# NEED FOR GOAL-ORIENTED METHOD FOR DEVELOPING URBAN TRANSPORT STRATEGIES FOR INDIAN CITIES

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## ABSTRACT

The development of urban transport strategies can be done by using either bottom-up approach, or top-down approach. The bottom-up approach is based on understanding of the problems as a first step for the strategy development. Typically, the Comprehensive Mobility Plan (CMP) studies are done in India using bottom-up approach. Whereas, the top-down approach is based on a set of goals and objectives as the starting point to develop the urban transport strategies.

Mostly, only isolated approaches to solve single or combination of problems are used in most of the Indian cities, which are bottom-up in nature. An integrated or top-down approach which considers different combinations of measures (in infrastructure and traffic management) and their joint impact on the different goal areas (mobility, safety, environment, economy etc.) are fairly not used. One of the reasons is that the responsibilities for the overall transportation system is distributed among many different institutions and not always clearly defined.

This paper discusses a new goal-oriented and co-operative method, which will be top-down in nature, for establishing comprehensive urban transport strategies for Indian cities.

*Key words: top-down approach, urban transport strategy, analytical hierarchy process, multi-criteria assessment, mobility plan, urban transport measures*

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## 1. INTRODUCTION

Transport studies and transport strategies in India are done conventionally based on the bottom-up approach, where the heart of approach lies in identification of a spatially detailed, quantified and comprehensive set of problems of the transport system, followed by an analysis of their causes. So far, the major transport borne problems are solved in an isolated way

neglecting the advantage of implementing the measures in an integrated approach and getting the resulted synergies in most of the Indian cities. An integrated approach which considers different combinations of measures (in infrastructure and traffic management) and their joint impact on the different goal areas (mobility, safety, environment, economy etc.) are fairly not used. One of the reasons is that the responsibilities for the overall transportation system is distributed among many different institutions & authorities and not always clearly defined. Approaches traditionally adopted for developing urban transport strategies for Indian cities focus largely on infrastructure expansion (private vehicle centric, in particular) to meet the demand and do not adequately consider traffic and demand management measures.

However, top-down approach for similar exercise is adopted in many cities around the world and project **Fr**ankfurt **U**rban **I**ntegrated **T**raffic Management (FRUIT) is one such successful study for Frankfurt Rhein-Mein region of Germany (Boltze et.al 1995), which is the prime motivation behind the current study. In project FRUIT, A structured goal concept is formulated for the concept of traffic management to solve the traffic and transport borne problems. An expert panel (including operators, stakeholders, and representatives of each public authority) is formed to outweigh the goals and measures based on their perceptions to avoid any bias in assessment. For the purpose of assessment, the utility analysis is used in which benefits were defined in a strongly formalised procedure by an expert panel according to their subjective assessment and based on their individual expertise.

Also, the recent recommendations from the Ministry of Urban Development (MOUD), Government of India, mandated to conduct traffic and transportation plans in form of comprehensive mobility plan (CMP) or comprehensive traffic & transportation plan (CTTP) suggesting to adopt a holistic approach for identifying urban transport strategies, in compliance with National urban transport policy (NUTP) 2006. The central government is encouraging the state governments with a provision of 80% subsidies towards the costs of such detailed studies. The central government's recent change in attitude, concerns, and policies for urban transport is an additional motivation for this study. This study will be helpful to adopt top-down approach for conducting the CMP studies or CTTS and thus fulfilling the main thrust of MOUD and NUTP.

## 2. URBAN TRANSPORT STRATEGY DEVELOPMENT PROCESS FOR INDIAN CITIES

While FRUIT study being the prime motivation, the goal concept as such needs to be adopted and modified for its applicability to Indian cities and which forms the major contribution of this study. The major difference is to also include infrastructure measures besides traffic management measures for developing urban transport strategies. This is because the Indian cities are still to saturate with respect to all possible infrastructure links, and so they also need to be considered in overall urban transport strategies. From this clear understanding, the following steps are followed to develop the urban transport strategies for Indian metropolitan areas.

As the first step, current situation of Indian cities were understood with respect to transport as well as the socio-economic conditions. The overall urban transport situation is known by understanding the transport problems, performance of transport and the state of urban development.

Identification of problems and the deficiencies of existing transport system (based on top-down approach) are necessary to form the strategic policy framework. Apart from many other transport problems, congestion, pollution, accidents are the major transport problems in the metropolitan areas of India. A goal oriented strategic policy framework is developed for the urban areas of India aiming at a sustainable transportation system. (Figure-1)

A list of candidate urban transport measures is formed. This includes the measures which are already applied in European cities (potentially useful for Indian cities also) and those that are suitable for the Indian urban conditions. In this study the measures are treated as 'urban transport measures' because this includes the combination of infrastructure, traffic management, information and pricing measures which influences the overall urban transportation system.

In impact analysis, each measure's impact on the traffic is tabulated. The impact of a measure on the traffic can have influence with respect to its avoidance, shift and control. Firstly, the traffic can be avoided by combining the trips, substitution and modification of the trips; Secondly, traffic can be shifted by time, mode and destination; and thirdly, the traffic i.e, its component vehicles and people can be controlled.

All the developed measures will not be suitable for all urban environments and these measures have to be assessed properly by scientific methods. Four assessment methods are reviewed for their suitability to assess the strategic measures. These methods include rating methods, simulation tools, multi criteria method and cost benefit analysis. Finally, multi criteria assessment method is selected for assessing the whole range of candidate measures.

A questionnaire is prepared based on Analytical Hierarchy Process (AHP) technique, where pair wise comparison matrices can be formed. For this, the questionnaire is asked to be filled by the transport stake holders (experts) including academicians, transport planners and transport operators. A qualitative scale is adopted for comparison between the criteria and sub criteria on a scale of 1- 2.5 (1 meant for both criteria to be equally important and 2.5 meant for basic criteria to be extremely significant)

After obtaining the responses from the experts, the weightages are drawn for the criteria and sub criteria. A qualitative scale on range of 0-3 is adapted to asses each measures effectiveness and applicability. Finally level of effectiveness and level of difficulty is found for

each measure to check whether the measure can be included in the urban transport strategy or not.

The selected measures (which can be included in the transport strategies) are listed. Finally urban transport strategies are formulated as a package of measures which includes both basic measures and supportive measures. The subsequent sections describe each step in more detail.

