A Methodology for Evaluation of a City–Level Road Network for Passenger Transportation: Case Study Kolkata

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***Abstract*--This study intends to develop a methodology for assessment and evaluation of city-level transportation network in the context of India. The Indian cities have their own differences with the cities in the developed countries. The data and information available in most Indian cities are also inadequate. The methodology for assessing the city-level transportation network developed in this dissertation is an attempt to provide a decision-making mechanism within the constraints of data and information characteristic of Indian cities.**

To arrive at a suitable methodology, the following steps have been followed –

- *A study of the existing evaluation models and their applicability in the Indian context.*
- *The formulation of the proposed methodology.*
- *Case study area Kolkata and its passenger transportation scenario analysed.*
- *Application of the methodology on Kolkata.*

Key Words--Transport planning methodology, Assessment and evaluation, City-level, Road network, Adequacy, Physical distance, Time distance, Capacity.

I. INTRODUCTION

The urban areas in India are growing at fast rate, mostly in an unplanned manner. Transportation facilities are quite often inadequate and inefficient. Again, within the urban areas, different levels of transport facilities exist. Moreover, the decisions on improvements and augmentation have to be taken up under resource constraints and hence, should be phased properly according to degree of need and priorities.

There are methodologies to assess the levels of service of city-level road network for passenger transportation, but they all require the basic data on origin – destination of trips for analysis, which, in most of the Indian cities are unavailable.

There is, therefore, a need to develop a methodology for evaluation and monitoring of the adequacy and levels of service of city-level road network for passenger transportation in Indian cities.

Kolkata has been chosen as a case study. The intra-city journeys within the Kolkata Metropolitan Area (KMA) are nightmares to the commuters. As the metropolitan boundary sprawls further ahead, the need for an efficient and smooth traffic system is strongly felt - an improved network that would transform transportation system into a "service", and not a hindrance.

II. OBJECTIVES OF THE STUDY :

The study intends –

1. To develop a methodology for evaluating the levels of urban road network for passenger transportation in respect of the acceptable levels of adequacy.
   a. Defining adequacy (adequacy in this case is to a great extent qualitative. What may seem adequate for someone might be inadequate for some other).

b. Devising a methodology for evaluating the levels of urban road network for the Indian cities, considering

- Indian cities have completely different set of passenger transportation characteristics from cities of developed (eg, European or North American) countries.
- Transportation data available in Indian cities are limited.

2. To apply the methodology on the Kolkata Metropolitan Area (KMA) for assessing the adequacy and levels of service of passenger transportation by road.
3. To select the inadequate inter-zonal routes within KMA, and to give recommendations for their up-gradation into adequate standards.

The scope of the study is limited to the urban road passenger movement patterns' characteristics of Indian cities. The data and information are restricted within the boundaries of their availability in the majority of Indian cities. Kolkata has been chosen as a case study to demonstrate the effectiveness of the methodology. This study stops short of devising routes and schedules of passenger vehicles due to academic limitations.

III. METHODOLOGY :

The methodology of work *(ref. Fig. 3.1)* is defined as follows:

- Detailed study and analyses of primary and secondary data -
  - Study of structure of KMA along with its existing land-use and transportation network.
  - Study of survey data on KMA transportation network.
  - Analyses of the data as well as projected results for future.
  - Effectiveness of the existing methodologies and the need for an appropriate methodology.
- Proposal of the evaluation methodology that is based on available data and is capable for identifying the gaps in the urban road network in Indian cities.
- Evaluation and assessment of the KMA Road Network for existing as well as for the projected set of data.
- Proposals for improving KMA Road Network.
- Conclusion.

