Performance Evaluation of Intermediate Public Transport by Benchmarking and Numerical Rating Approach

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Abstract

The substantial increase in urban population, industrial and commercial activities in most of the Indian cities have increased the demand for transport. The urban population growth forced the cities to spread and this expansion has resulted in an increased need for mobility. The public transport systems face a challenge to keep in pace with this rapid increase in demand and growing need for connectivity. Inadequate transport facilities will further lead to sub optimal use of public transportation and the relative output of the city public transportation will be further reduced. In recent years, the growing necessity for public transportation and the incapacity of the administration to invest has led to the emergence of Intermediate Public Transport (IPT). So, there is a need to assess the quality of IPT. The IPT nowadays has become an indispensable mode of transportation across urban India. The service flexibility of IPT makes it a vital transport system to fill the gap within the organized public transport system. IPT acts as a feeder to mass transit system in large cities and acts as a primary mode of public transport in small cities. In urban area IPT helps in improving the mobility, but uncontrolled growth of IPT results in reduced air quality and safety due to increased emissions and traffic congestion. An effective management of IPT helps in sustainable urban transport. For effective management, we must monitor the performance. To carry out the study, Visakhapatnam city has been selected as a case study area. The performance of IPT in Visakhapatnam city has been evaluated by considering performance areas and key performance indicators representing the respective area are chosen. The overall performance of the IPT system is assessed based on these performance indicators by using the concept of benchmarking which considers city, system and passenger perspective. The performance report of IPT by benchmarking has been derived which shows that IPT of Visakhapatnam city is performing in better way in the areas of travel speed, affordability and it is also observed that it is safer mode to travel compared to private two wheeler mode. The areas that need to be improved are identified and suggestions are given to improve them in the report card. To consider the user perception of the quality of service and their level of satisfaction numerical rating approach has been chosen, by numerical rating, deficiency from acceptable level is observed in average waiting time and vehicle occupancy.

Keywords: Intermediate Public Transport, Performance Indicators, Service attributes, Benchmarking, Numerical Rating Approach, Passenger satisfaction

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I. INTRODUCTION

A. General

Most of Indian cities are overburdened by a high population growth, inadequate transport facilities and depletion of air quality standards. The urbanization, coupled with increasing economic activities has increased the migration of people to cities. This resulted in urban sprawl and also the travel demand for public transport is increased. An inefficient public transport, lack of alternative transport modes like safe walking and cycling facilities has forced many to shift from public transport to personalized modes as their daily mode of commute. To accommodate this rapid growth in private transport requires very extensive road capacity, which would induce more greenhouse gas emissions.

This will cause in increased traffic volumes, congestion and reduced speed, mobility and safety. This may further reduce the dependence on public transport. Alternatively, public transport is adequate for mass mobility. Experience has shown that, public transport has a great significance in reducing traffic congestion, offering alternative means of travel, and contributing greatly to the quality of urban life. It is well acknowledged that in order to manage and improve a service one has to first able to measure it. Hence, to make public transport attractive and thereby increase their modal share, public transport services in the cities not only need to be planned, operated and marketed well, they need to be measured and monitored on a continuous basis.

As a lag between growing public transport demand and service capacity results in an increase of travel cost, congestion, and unreliable service, thereby creating economic loss and environmental degradation. Therefore, assessing the performance of the public transport based on the need of the passenger can help in increasing the share of public transport in the urban transport. Therefore, it is of substantial value that approaches for monitoring, assessing and modeling public transport system performance are developed, in order to ensure a provision of better services. However, many of these cities are finding it a challenge to implement such a policy vision on the ground due to a number of barriers which are mostly political, institutional and even cultural. While there is a lot of emphasis on new and expensive infrastructure creation to meet the supply gaps in public transport; softer (and often low cost) interventions like improving service quality, accessibility and taking into account passenger perception are totally neglected. There is no mechanism that exists which can assess if the available transport modes are fulfilling their expected roles and meeting various standards regarding environmental, safety, equity, and comfort. In most of the cases there are no standards. Assessing the performance using the benchmarking concept can be effective as it compares the present performance of the public transport against the future needs and thus helps in finding out present quality of public transport and the improvements to be undertaken so that the overall system develops.

B. Aim of the Study

The aim of the present study is to evaluate the performance of the IPT system by Benchmarking process, considering key performance indicators. To evaluate the quality of service by the Numerical Rating approach by considering passenger's perception and their level of satisfaction in such a way that this process is also applicable to any Indian city with IPT as one of the public transport modes.