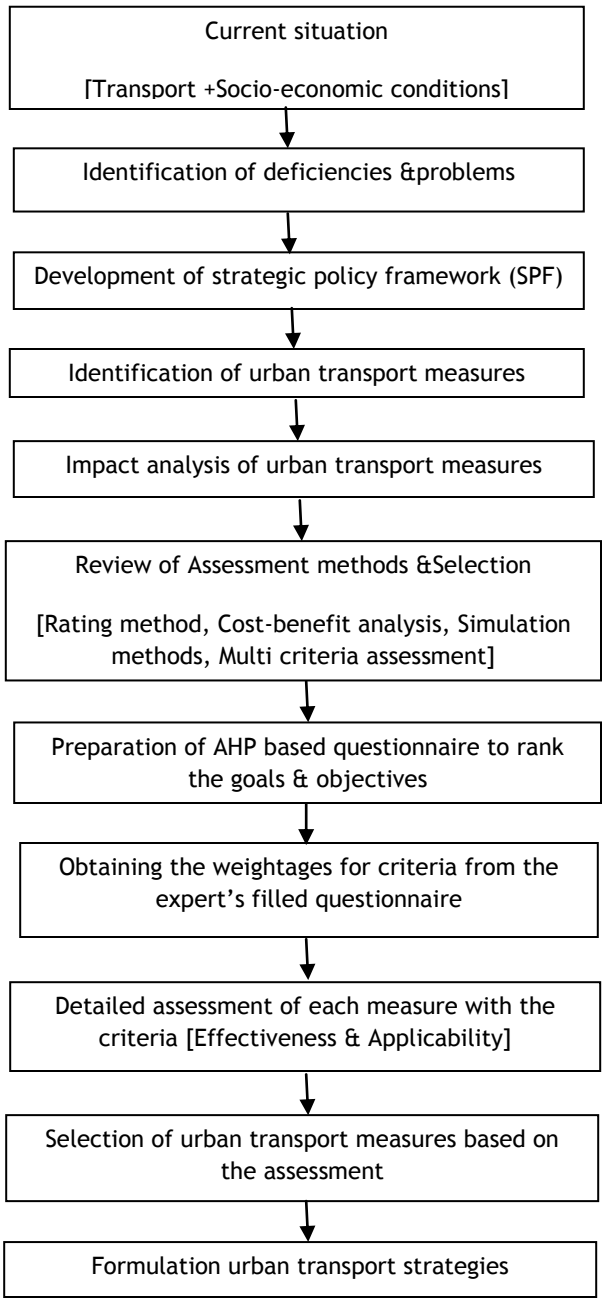


Figure1 – Flow chart of goal oriented method for urban transport strategy development in Indian metropolitan areas

# 3. CURRENT SITUATION IN INDIAN CITIES

The transport situation in Indian cities is worsening day by day. The growth in urban population has resulted in excess load on public transport and on the roads with the increasing vehicular ownership. Increase in economic levels of the society is one of the evidence causing the changes in modal split. Existing land use policies are responsible for non-centric growth making towns into cities and further into mega cities with its huge urban sprawl. This resulted in increase in average trip lengths, travel times and increased number of accidents.

# 4. IDENTIFICATION OF DEFICIENCIES AND PROBLEMS

A problem for an individual or a group of individuals is the difference between the desired state for a given situation and the actual state whose difference can't be eliminated immediately (if ever). This definition brings certain features of the problem; first, the problem need not be to the whole population since the whole may not perceive the nature and/ or magnitudes of the problem. Second the problem arises out of ambition to achieve the desired state whose desire level depends on nature of goals and objectives. Third, the fact that the problem can't be eliminated immediately (if ever), since it is involved with the human psychological conditions of anger, anxiety, yearning or even agony associated with the problem. If none of these are present, then we can say that there are no shadows of problem.

In this section, identification of urban transport problems by four approaches is explained with the help of work flow diagrams.

## 4.1 Top-down approach

In this approach, goals and objectives are formed to achieve the vision of an urban area and objectives are further classified on the basis of their measurement, such as qualitative and quantitative. The current transport situation is analysed and compared with the set of objectives to determine whether the objectives are being met or not. If not, it indicates the problems underlying corresponding objectives.

## 4.2 Problem oriented approach

This approach starts by defining types of problem and to use data on current (or predicted) conditions to identify when and where these problems occur. The objectives are implicit in the specified problems, and may never actually be stated. This approach has the merits of being easily understood. However, it is critically dependent on developing a full list of potential problems at the outset. If particular types of problems (like distribution of benefits to all groups of people) are not identified because the underlying objective (equity) has not been considered, the resulting strategy will be partial in its impact. It is thus probably still wise to check with elected members and the stakeholders so that the full set of problems has been identified. Pucher et.al (2005) explained the problems that are commonly seen in any developing country including India.

In figure 2, authors tried to explain the causes for the major transport problems viz., congestion, pollution and accidents using fish-bone diagram. However, it shall be noticed that is not a comprehensive list of causes and one can add depending upon the local urban conditions etc.

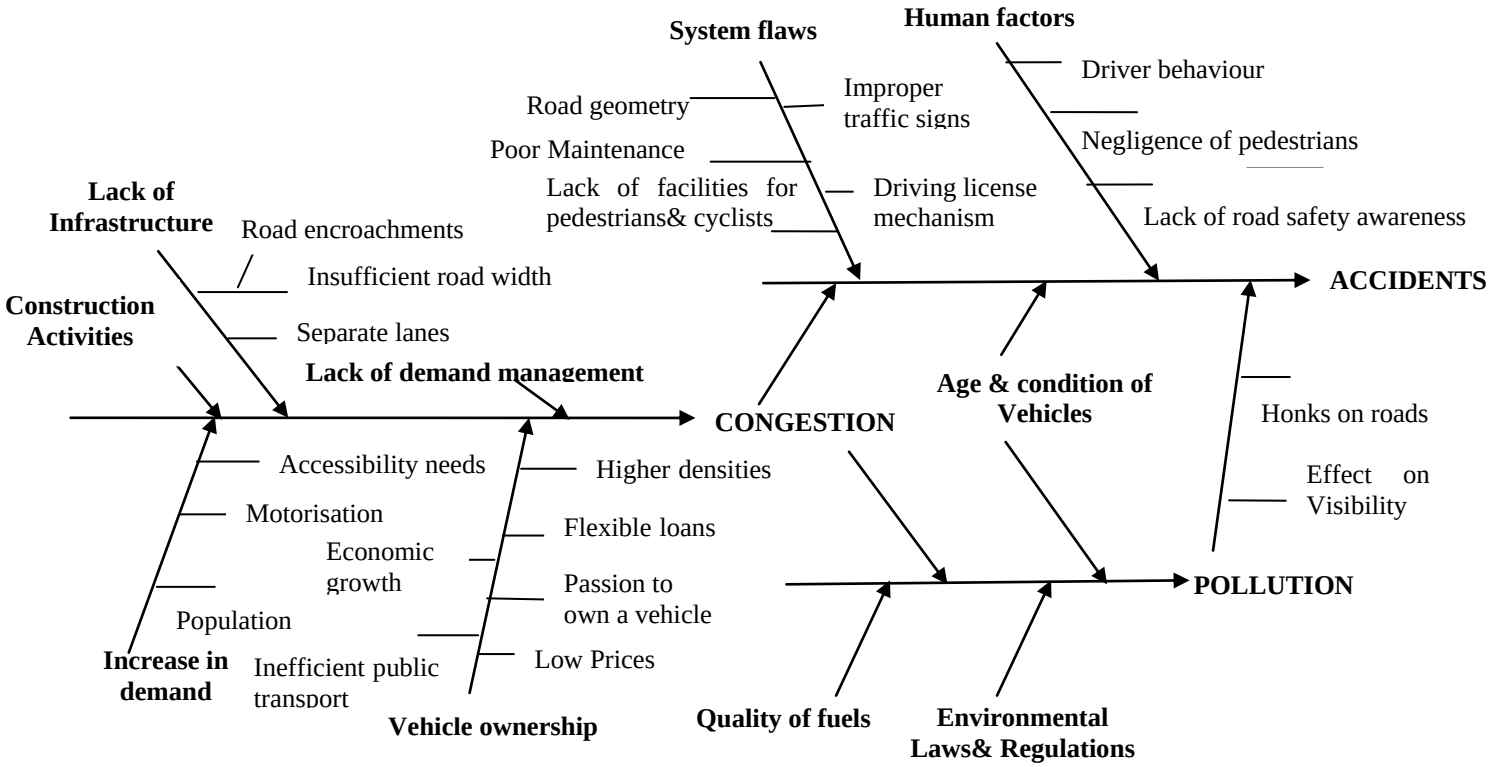


Figure 2 – Fish bone or Cause and effect diagram for major urban transport problems

### 4.3 Transportation indices

The identification of problems using the transportation indices is a similar approach to objective led approach since the developed indices are based on certain objectives rather than directly focussing on problems. To identify the deficiencies and to evaluate the performance of transportation system, the transportation indices are helpful and these are developed by making use of the data. For each aspect like accessibility, safety, environment etc., numerous indicators can be developed but its selection mainly depends on the level of the data required, availability of resources (financial, technical, human), and level of difficulty in understanding the indicator to the non-specialists, meaning & clarity of the indicators.