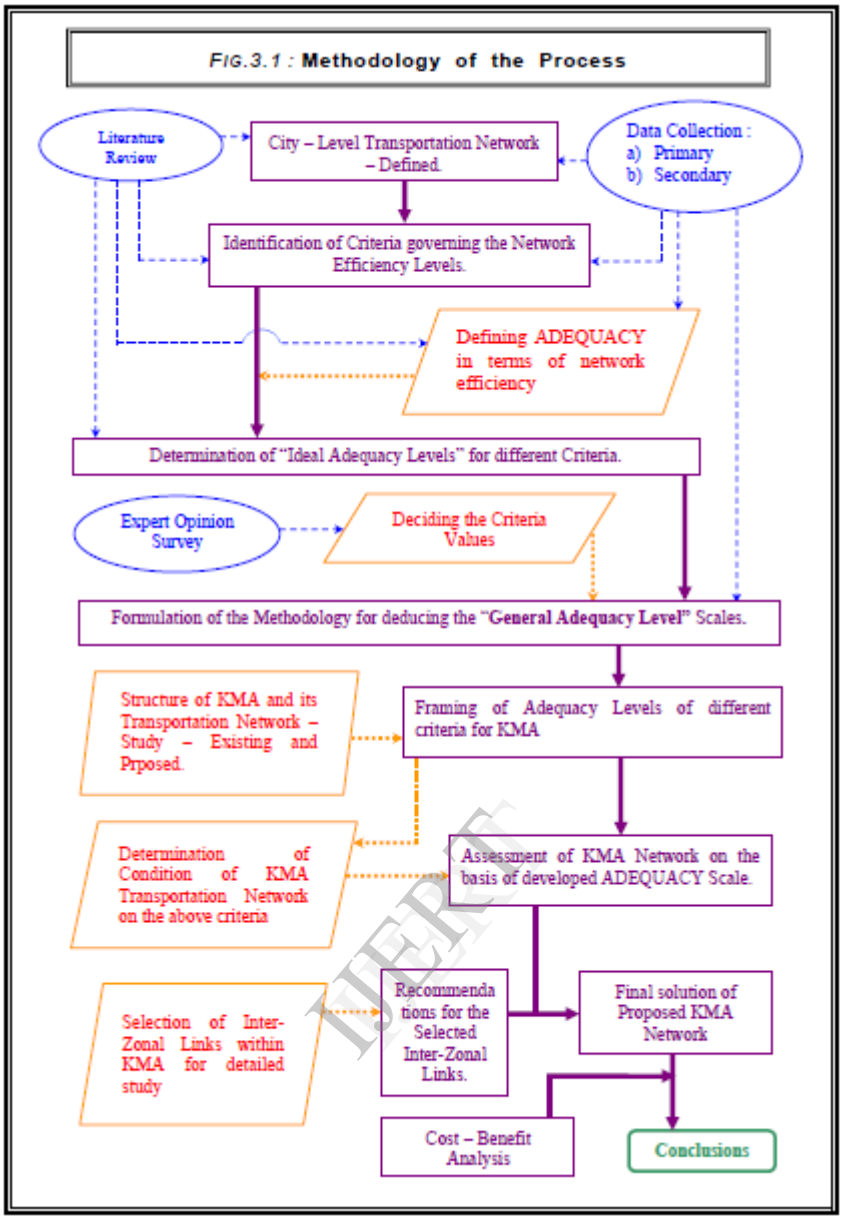


Fig. 3.1

IV. KOLKATA : AN INTRODUCTION

It is the predominant urban centre and a primate city in Eastern India, with a population of 12.13 million (1991 census). The KMA covers an area of 1380 sq. km. and is divided into 18 planning zones rendered by KMDA. It acts a national centre of economic activities like industry, trade and commerce. It is a nerve centre of higher education, specialised health services, recreational and cultural facilities. Is a very important node for traffic and transport, both passenger and goods.

A. Land Form and Existing Development Pattern

- KMA has grown in a linear form along the river Hoogly.
- Within a very short distance on either side (within about 3 kilometres), the level falls quickly leading to low lying lands, which presented great difficulties for urban development on large scale in East or West directions.
- Hence, almost all of the major rail and road arteries have been developed parallel to the river alignment, with mostly secondary connecting branches along east-west direction.

B. Existing Land Use

- The generalised land use break up indicates that the residential use is predominant, about 32 % of total. Next predominant use is industrial, institutional, public and commercial respectively according to their magnitude. Vacant land including arable land, forest and waste land, water bodies, swamps and marshes cover up to 53 % of total land.
- Transportation covers around 7 % of the total land.
- Disposition of overall land use pattern shows (*Ref. Fig. 4.1*) that the major industries are located within some cluster / patches along the river Hoogly.
- The prime commercial centre / CBD is located in the metro core comprising Kolkata and Haora, with some secondary centres at some local level. The residential areas are disposed along the main transit routes of rail and road.

