for the transport infrastructure development project in Kolkata as the Govt. of India and Govt. of West Bengal requested the Govt. of Japan to conduct such a study. Report was submitted by JICA after completion of the feasibility study for construction of vehicular flyovers at several road intersections and other transport infrastructure developments at Kolkata. JICA considered individual traffic criteria as 'delay', 'air pollution', 'noise pollution' etc. for explaining the traffic situation at different road intersections (JICA, 1992). Priority ranking of alternate locations, based on any such individual traffic criterion varied from that on the basis of other criterion as no single location had the superiority on the other locations in respect of all the criteria under consideration.

Therefore an attempt has been made in this paper to find out the justification of ranking the constructions at different alternate locations / road intersections using multi criteria analysis and to do an assessment of the impact of recent infrastructure development programmes in Kolkata in the form of construction of new vehicular flyovers / elevated paths. Six traffic criteria, i.e. air pollution, noise pollution, morning delay, evening delay, present congestion and future expected congestion, have been taken together under consideration which makes the traffic situation at road intersections critical. A sample survey was conducted with 450 randomly

chosen stakeholders, 50 at each of the nine important road intersections under consideration, belonging to different groups of road users. The 450 road users have been classified into five categories as the Pedestrians, Private Car Users, Para Transit (Taxi/Auto Rikshaw) Users, Public Transport (Bus) Users and Freight Transporters. The individual road users were asked to assign weights to the six predetermined traffic criteria according to their individual opinion. The weight-vectors corresponding to each group of road users have been calculated as the average of all values assigned by individual road users belonging to a group. Preference Values and Non-preference values were calculated on the basis of weights assigned by all the above mentioned groups of stakeholders, taken all of them (450) together as well as individual groups, under the specific MCA tool of Concordance-Discordance Analysis as the method allows wide participation of stakeholders.

At the beginning we had to arrange the values of above mentioned six traffic criteria (before construction of flyovers) at different alternate locations of road intersections in order of preference and thereby get a 6 x 9 matrix (characteristics matrix) as there were six criteria and nine alternate road intersections under consideration. The method followed to rank the infrastructure development projects at alternate locations may be explained in the following steps:

Step-I

Concordance set $P_{mm'}$ is formed taking *n* as an element, if value y (obtained in characteristics matrix) of the criterion *n* for the alternative *m* assumes a higher rank than or same rank as that of alternative *m′*, which is expressed as $P_{mm'} = \{n \mid y_{nm} \geq y_{nm'}\}$, $m \neq m'$. Again, if value y of criterion *n* assumes lower rank for alternative *m* than alternative *m′*, *n* is chosen to be an element of discordance set $Q_{mm'}$ when $Q_{mm'} = \{n \mid y_{nm} < y_{nm'}\}$,
$m \neq m'$.

Step-II

Here the concordance index, $p_{mm'}$, has been calculated as the sum total of the weights associated with those criteria which are the elements of concordance set. The successive values of the concordance indices, P, are included in a concordance matrix. Again, the summation of the weights of the criteria of the discordance set each one multiplied by their respective rank differences, i.e. the difference between y_{nm} & $y_{nm'}$, provides the discordance index, $q_{mm'}$, and similar way discordance matrix, Q, is formed.

$$p_{mm'} = \sum_{n \in P_{mm'}} w_n \quad \text{and} \quad q_{mm'} = \sum_{n \in Q_{mm'}} w_n |y_{nm} - y_{nm'}|$$

Step III

At this stage Concordance (Preference) Values and Discordance (Non preference) Values have been calculated for the various alternatives. The sum total of $p_{mm'}$ for all the other alternatives provides the dominance of the alternative *m* over the other alternatives. On the other hand, for all other alternatives the summation of $p_{m'm}$ for the alternative *m* gives the total dominance of the other alternatives over the alternative *m*. Therefore, the net concordance dominance (p_m) of alternative *m* is given by the difference of the first and second values. In a similar way, net discordance dominance (q_m) of alternative *m* can be decided. The alternatives are then ranked according to both concordance set and discordance set. Detail calculation has been done following above multi criteria analysis under which pair-wise comparison of alternatives based on the six chosen criteria has been done.

Results of the study show that the ranking of road intersections (where infrastructure development could take place) by three groups of stakeholders as Pedestrians, Public Transport Users and Freight Transporters remains same when it marginally deviates from the ranking done by the other stakeholders as Private Car Users, Para Transit users. The ranking of alternative road intersections done on the basis of weights assigned by all the above mentioned groups of stakeholders give a picture of importance given to the different traffic criteria at a particular road intersection compared to those at other intersections by each group of stakeholders. The method may be extended to take any additional criterion other than the ones considered in the present study and also to take other groups of stakeholders.

According to our study, there has been dramatic increase in the flow of traffic along the newly constructed flyovers immediately after the constructions took place. It was felt that although the objective of such infrastructure improvement is to ease the traffic flow at road stretches / intersections, in many cases such improvements could not ensure faster movement, as generation of new traffic took place with improvement of road infrastructure. This is mainly because of the fact that flyovers make possible traveling a long distance at a shorter time but existence of bottlenecks to accommodate huge number of fast accumulated vehicles at the two ends results ultimately in loss of time to reach the final destination. The benefits of such

infrastructure improvements may be enjoyed fully only if proper planning and execution is done for the entire network of transportation in an urban city.

Conclusion:

The study provides a method of analyzing the criticality of road traffic situation at different parts of road network through the application of MCA technique which may help better management of road traffic movement. Such a method of ranking of alternate transport projects may help choosing the most essential project particularly when resource constraints are there, on the basis of several quantitative and qualitative traffic criteria instead of only quantitative criteria, as it is done under CBA technique. The application of multi criteria analysis is considered useful where the specific road intersections are not having absolute dominance over the others in respect of all traffic criteria. Concordance values show the preference / non-preference ranking whereas the Discordance Values show the degree of Non Preference of intersections.

Note: *This paper is drawn from the original research work of Jayanti De under the guidance of Dr. Madhumati Dutta and Dr. Sudip Roy on 'Socioeconomic Impact of Grade separated Road Intersections in Metropolitan Cities – A Case Study of Kolkata'*

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