### 4.4 Miscellaneous methods

In this, urban transport problems are identified using some techniques or from resources. These techniques include collecting information about the current urban transportation system from the expert interviews/perceptions, political speeches, public hearings, media, published articles, internet blogs etc.

# 5. DEVELOPING STRATEGIC POLICY FRAME WORK

From the understanding of transportation system and the efforts that are made to mitigate traffic borne problems which could not solve comprehensive problems, it is clear that lack of proper strategic policy framework is the root problem in planning and implementation of urban transport projects. The figure 3 shows the proposed strategic policy framework.

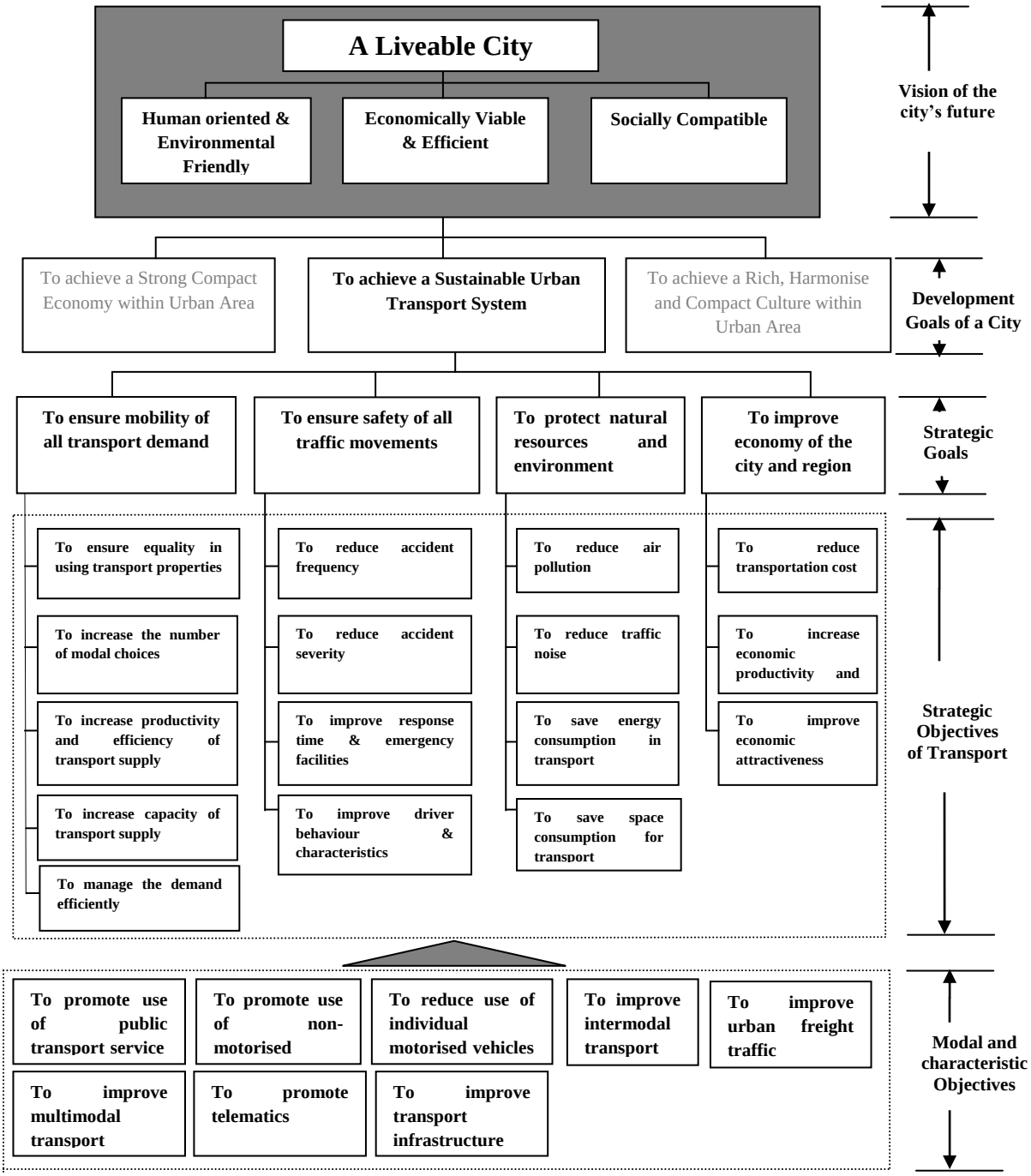


Figure 3 – Strategic Policy Framework

For an urban area, which are aiming toward a liveable city, should include the following characteristics: human-oriented and environmental friendly, economically viable and efficient, socially compatible, Vuchic (1999).To improve 'quality of life' as a vision statement, Albert Speer and partner (1993) developed a set of goals for Frankfurt urban area and Hung (2006) has insisted upon the same goals to study the traffic management for motor cycle dependent cities (Hanoi, Bangkok). The figure 3 shows the strategic policy framework and is formulated keeping liveable city as the vision and sustainable urban transport as the primary goal for a city. The strategic goals are framed to achieve the sustainable urban transport and further the objectives in line to achieve the strategic goals. Although, the goals and objectives are significantly interrelated they are presented independently because of its necessity in understanding the contents of societal expectation from an urban transport system.

## 5.1 Goals and Objectives

### *5.1.1 Mobility*

Mobility is ensured with the objectives viz., increasing the modal choices, ensuring the equality in providing the transportation services, increasing the productivity and efficiency of transport supply, to increase the capacity of transport supply and to manage the demand efficiently.

### *5.1.2 Safety*

The objectives like reducing the accident frequency (number of accidents, accident rate, accident densities), reducing accident severity (number of fatalities per year, fatal rates, total costs per accidents etc.,), improving the response time when an accidents occurs (reducing the average response time for public safety vehicles such as police, fire and other emergency rescue operations) and improving the driver behaviour and characteristics (number of accidents involved in by a driver)

### *5.1.3 Environment and natural resources*

This goal is achieved by fulfilling the following objectives; to reduce the air pollution (concentration of pollutants during a time period, quantity of pollution per person or ton kilometre, per vehicle kilometre or per capacity unit kilometre), to reduce the noise pollution (the average noise level at certain time point at representative observed locations in the targeted area), to save energy consumption in transport (average kilowatts of power per person kilometre, per vehicle kilometre, quantity of gasoline or diesel per person kilometre or per vehicle seat kilometre) and to save space consumption for transport ( percentage of road and interchange area in total urban area, ratio of total occupied square kilometres * hours over total available square kilometres * hours of roads or parking facilities)

### *5.1.4 To improve economy of the city and region*

To reduce the total transport cost, (total costs per person-km, total costs per ton-km or total costs per hour of activities that generate the trips etc.); to increase the economic productivity

and efficiency (average time for transport per working hour, per ton of materials or per product unit); to improve the economic attractiveness (average income, employment ratio)

# 6. URBAN TRANSPORT MEASURES

Measures for achieving sustainability include demand management, operations management, pricing policies, vehicle technology improvements, clean fuels, and integrated land use and transport planning. Retzko (2005) had recommended two groups of organisational and physical transport measures for liveable cities. In this study, the measures are formed based on the combination of characteristics (indicates the area or field in which the measure belong to), and mode (indicating the desired impacts on respective modes).

**Public Transport Measures** focus on encouraging travellers to use public transport services. These measures make the travellers to get attracted to public transport rather to travel with their individual modes. From the operator point of view these measures encourage them to provide a qualitative and comparable public transport services. So, these measures primarily aims shift of mode from private to Public transport.