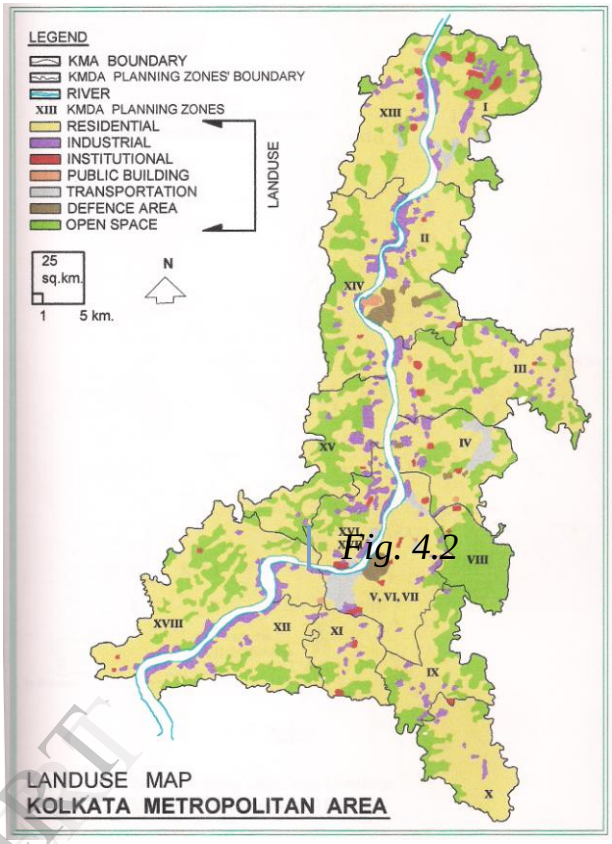


Fig. 4.1

C. Highway and Street Hierarchy

- The road network is the main network of travel in the KMA (*Ref. Fig. 4.2*).
- The road network of KMA can be classified in the following categories –
  - Primary Road System
    - National Highway
    - Regional Highways (State Highways and District Roads)
    - Metropolitan Highways
    - Major Arterial Roads
  - Secondary Road System

V.

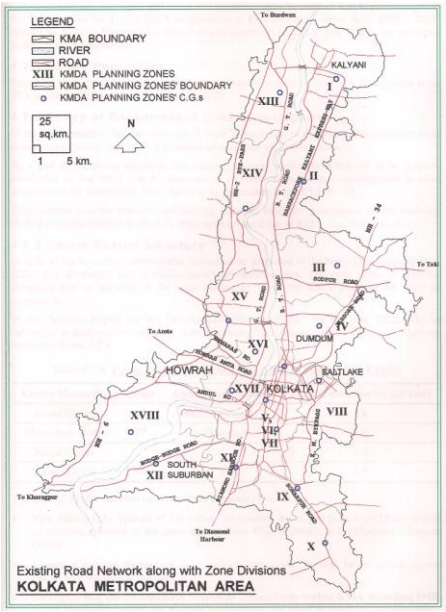


Fig. 4.2

D. Travel Growth Trend of Kolkata

Based on the present trend of growth rate, the future population of KMA 19.7 millions in 2021.

The fast vehicular traffic on the major corridors of CMC and HMC has been growing at the rate of 2.5 % per annum. However on new roads or peripheral ones, where the volume-capacity (V/Q) ratio is low, the growth rate is 5 – 8 %. The average annual growth outside the metro core is 3.5 % per annum, due to higher growth rate of population in the non-core areas.

From the volume-capacity ratio analysis, it has been found that in almost 65 % of the roads the V/Q ratio crossed the value of 0.75 – reflecting the high congestion of the roads.

VI. Evaluation of Existing Methodologies

The models for assessment of transportation network require data which are not available in most Indian cities. Prime among the inventory of the require data is information regarding Origin – Destination Matrix. Some of these methods are illustrated in the following paragraph, which require O-D data.

1. Transportation planners Hai Yang, Michael G.H. Bell & Qiang Meng have developed a theory for "Modelling the Capacity and Level of Service of urban transportation networks". In it, they have considered an O-D matrix, which is not fixed and depends on the land-use.