C. Objectives of the Study

- To identify different IPT modes operating in Visakhapatnam.
- To develop Key Performance Indicators (KPI's) based on the performance areas of availability, mobility, safety, affordability, ITS facility, comfort and convenience.
- To assess the vehicular occupancy of IPT modes operating in Visakhapatnam, assess the passenger attitude and trip maker characteristics.
- To compare IPT mode to two-wheeler mode in terms of mobility and safety.
- To identify areas of excellence and gaps and to derive performance report card to set targets.
- To determine the passenger satisfaction with the existing IPT system.

D. Scope of the Study

The overall performance of IPT can be assessed by using the selected indicators. The calculated Level of Service (CLOS) of each indicator is considered based on the standard LOS categories derived from various handbooks and some are introduced by the author, so that the overall performance of the IPT system of Visakhapatnam is evaluated. Major locations are considered for the vehicular occupancy survey. Speed and delay survey was conducted on all the major corridors on which IPT ply, All-or-Nothing assignment is used for the travel time calculation between the links due to its simplicity.

E. Conclusion

The performance evaluation of IPT is important in assessing the overall performance of public transportation system of a city. The study is carried out in a planned and progressive manner to achieve all the objectives.

II. THE CASE STUDY: VISAKHAPATNAM

A. Introduction

Visakhapatnam, popularly known as Vizag is the largest urban agglomeration in Andhra Pradesh. It has been and continues to be a hub of economic activity in the region, thereby leading to more and more people migrating to the city. Visakhapatnam is the largest city, both in terms of area and population of Andhra Pradesh. Visakhapatnam is located 363 kilometers (226 mi) north east of the proposed state capital of Amaravati and 587 kilometers (365 mi) of Hyderabad, the common capital of Andhra Pradesh and Telangana. It is the administrative headquarters of Visakhapatnam district and also the Financial Capital of Andhra Pradesh.

B. Visakhapatnam City Profile

From 1858, when its 'Municipal Association' was formed, to 2012, the city has developed into a significant economic, educational, health and tourism hub for the people of north-eastern Andhra Pradesh and southern Orissa. Greater Visakhapatnam Municipal Corporation (GVMC) was formed in 2005 by merging the erstwhile Visakhapatnam Municipal Corporation (VMC), Gajuwaka municipality and 32 other villages.

1) *Location and Topography*

Vizag is located on the east coast of India, in 17o 42' North latitude and 82o 02' East range of hills. Based on Visakhapatnam City Development Plan the topographical conditions of the city and its environs can be divided into four categories viz., Hilly region, Upland tracks, Rolling plains and Plains. The Kailasa and Yarada are the major hill ranges in the city.

2) *Area and Population*

The GVMC area of 534km2 represents the urban agglomeration area of the city with a population of 20,91,811 as per the 2011 census. This is taken as the study delineated area. Out of the total planning area, only 31 per cent is currently built up and the rest is covered by agriculture, forests and hills. As a result, the population densities are higher than 27,000 people per hectare in the core city, and the outskirts are very sparsely populated. Also the city has 686 slums, which together comprise 44 percent of its total households. Excluding these areas, the urban built-up area of the city is concentrated in 166 km2 spread across the 534 km2 of the total city area.

Source: GVMC, Visakhapatnam City Development Plan (CDP)

3) *Demographics*

The GVMC consists of the VMC, 32-merged Villages and the erstwhile Gajuwaka Municipality. The population of Vizag urban agglomeration increased from 1.05 million in 1991 to 1.32 million in 2001. The growth of population was more than 80% during 1971-81 and 37.11% during 1991-2001. Due to formation of GVMC and merger of surrounding villages, several well established urban components of the city are located within the GVMC. The demographic profile of the city shows the presence of a largely young population, with 68 per cent under 40 years of age.

Source: Visakhapatnam City Development Plan (CDP)

C. *Vehicle Population*

Every year not less than 90,000 of all types of vehicles are getting registered for Visakhapatnam city, the vehicle growth pattern of Visakhapatnam city is shown in Table 2.1

Table - 2.1
Vehicle growth pattern for the city of Visakhapatnam

Vehicle type	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
2 wheeler	*247972*	*293133*	*340567*	*308303*	*523257*	*571311*
Autos	*23429*	*28170*	*31879*	*18449*	*26824*	*33432*
Four wheeler	*39692*	*48592*	*58713*	*52452*	*68540*	*80163*
Commercial	*29500*	*35271*	*40493*	*28922*	*37318*	*45555*
Total	*340593*	*405166*	*471652*	*408126*	*655939*	*730461*

Source: Visakhapatnam Assistant Commissioner of Police (Traffic)

D. *Road Network*

Visakhapatnam is one of the major cities on the east coast of India connected by a major highway NH-16 and a part of the Golden Quadrilateral of Indian highways connecting Chennai and Kolkata. The total road network within the port limits is about 85 kms. About 23.5 kms of road network is available within the operational area connecting the entire stacking areas for free movement of vehicles. Port connectivity road length 12.47 kms was completed and implemented jointly by the port and NHAI through SPV-Visakhapatnam Port Road Limited. The flyovers cum road project facilities are in smooth movement of cargo traffic between the port and National Highway-16 in the city.