**Non-Motorised Transport Measures** focus on encouraging travellers to use the non motorised modes such as bicycle and walking. Most measures like creating NMT zone, facilitating sidewalk and crossing facilities etc., can encourage the travellers to travel by NMT modes.

**Individual Motor Vehicle Measures** focus on efficient usage of individual motorised modes i.e., motorcycle and private car. For motorcycle, measures focus on improving the safety and reducing the impacts on environment. For car, the measures focus on minimizing their usage and in further their ownership.

**Multimodal Transport Measures** focuses on the measures which impacts on the traffic by controlling and regulating the flows, and there by facilitates smooth running of the traffic. These measures are developed by optimizing the benefits of all modes utilizing the same infrastructure and services.

**Intermodal Transport Measures** try to minimize the travel time by providing efficient mode transfer facilities and facilitates safe, quick and convenient mode change services.

**Infrastructural Measures** aims to improve the accessibility needs of all demand. Besides this primary objective of mobility, the measures which improve safety, economy, environment and control of traffic are included.

**Telematics** are the measures which focus on reducing the number of trips with the provision of telecommunications and other technologies. These measures can reduce the trips which the traveller can fulfil his/her needs without moving physically

**Freight Transport Measures** try to minimize and eliminate the interactions between the passenger traffic and freight traffic by providing additional and/or restricting the available infrastructure and services (partially or fully) to the freight traffic. In addition, the measures to reduce the environmental impacts of freight transport are considered.

# 7. IMPACT ANALYSIS (QUALITATIVE METHOD)

The developed measures will impact the traffic in three ways such as 'to avoid', 'to shift' and 'to control'. The table 1 shows the different measures, whose impacts with respect to different traffic strategies is presented. The letter '**X**' indicates the *significant impact* of the measure; '**Y**' indicates *minor impact* and blank cell indicating *no impact* of particular measure against particular strategy.

*Table 1 – List of candidate urban transport measures*

| | **Measure** | **To avoid traffic** | | | **To shift traffic** | | | **To control traffic** | |
|---|---|---|---|---|---|---|---|---|---|
| **No** | **Category** | **Combining trips** | **Substitution** | **Modification** | **Time** | **Mode** | **Destination** | **Vehicle** | **Travelers** |
| **PT** | **Public Transport Measures** | | | | | | | | |
| 1 | Public transport routing improvement | | | | | **X** | **Y** | **Y** | |
| 2 | Public transport scheduling improvement | | | | | **X** | | **Y** | |
| 3 | Public transport accessibility improvement | | | | | **X** | **X** | | |
| 4 | Public transport ticketing improvement | | | | **Y** | **X** | | | |
| 5 | Public transport users incentives | | | | **Y** | **X** | **Y** | | |
| 6 | Public transport operator incentives | | | | **Y** | **X** | | | |
| 7 | Public transport fleet management | | | | **Y** | **Y** | | **X** | |
| 8 | Public transport information | | | | **Y** | **Y** | **Y** | | **X** |
| 9 | Para transit improvement | | | | **Y** | **X** | **Y** | | |
| 10 | Public transport Right of Way prioritization | | | | **Y** | **X** | **Y** | **Y** | |
| **NMT** | **Non-Motorised Transport Measures** | | | | | | | | |
| 1 | Footpaths and crossing facilities | | | | | **X** | **Y** | | **X** |

| | **Measure** | **To avoid traffic** | | | **To shift traffic** | | | **To control traffic** | |
|---|---|---|---|---|---|---|---|---|---|
| **No** | **Category** | **Combining trips** | **Substitution** | **Modification** | **Time** | **Mode** | **Destination** | **Vehicle** | **Travellers** |
| 2 | Bicycle lane and facilities | | | | | **X** | **Y** | | |
| 3 | Non-motorised transport zone | | | | | **X** | **Y** | | |
| 4 | NMT information service | | | | **Y** | **X** | **Y** | | **X** |
| 5 | NMT user incentives | | | | | **X** | | | |
| 6 | Parking measures | | | | | **X** | | | |
| 7 | Security assurance measures | | | | | **Y** | | | |
| **IMV** | **Individual Motor Vehicle Measures** | | | | | | | | |
| 1 | Parking pricing system | | | | **Y** | **X** | **X** | **X** | |
| 2 | Parking information & guidance | | | | **Y** | | **Y** | **X** | |
| 3 | Private vehicle ownership reduction | | | | | **X** | | **Y** | |
| 4 | Road pricing for private car | | | | **X** | **X** | **X** | | |
| 5 | Vehicle registration control and licensing system | | | | | **X** | | **Y** | |
| 6 | Vehicle sales taxes and duties based on their efficiency | | | | | **X** | | **X** | |
| 7 | Vehicle technology improvement measures | | | | | **Y** | | **X** | |
| 8 | Traffic calming and speed reduction | | | | **Y** | **Y** | **Y** | **X** | |
| **MM** | **Multi-Modal Measures** | | | | | | | | |
| 1 | Dynamic traffic information | | | | **X** | **Y** | **X** | | **X** |
| 2 | Ramp meter system establishment | | | | | | | **X** | |
| 3 | Flexible or staggered working and schooling hours | | | | **X** | | | | |
| 4 | Road safety audit system | | | | | | | **X** | |
| 5 | Land use change | **X** | | | | **Y** | **X** | | |
| **IM** | **Inter-Modal measures** | | | | | | | | |
| 1 | Park and ride facilities | | | | | **X** | | | |
| 2 | Trip chaining incentive measures | **X** | | | | | | | |
| **IM** | **Infrastructural Measures** | | | | | | | | |
| 1 | New BRT/LRT/other transit system | | | | | **X** | **X** | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2 | Construction of missing transport links | | | | | **Y** | **X** | | |
| 3 | Ring road system establishment | | | | | | **Y** | **X** | |
| **TC** | **Telematics** | | | | | | | | |
| 1 | Telecommuting | | **X** | **X** | | | | | |
| 2 | Teleshopping | | **X** | | | | | | |
| 3 | Teleconference | | **X** | | | | | | |
| 4 | Distant learning incentives | | **X** | | | | | | |
| **FR** | **Freight Transport Measures** | | | | | | | | |
| 1 | Fleet management | | | | | | | **X** | |
| 2 | City logistic management system | **X** | | **Y** | **Y** | **Y** | **Y** | | |
| 3 | Lorry parks | | | | | | | **X** | |
| 4 | Transhipment facilities | | | | **Y** | **X** | **Y** | | |
| 5 | Lorry routes and bans | | | | | | | **X** | |

# 8. ASSESSMENT OF STRATEGIC MEASURES

The assessment of measures is done to judge the suitability of a measure to include in transport strategies. The assessment of the developed strategic measures can be done in two ways broadly, ‘qualitative assessment’ and ‘quantitative assessment’. Their characteristics explain the differences between them. For example, the qualitative assessment is *subjective, descriptive and universalistic* while the quantitative assessment is *objective, explanatory and particularistic.* In many cases it is very difficult to distinguish the approaches of assessment based on the above definition because some approaches fall in both the categories depending on the level of assessment. Example: Cost-benefit analysis, Environmental impact analyses can be done in both methods.

FGSV (2001) synthesised the assessment process into three categories: informal process, formal process, and combined process. The informal process is suitable for evaluating the qualitative criteria, while the formal process is applied when all assessment criteria are quantitative. A combined process is applied when the criteria is combined with qualitative and quantitative ones. Therefore the most important task in assessing the measures is to select the right criteria that will be able to indicate the contents of suitability.