2. Iida (1972): Proposed a heuristic model based on a simple incremental assignment technique.

   At each step, a certain portion of a suitably large O-D demand matrix is assigned to the network based on the updated link travel time according to the latest partial link flows, and the network capacity is defined at the point at which a cut consisting only of saturated links comes out.

3. Ferrari (1995) and Yang & Bell (1997): Investigated the relationship among traffic restraint, road pricing and network equilibrium where road pricing is used to bring down equilibrium network flow below its capacity. In this method, they have analysed the relationship of the O-D trip costs in respect of O-D volumes.

VII. The New Methodology for Assessment

Unlike the classical and contemporary models of transportation network assessment models, the new methodology for assessment of road network proposed here does not rely upon the origin-destination trip distribution data. Rather, it is structured on some grass-root characteristics of trips, viz., physical distance, time distance, flow-capacity ratio, safety, comfort and reliability.

A. The whole metropolitan area is divided into some smaller area / zones on basis of –
   a. Administrative Boundary (already existing).
   b. Land-Use Pattern.
   c. Landform and other Geographical features.

B. The Geometrical / Geographical / Functional / Economical centres are selected, which act as the "Centre of Gravity" of transportation of the zone. Generally, they can be selected as –
   a. The place which attracts as well as generates the "lion's share" of the total trip generation / attraction of the zone.
   b. The place, which is almost at the centre of gravity of the network of most trip attracting / generating centres, geometrically / geographically.

C. The most frequented **Inter-zonal Routes** (links) between the CG pairs are determined.

D. The "inadequate" routes are identified by the following steps.

A. Step I: *Physical Distance*

1. The length of the links, i.e., route distances between the O-D pairs are found out.
2. The "crow-fly" distances, i.e., direct distances between the O-D pairs are measured.
3. The two above measures are plotted pair-wise in a scatter diagram (refer to Fig. 6.1 - 6.2 for the method), and the linear regression line is drawn. The regression line would give the "Direct / Route Distance" slope (**best possible** slope is **458**).
4. Comparing the actual regression angle with the ideal gridiron angle, it is inferred whether the metropolitan transportation system in general is better (ideal angle less than actual angle) or vice versa. The higher line with the higher angle is taken as the "central regression line" for further analysis (hence, referred as α).
5. The O-D pairs are separated as "above central" and "below central" the central trend-line α, thus giving two sets of links. Similarly, as the central line, they would have their own regression lines.
6. The above step is repeated to subdivide the data into smaller parts, thus increasing the accuracy of the method. It would also help to phase the development program.
7. The routes having lower angle are compared with those having higher angle to identify the segments, which should be augmented or have alternatives to reduce the travel length.

Framing the Standard

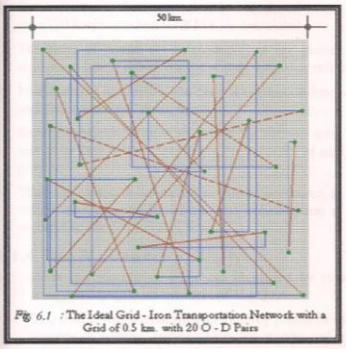


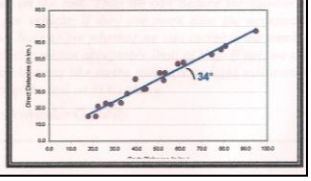
Fig. 6.1 : The Ideal Grid - Iron Transportation Network with a Grid of 0.5 km. with 20 O - D Pairs

A square is drawn with 0.5 km. X 0.5 km gridiron pattern, taking the largest direct distance as the diagonal (*Fig. 6.1*). A reasonable number of sample O-D pairs are plotted at random. The direct and route distances for the sample pairs are measured. When the direct vs. route distances are plotted on a chart, the regression line (*Fig. 6.2*) for the scatter gives the ideal slope of the best practical transportation network for a planned city. For the case of Kolkata, this is found to be 34°.