It is possible to use various methods like micro-simulation modelling, cost-benefit analysis, environmental impact assessment, ratings methods, multi-criteria assessment etc to assess the urban transport measures. Each of the method has its own advantages and constraints. After studying the feasibility of adopting the above mentioned methods, multi-criteria assessment tool is used for this study and will be discussed in subsequent sections.

## 8.1 Multi criteria assessment

In multi-criteria assessment the developed measures are assessed with more than one criterion. In this, the assessment is based on more number of points of reference by which the individual measures are analysed and evaluated. This kind of assessment is normally used in strategic assessment and policy appraisal processes.

Remak and Rosenbloom (1976) recommended an assessment model that assesses the measures by two major groups of criteria, Benefit and Feasibility. Bohlinger (2006) adopted a four steps measure assessment model that includes six groups of criteria; (i) goal and objective suitability, (ii) applicability, (iii) compatibility, (iv) flexibility, (v) complexity, and (vi) adaptability. The assessment model for measures and further for urban transport strategy in this study is based on multi-criteria assessment model with two groups of criteria: (i) effectiveness; and (ii) applicability. The criteria of the two groups are shown in figure 4 (a) & 4 (b) below

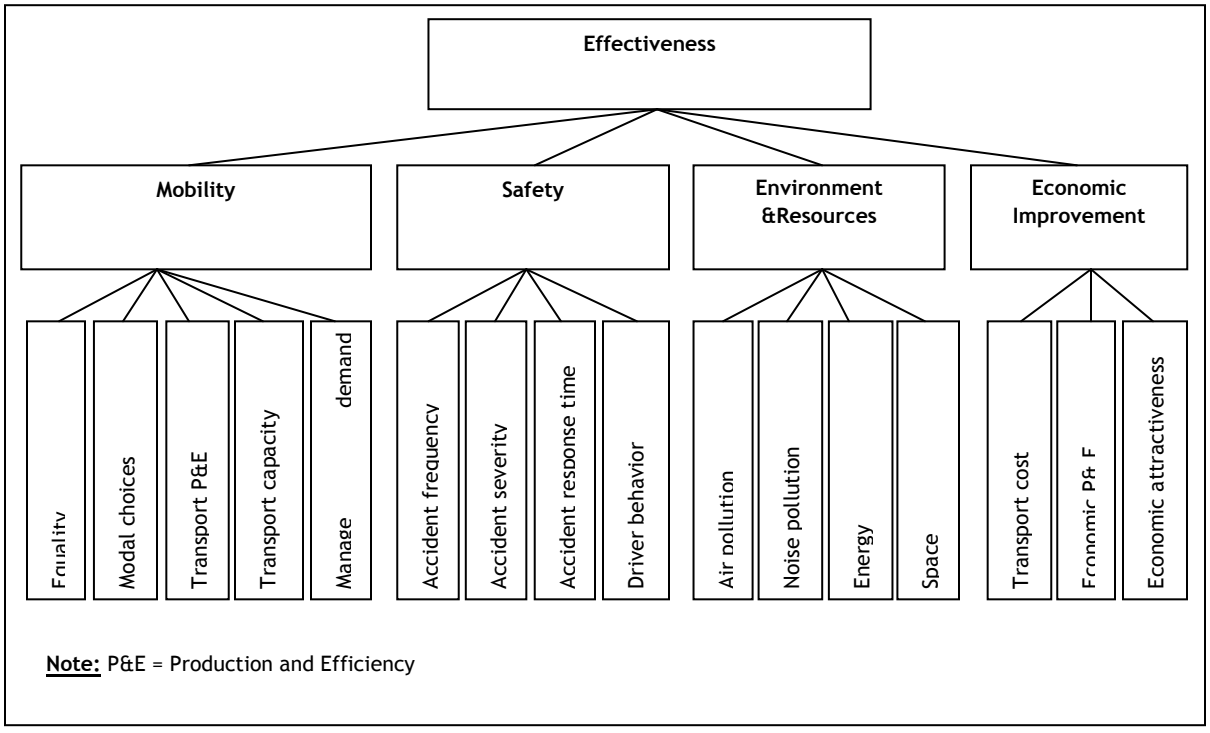

Figure 4 (a) – Multi-criteria Assessment using Analytical Hierarchy Process for Effectiveness

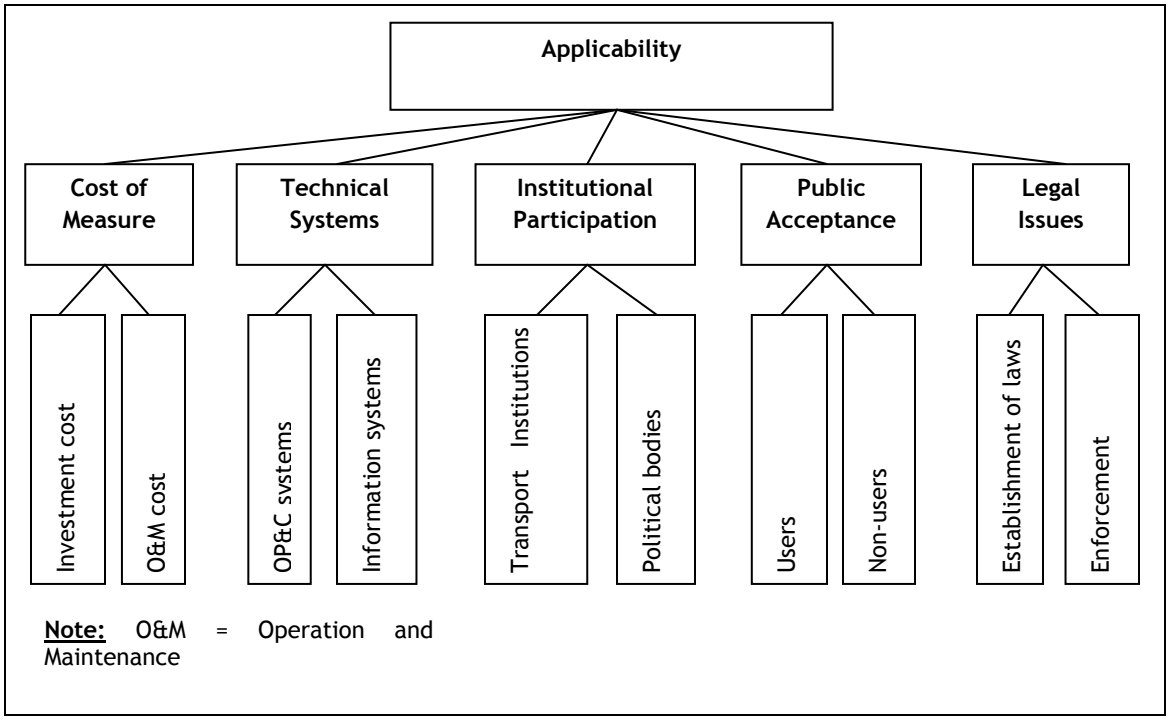


Figure 4 (b) – Multi-criteria Assessment using Analytical Hierarchy Process for Applicability

### *8.1.1 Effectiveness Assessment criteria*

Effectiveness is measured by the impacts of measures toward four strategic goals and its subsequent objectives of urban transport system.

*Mobility*

This criterion represents the goal *to ensure the urban mobility*, which is achieved by the fulfilment of four objectives, including ensuring equality in using public transport properties, to increase modal choices, to increase productivity and efficiency, to increase capacity of transport supply and to manage the demand efficiently.

*Safety*

This criterion represents the goal *to ensure urban traffic safety*, which is achieved by the fulfilment of two objectives, including to reduce frequency of traffic accidents (represented by accident frequency), and to reduce severity of traffic accidents (accident severity).

*Environment*

This criterion represents the goal *to protect urban environment and natural resources*, which is achieved by the fulfilment of four objectives, including to reduce air pollutions from transport (air pollution), to reduce noise from transport (noise), to save energy consumption in transport (energy), and to save urban space used for transport (urban space).

*Economy*

This criterion represents the goal *to improve economy* of the city and region, which is achieved by the fulfilment of three objectives, including to reduce transport cost (represented by transport cost), to improve economic productivity and efficiency (economic productivity and efficiency), to improve economic attractiveness of the city and region (economic attractiveness).

### *8.1.2 Applicability Assessment criteria*

As earlier stated, all the traffic management measures are not applicable to any area as a whole. There are no *'one-size fits all'* measures. These measures need to fulfil certain requirements and have to overcome certain barriers. In this study, all these requirements and barriers of a measure are measured indirectly by measuring the *level of difficulty* of each measure to know its level of applicability. It is quite obvious that a measure with a higher level of difficulty have a lower level of applicability and vice versa. Five barriers are considered as criteria for assessing applicability of measure viz., costs of measure, required technical systems, required institutional participation, required public acceptance and required legal issues.

*Costs of measure*

The cost of a measure is the first barrier in traffic management, which defines the affordability of the city in implementation of a measure. The cost includes two components, investment cost and operations cost.

*Technical systems*

Beside the internal technical equipments, which are components of the measure, the required technical systems are defined as the additional operation &control and/or information systems, the provision or improvements of which must be required as basic infrastructures for implementation of the measure.

*Institutional Participation*

The institutional participation is defined as the required support and participation of the institutions, *which are not the initiator or implementer* of the assessed measure. The required institutions are classified into two groups: *transport related institutions* and *political decision making institutions*. Transport related institutions, represented by *transport institutions*, include three sub-groups: (i) transport operators (e.g. bus companies, parking house owners), (ii) transport authorities (e.g. public transport authority, road construction authority), and (iii) traffic enforcers (e.g. traffic police, transport inspection). Political decision making institutions (sub-sequent by political institutions) related to decision of traffic management measures include administrations (e.g. government) and elected institutions (e.g. parliament) of city, region (inter-city) and national level.

*Public Acceptance*

For implementing a traffic management measure, two main groups of public are concerned. The *users* are clearly defined as the one, who directly use the transport service under impacts of the

traffic management measure. The other people, who are affected by implementing the traffic management measure, are defined as *non-users*.

*Legal Issues*

For the implementation of traffic management measures, it is necessary to modify and/ or to create laws. So, legal issues are divided into two considerations i.e., (i) Establishment and (ii) Enforcement.

# 9. ANALYTICAL HIERARCHY PROCESS

The analytic hierarchy process (AHP), developed at the Wharton School of Business by Thomas Saaty, allows decision makers to model a complex problem in a hierarchical structure showing the relationships of the goal, objectives (criteria), sub-objectives, and alternatives. AHP allows for the application of data, experience, insight, and intuition in a logical and thorough way. AHP enables decision-makers to derive ratio scale priorities or weights as opposed to arbitrarily assigning them. In doing so, AHP not only supports decision-makers by enabling them to structure complexity and exercise judgment, but allows them to incorporate both objective and subjective considerations in the decision process. The Analytic Hierarchy Process overcomes the problems with weights and scores approaches (outcomes of one or more of alternative courses of action are uncertain since they are influenced by numerous factors) by structuring complexity as a hierarchy and by deriving ratio scale measures through pair wise relative comparisons.

AHP is based on three basic principles: decomposition, comparative judgments, and hierarchic composition or synthesis of priorities. The decomposition principle is applied to structure a complex problem into a hierarchy of clusters, sub-clusters, sub-sub clusters and so on. The principle of comparative judgments is applied to construct pair wise comparisons of all combinations of elements in a cluster with respect to the parent of the cluster. These pair wise comparisons are used to derive 'local' priorities of the elements in a cluster with respect to their parent. The principle of hierarchic composition or synthesis is applied to multiply the local priorities of elements in a cluster by the 'global' priority of the parent element, producing global priorities throughout the hierarchy and then adding the global priorities for the lowest level elements (the alternatives).

## 9.1 Application of AHP to prioritise the criteria of effectiveness and applicability

In the study, a questionnaire is prepared to make a pair wise comparison of criteria and sub-criteria of effectiveness & applicability and is rated from the experts of transportation industry that includes academicians, bureaucrats and traffic & transport professionals. The criteria are compared on a scale of 1-2.5 where 1 indicates both criteria are equally important and 2.5 indicate the basic criterion is extremely important to other. The weights are obtained after evaluating the ratings from the experts (from different parts of the country) whose sample size was nine and are averaged to prioritise the criteria.

In terms of effectiveness, ensuring the urban mobility is rated as the most expected impact from urban transport with a weight of 33%. Following mobility are safety (31%), environment and resources (20%) and economy (17%). In terms of applicability, legal issues are rated as the most difficult barrier (25%) followed by public acceptance (22%), institutional participation (18%) and technical requirements, cost of a measure (17%). Table 2 shows the weightages obtained for criteria and sub-criteria of effectiveness and applicability.

## 9.2 Calculation of Effectiveness Score of Measure

Based on the given rates of measure's impacts and the given weights for effectiveness criteria (goals and objectives), effectiveness score (ES) of measure is calculated by formula (1). Measures would be more effective if the Effective score is higher and vice versa. In the formula below, the weightages for the terms $WC_m$ and $WS_{mn}$ are derived from the expert interviews and $EP_{mn}$ is given for each criteria of each measure by the author to compute the effectiveness scores.

$$ES_{ij} = \sum_{m=1}^{4} WC_m * \left[ \sum_{n=1}^{k} WS_{mn} * EP_{mn}^{ij} \right] \text{.....} formula(1)$$

Where,

$ES_{ij}$ : Effectiveness Score of Measure j, under category i

$WC_m$ : Weight of goal (criterion) m, m= 1 to 4

$WS_{mn}$ : Weight of objective (sub-criterion) n, under goal m

$EP_{mn}^{ij}$ : Effective point of measure j in category I, on objective n, under goal m

## 9.3 Calculation of Difficulty Score of Measure

Based on the given rates of measure's impacts and the given weights for applicability criteria (barriers and difficulties), one can calculate the difficulty score (DS) of measure by formula (2). Measures would be more applicable if the difficulty score is low and vice versa. In the formula below, the weightages for the terms $WC_x$ and $WS_{xy}$ are derived from the expert interviews and $DP_{xy}$ is given for each criteria of each measure by the author to compute the difficulty scores.

$$DS_{ij} = \sum_{x=1}^{5} WC_x * \left[ \sum_{y=1}^{x} WS_{xy} * DP_{xy}^{ij} \right] \text{.....} formula\ (2)$$

Where,

$DS_{ij}$ : Difficulty Score of measure j, under category i

$WC_x$ : Weight of criterion x (x=1 to 5)

$WS_{xy}$ : Weight of sub-criterion y, under criterion x

$DP_{xy}^{ij}$ : Difficulty point of measure j in category i, on sub-criterion y, under criterion x