The 20 Pairs for Ideal Angle Analysis

Serial No.	Route Distances (in km.)	Direct Distances (in km.)
1	94.8	67.0
2	32.8	23.6
3	59.0	47.2
4	52.6	37.2
5	44.4	31.9
6	21.4	15.2
7	39.5	37.9
8	22.4	21.4
9	74.5	52.9
10	50.7	41.7
11	61.5	48.0
12	17.9	15.1
13	28.4	22.6
14	25.9	23.2
15	35.8	29.0
16	33.0	23.4
17	43.3	31.8
18	78.8	55.8
19	80.9	58.0
20	53.2	41.7

Fig. 6.2: Route v/s Direct Distances for Ideal Grid Iron Transportation Network



B. Step II: *Time Distance*

1. The travel time between the O-D pairs is deduced from the primary surveys.
2. From the route distances (already introduced in the analyses under Step A), the travel time (20 kmph is taken for KMA) is calculated.
3. The pairs of actual v/s calculated time are plotted in a scatter diagram and a linear regression line is drawn for the scatter, hereafter referred as "central regression line".
4. Points above and below the central regression line are separated as the "above central" and "below central" route times.
5. Separate regression lines are drawn for the two sets. They will further subdivide the two sets as in Step A, thus increasing the accuracy of analysis. It would help in phasing of the project.
6. Thus the routes of lower slope can be compared to those of higher slope. Hence, they would give the stretch where time consumption is more, and hence, augmentation is required to cut down travel time.

Steps I and II are the necessary analyses for assessment of road network, which are subsequently supplemented by capacity analysis (step III), cost analysis (step IV), pollution analysis (step V) and safety analysis (step VI).

C. Step III: *Capacity Analysis*

- After the inadequate links are identified by steps I and II, they are checked for adequate capacity on the basis of V / Q ratio.

- The traffic volumes at different survey points in PCU can be obtained from secondary sources or primary survey. Also, the widths and number of lanes of the roads can be obtained from similar source.. From these data, it can be analysed whether the links are physically inadequate or not. Thus, the links can be selected according to the inadequate level of capacity and can be planned for.

D. Step IV: *Cost Analysis*

Capacity analysis can be divided on two heads –

(i) Vehicular Capacity – in which, the flow of vehicles in PCU is to be surveyed on the link under inspection. If the flow- capacity ratio, i.e., V / Q ratio is high or more than permissible to avoid congestion, then we have to think of remedial measures like widening of road, provision of flyover at junctions, planning a by-pass, etc.

(ii) Passenger Capacity – in this, the flows of passengers by all modes on the investigated link are assessed.

Our analyses for Kolkata involves only Vehicular Capacity.

From the primary household survey, one can obtain the willingness to pay. Hence, it can be inferred whether it is possible to impose further user charges or not. For KMA, it is found from opinion survey that people are willing to pay more than the present cost of 50 paise per km, as charged by the buses, provided there are suitable improvements in travel time, comfort and safety.

E. Step V: *Pollution Analysis*

From the National Ambient Air Quality Monitoring Programme, one can find out the pollution levels on the roads. Thus, one can obtain the environmentally inadequate links that require improvement.

F. Step VI: *Safety Analysis*

From the monthly police reports on accidents, one can get the accident-prone roads (links) within KMA. Thus we have the links of inadequate safety.

The methodology discussed so far can be used iteratively for analysing the transportation network minutely for obtaining acceptable solutions.

G. Inferences

The results arising out of the analyses and the consequential inferences are indicated herein.

→ Physical Distance

21 route have been found inadequate from the Physical Distance Analysis. Out of which, two routes cannot be improvised by road transportation, and hence are to be considered for trans-river trips by ferry.

For 19 routes, either alternative links (i.e., only part(s) of the routes are amended) or totally alternative routes have to be devised.

→ Time Distance

Time analysis has been done considering the proposed route lengths, wherever applicable. 12 routes were pointed out that need speed improvisation. Out of them, 9 need partial widening or introduction of new links. Rest of them need either grade-separated crossings or lane separation for different modes for augmentation.

→ Capacity Analysis

In the capacity analysis, 16 traffic-volume survey points, which falls on the inter-zonal routes considered for analysis, have been taken.

For all these points, traffic volumes were given by KMDA survey. From the widths of the roads, their capacities were deduced [*Ref:* table for Recommended Design Service Volume, "Guidelines for Capacity of Urban Roads in Plain Areas", The Indian Roads Congress, 1990].