*Table 2 – Weights of criteria and sub criteria of effectiveness and applicability*

| Weight of Criteria | | Criteria | Internal weight of Sub-criteria | | Sub-criteria | Final weight of Sub-criteria (WC*WS) | |
|---|---|---|---|---|---|---|---|
| **Effectiveness** | | | | | | | |
| 100% | 33% | To ensure urban mobility | 100% | 14% | To ensure equality in using urban transport properties | 4.5% | 100% |
| | | | | 17% | To ensure modal choices in urban transport | 5.3% | |
| | | | | 25% | To increase productivity and efficiency of transport supply | 8.3% | |
| | | | | 21% | To increase the capacity of transport supply | 7.3% | |
| | | | | 22% | To manage the traffic demand efficiently | 7.3% | |
| | 30% | To ensure safety of all traffic movements | 100% | 28% | To reduce accident frequency | 8.3% | |
| | | | | 26% | To reduce accident severity | 7.7% | |
| | | | | 26% | To improve emergency response time | 8.2% | |
| | | | | 20% | To improve driver behaviour & characteristics | 7.0% | |
| | 20% | To protect natural resources and environment | 100% | 33% | To reduce air pollution | 6.4% | |
| | | | | 25% | To reduce noise pollution | 5.0% | |
| | | | | 23% | To save energy | 4.3% | |
| | | | | 19% | To save urban space | 3.7% | |
| | 17% | To improve economy of the city and region | 100% | 37% | To reduce total transport cost | 6.0% | |
| | | | | 38% | To increase economic productivity and efficiency | 6.7% | |
| | | | | 26% | To improve economic attractiveness of the city and region | 4.4% | |
| **Applicability** | | | | | | | |
| | | | | | | | |
| 100% | 17% | Cost of measure | 100% | 50% | Investment cost | 9.0% | 100% |
| | | | | 50% | Operating cost | 7.5% | |
| | 17% | Technical Systems | 100% | 56% | Operating systems | 9.5% | |
| | | | | 44% | Information systems | 8.2% | |
| | 19% | Institutional participation | 100% | 58% | Transport related institutions | 10.6% | |
| | | | | 42% | Political institutions | 9.4% | |
| | 22% | Public acceptance | 100% | 60% | Users | 12.9% | |
| | | | | 40% | Non-users | 8.5% | |
| | 25% | Legal issues | 100% | 44% | Establishment | 10.2% | |
| | | | | 56% | Enforcement | 14.3% | |

## 9.4 Terms of Measure Selection

It is already mentioned that a rating scale of 1-2.5 is adopted to evaluate the weightages of effectiveness and applicability criteria from the experts and on a scale of 0-3 for each measure is adopted from author to find out the scores of effectiveness and applicability. Therefore, it is obvious that a measure with weightage of 3 and 0 against effectiveness and applicability respectively, will completely achieve the goals and objectives of the study. However this is an ideal condition to set for a measure. After scrutinizing the measures with its effectiveness and

difficulty scores, certain thresholds are tuned to define different categories of effectiveness and applicability. Equal importance has been given to both effectiveness and applicability in defining the order of priority.

Finally, the measures are selected to be in the list of recommended measures by the following conditions

- The first priority group consists of measures that have High level of Effectiveness and a Low level of Difficulty (ES > 2.3and DS <1.5)
- The second priority group consists of measures that have either a high level of effectiveness or medium level of difficulty (ES > 2.3and 1.5<DS <2.3), or a Medium level of effectiveness and a Low level of Difficulty (1.6<ES<2.3 and DS<1.5)
- The third priority group consists of measures that have a Medium level of Effectiveness and Medium level of Difficulty (1.6<ES < 2.3 and 1.6<DS <2.3)
- The fourth priority group consist of other measures

From the calculation of effectiveness scores and difficulty scores, the following measures are grouped;

*Measures with order of priority '1':* Routing Improvement, Scheduling Improvement, Public Transport User Incentives, Public Transport User Incentives, Right of Way Prioritisation, Footpaths and Crossing facilities, Bicycle lanes and Facilities, NMT Information Improvement, Vehicle Registration Control and Licensing System, Traffic calming and speed reduction, Urban Traffic Information Service, Land use change, Park and Ride Facilities, Construction of Missing Transport Links, City Logistics Improvement, Lorry routes and Bans

*Measures with order of priority '2':* Accessibility Improvement, PT Ticketing Improvement, PT Fleet Management, PT Information System, Para-transit Improvement, Non-Motorised Zone, NMT user incentives, Parking Measures, Security Assurance Measures, Parking Pricing, Parking Information & Guidance, Road Pricing for Private Car, Vehicle taxes and duties based on efficiency, Vehicle Technology Improvement, Ramp meter System, Flexible or Staggered Working and schooling Hours, New BRT/LRT/other transit system, Ring Road System Establishment, Lorry Parks, Transhipment Facilities

*Measures with order of priority '3':* Private Vehicle Ownership Reduction Measures, fleet management

*Measures with order of priority '4':* Road Safety Audit, Trip chaining Incentives, Telecommuting, Teleshopping, Teleconference, Distant learning incentives.

# 10. URBAN TRANSPORT STRATEGY FORMULATION

A two-step formulation model is presented as the recommended process to systematically integrate different urban transport measures into strategic urban transport packages, which presented as different alternatives in urban transport Planning. Following this model, basic urban transport measures, supportive urban transport measures and specific conflict-solving measures are proposed and assessed in order to formulate the strategy package. After getting the priority list of measures (refer Table 3), a two-step model is followed to formulate possible urban transport strategies for Indian cities.

The formulated urban transport strategies includes ***Basic Measures***, whose implementation is the major step for achieving the urban transport goals and objectives; ***Supportive measures*** which aims to improve the applicability or to reduce the difficulty in implementation of basic measures; and ***conflict-solving measures***, which are non-traffic management measures solving the remained difficulties and conflicts in implementation of the basic measures.

*Table 3 – Basic urban transport measures*

| **Measure** | | | **Traffic Impact** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **To avoid traffic** | | | **To shift traffic** | | | **To control traffic** | |
| **S.N** | **Code** | **Title** | **Combining trips** | **Substitution** | **Modification** | **Time** | **Mode** | **Destination** | **Vehicle** | **Travellers** |
| 1 | PT1 | Public transport routing improvement | | | | | **X** | **Y** | **Y** | |
| 2 | PT2 | Public transport scheduling improvement | | | | | **X** | | **Y** | |
| 3 | PT5 | Public transport users incentives | | | | **Y** | **X** | **Y** | | |
| 4 | PT 6 | Public transport operator incentives | | | | **Y** | **X** | | | |
| 5 | PT10 | Public transport Right of Way prioritization | | | | **Y** | **X** | **Y** | **Y** | |
| 6 | NMT1 | Footpaths and crossing facilities | | | | | **X** | **Y** | | **X** |
| 7 | NMT2 | Bicycle lanes and facilities | | | | | **X** | **Y** | | |
| 8 | NMT4 | NMT information service | | | | **Y** | **X** | **Y** | | **X** |
| 9 | IMV5 | Vehicle Registration Control and Licensing System | | | | | **X** | | **Y** | |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | IMV8 | Traffic calming and speed reduction | | | | **Y** | **Y** | **Y** | **X** | |
| 11 | MM1 | Urban traffic information system | | | | **X** | **Y** | **X** | | **X** |
| 12 | MM2 | Land use change | **X** | | | | **Y** | **X** | | |
| 13 | IM1 | Park and ride facilities | | | | | **X** | | | |
| 14 | Infra2 | Construction of missing transport links | | | | | **Y** | **X** | | |
| 15 | FR2 | City logistics improvement | **X** | | **Y** | **Y** | **Y** | **Y** | | |
| 16 | FR5 | Lorry routes and bans | | | | | | | **X** | |

## 10.1 Traffic avoidance strategy

This strategy influences urban transport system by its primary impact (traffic avoiding) specifically by combining personal and freight trips. From the Basic Measures, possible measures of traffic avoiding strategy are: land use change and city logistics improvement. The major difficulty in implementing this package are acceptance from the impacted land users and total cost of measure which shall be addressed by improving the awareness of land users and to give them acceptable compensation in term of financial and social benefit. To deal with the cost of measure, there is no measure which generates revenue among basic measures. However, inclusion of supportive measures (*parking pricing and road pricing for private car*) which generates money from the IMV users would make the package viable against cost barriers.