From the Volume-Capacity Analysis for those 16 points, 6 points were identified which had V/Q ratio greater than 1.

VIII. PROPOSALS

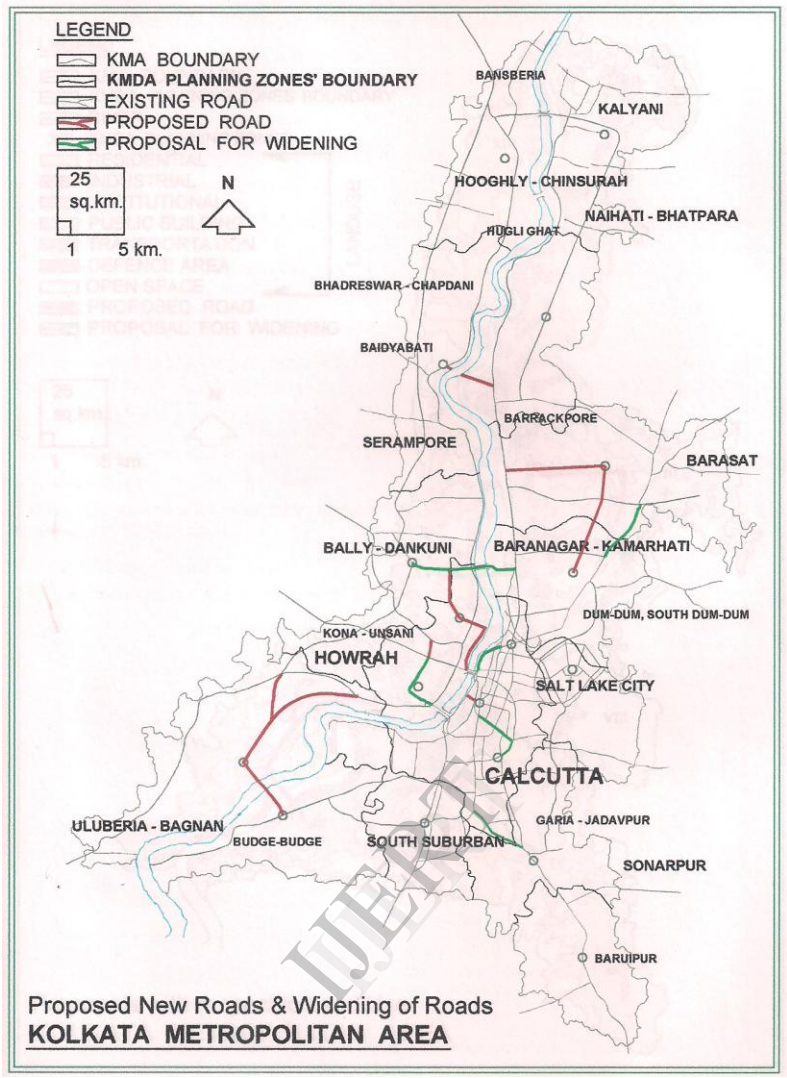


Fig. 7.1

The final solutions are given after combining and coordinating the results of the analyses and inferences coming out of criteria-wise proposals. It consists of multifold actions, such as –

- Proposal for new roads and bridges;
- Widening of existing roads;
- Development of intersections;
- Construction of grade-separation for intersections;
- Provision of bus-only lanes; etc.

The new roads and the roads requiring some sort of action in the above terms are shown in a combined way in *Fig. 7.1*.

IX. CONCLUSION

The scope of the dissertation is primarily to develop a methodology for assessment of a transportation network. The case study of Kolkata has been taken to illustrate the method.

The study did not intend to give a detailed development plan for the KMA road network for passenger transportation. Hence, it did not go into the detail of the proposals. Its intention was simple – to highlight the inadequate routes within the network and in some cases, to point out the links affecting the adequacy of the routes. Thus, macro-level solutions are provided.

The proposed methodology is operationalised for Kolkata and indicates the need for improving road network of Kolkata on logical foundations.

The methodology requires further improvement in terms of routing and scheduling of public transits and assessing the secondary road networks. However, this is a beginning, and it is expected that the methodology proposed will go a long way in providing a basis for road network planning.

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