## 10.2 Traffic shifting strategy

As presented in the list of first priority measures, shifting travel demand in transport mode is the significant impact of ten over thirteen traffic-shifting measures. The other significant destination shifting measures are land use change, construction of missing transport links and urban traffic information system. Since, Land use change is already assigned in the Traffic Avoiding Strategy, it as basic measure is not included in the traffic shifting strategy package which consists of 5 Public transport measures (*PT routing, PT scheduling, PT user incentives, PT operator incentives, PT Right of way prioritisation*), 3 NMT measures (*Footpath and crossing facilities, Bicycle lanes and facilities, NMT information service*), one IMV measure (*vehicle registration and licensing*), one MM measure (*urban traffic information system*), one IM measure (*park and ride facility*) and one Infrastructure measure (*construction of missing transport links*).

The barrier for implementation of this package is ‘cost’ and assuming the revenue from park and ride facilities will be balanced with their operating & maintenance costs, there is no single basic measure which generates revenue to make the package financially viable. For this purpose, three supportive measures (*vehicle taxes and duties, parking pricing, road pricing for private car*) are added from the second priority group. Although these additional three measures in isolation have a major barrier from *public acceptance*, the basic measures of the strategy eases the difficulties of this aspect.

Finally, the traffic shifting strategy is recommended with fifteen measures of which twelve are basic measures and three are supportive measures.

### 10.3 Traffic controlling strategy

The significant influence of this strategy is on control of traffic components viz., vehicles and travellers. The proposed combination of these basic measures creates a significant impact on vehicles (Traffic calming and speed reduction, lorry routes and bans) and travellers (Foot path and crossing facilities, NMT information service, urban traffic information system).Therefore, the strategy is recommended with five measures (*Traffic calming and speed reduction, lorry routes and bans, Foot path and crossing facilities, NMT information service, urban traffic information system*).

### 10.4 Integrated Strategy

Integrated urban transport strategy aims to influence urban transport system in more than a single primary impact. So, theoretically it is possible to form a combination of four such integrated strategies. Firstly, an integrated urban transport strategy (IUTS) with the measures creating impact in all the three areas i.e., avoiding, shifting and controlling of traffic can be done. Secondly, one can formulate also three other reductive versions of IUTS, which are traffic avoiding and shifting strategy, traffic shifting and controlling strategy, traffic avoiding strategy. However, here it is focussed to formulate the reductive versions of IUTS. In the IUTS package, all the basic measures are included to fulfil the strategic goals of the study and in terms of applicability of these measures; the major barriers for this group are costs, Institutional participation and public acceptance. Therefore, supportive measures like parking pricing, road pricing for private car, vehicle taxes and duties will assist the package financially and it is essential to include some lobby measures and other measures for legal improvement to account public acceptance and institutional barriers. Unfortunately, in the other twenty six measures there are no such measures to eliminate these conflicts.

The final IUTS strategy consists of total nineteen measures of which sixteen are basic measures and three are supportive measures (parking pricing, road pricing for private car, vehicle taxes and duties).

## 11. Summary

This study started with the aim of developing a goal oriented urban transport strategies for the Indian metropolitan areas. In the process of obtaining the results, the major stages, problem analyses, investigation of transport measures and strategic developments were carried.

At the stage of problem analyses, major transport problems and other deficiencies of transport were identified. The urban sprawl, land use issues, increase of densities at Central Business Districts (CBD's) were identified as some other issues that needs serious attention. 44 candidate urban transport measures are developed and are qualitatively analysed for their impact over the traffic. AHP technique is used to obtain the weightages for the goals and objectives from the transportation stakeholders. Multi-criteria assessment technique is used and effectiveness and difficulty scores are calculated for each measure. Measures are grouped into different priority groups based on the terms of selection. In the order of priority, 16 measures are

selected as basic measures whose implementation is a major step in meeting the sustainable transportation system. Finally, four urban transport strategies are formulated viz., traffic avoidance strategy (two basic and two supportive measures), traffic shifting strategy (twelve basic and three supportive measures), traffic controlling strategy (five basic measures) and integrated urban transport strategy which includes all basic and supportive measures.

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# Response to Reviewers' Comments on the Paper (WCTR- ID 1088) Entitled "**Need for Goal-Oriented Method for Developing Urban Transport Strategies for Indian Cities**"

Authors thank the reviewers for giving valuable comments to substantially improve our manuscript. We have suitably modified the manuscript based on the comments. Below are the point wise responses to the editor and reviewers' comments.

| S.No. | Reviewers Comments | Response |
|---|---|---|
| **Revision 1** | | |
| R1-1. | Application of the Analytic Hierarchy Process (AHP) can be considered as a very useful approach for development of urban transport strategies in developing countries when finding the decision which best suits the needs and understandings of various decision makers is problematic. Please note that key words were not provided in the paper. | Authors have included the key words in the manuscript. Authors' expresses their thanks for specifying the keywords. |
| R1-2. | Please insert page numbers | As suggested, page numbers are inserted |
| R1-3 | Probably would be better to say “ current situation” instead of “ current scenarios” on pages 2 and 3, as well as in Fig.1 | The term current scenario is changed to " current situation" in the pages 2 and 3, as well as in Fig.1 |
| R1-4 | Seems better to use “ Analytical Hierarchy Process” instead of abbreviation AHP on p.3 when the term is firstly mentioned | The abbreviation AHP is expanded as Analytical Hierarchy Process on page 3. |

| | | |
|---|---|---|
| R1-5 | Logic of numbering of subheadings 1.1-1.1.13 is not matching with corresponding headings which are not numbered | The authors have corrected the numbering pattern and now it is logical. |
| R1-6 | Visibility of the Figure 3 is not sufficient | Visibility of the Figure 3 is corrected by increasing the font size at appropriate sections of the figure. |
| R1-7 | Table 1 provides quantitative criteria, rather than qualitative criteria as it is mentioned in the title of the table | The title of the table 1 is corrected to " quantitative criteria" |
| R1-8 | Usage of word Difficulty instead of Applicability does not look consistent (see the term Effectiveness Score Measure) | The term 'Difficulty' is different with the term 'Applicability'. If a measure with high difficulty scores means it is less applicable and vice versa. To give an example, the difficulty score of measure "New BRT/LRT/other transit system" is higher and therefore although the effectiveness score is higher, it could not categorise as a basic measure because it is less applicable.<br><br>The main reason to use the word difficulty and there by calculating difficulty score for the applicability criteria is "measures are applicable when they have less difficulties & barriers in implementation". Therefore, authors felt, appropriate to use the term difficulty instead of 'applicability' while calculating the difficulty scores. |
| R1-9 | It is not clear why the abbreviations LOE and LOD are used in the text (effectiveness score and difficulty score respectively) | Authors have gone through the text (effectiveness score and difficulty score) and changed the used abbreviations LOE and LOD into ES and DS respectively. |
| **Revision #2** | | |

| | | |
|---|---|---|
| R2-1 | Paper should be shortened as it is too long and tables & figures should be reorganized. | The paper has been shortened to 25 pages, which fits with the page limit specified in WCTR paper guidelines. |
| R2-2 | References need to be properly referenced | The references in the manuscript are revised and properly referenced. |
| R2-3 | Spacing and hyphenations needs correcting | Spacing and hyphenations are corrected |
| R2-4 | Inconsistent paragraph numbering | Paragraph numbering has revised and now their numbering is consistent |
| R2-5 | Spacing in tables should be corrected | Spacing in the tables have been corrected |
| R2-6 | Consider rewriting summary | Summary of the manuscript is rewritten and elaborated to give the overall view of the paper. |