Visakhapatnam city has following road network:

- 73 Kms of length of NH No.16
- 6 Kms of length of NH No.43
- 30 Kms length of SH No.38
- 43.1 Kms length of BRTS corridor
- 1007 Kms length of corporation roads
- About 8 Kms industrial bypass road
- There are 413 intersections in GVMC area.

III. METHODOLOGY

The methodology adopted for the study to achieve the objectives is shown in Fig. 1. The study area is selected in such a way that it has IPT as one of the public transport mode. The primary and secondary sources of data required for evaluating the KPI and service attributes are collected. A total of ten KPI are considered so that the overall performance can be evaluated using the selected KPI, and the performance areas that need improvement can be identified. Similarly, for numerical rating, eleven service attributes representing the quality of IPT in various aspects are considered. The methodology and the Level of Service (LOS) criteria for each indicator is considered based on the standard LOS categories derived from various handbooks and some are developed by the author as shown in Table 2. Both the evaluation methodologies together give the areas where IPT excels and where it needs improvement.

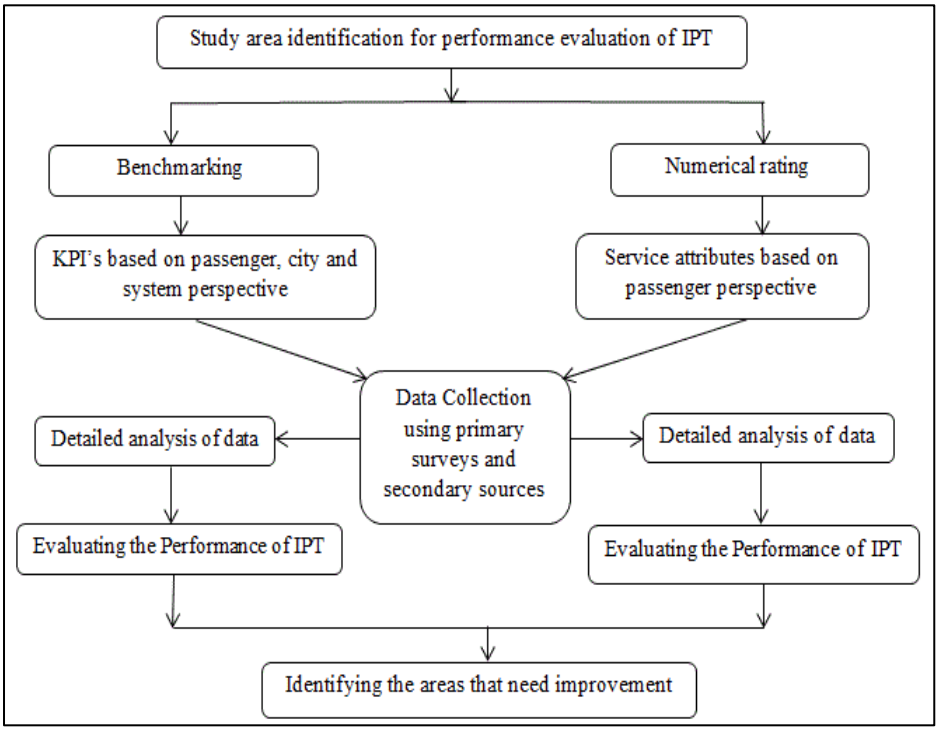

Fig. 1: Flow chart showing the methodology of the current study

IV. STUDY AREA

Visakhapatnam has both organized city bus system and IPT system. IPT system of the city consists of 3-seater, 6-seater auto rickshaws and 8-seater maxi cabs. In Visakhapatnam, IPT operates throughout the city by offering a door-to-door service and shared services in major corridors [10]. The Greater Visakhapatnam Municipal Corporation (GVMC) area of 534 km^2 represents the urban agglomeration of the city is chosen as the study area [10]. It has a population of 20,35,922 [11]. Visakhapatnam city road network consists of 73 kms length of NH No.16, 6 kms length of NH No.43, 30 kms length of SH No.38, 43.1 kms length of BRTS corridor, 1007 kms length of corporation roads, about 8 kms industrial bypass road, there are 413 intersections in the GVMC area [12]. The existing road network for the study area is categorized as arterial, sub arterial, collector and local streets as per IRC: 86-1983. Out of the entire road network, the arterial length of 67 kms and sub arterial length of 167.8 kms is considered which is shown in Fig. 2 has been developed in MicroStation with the help of geographic tools.

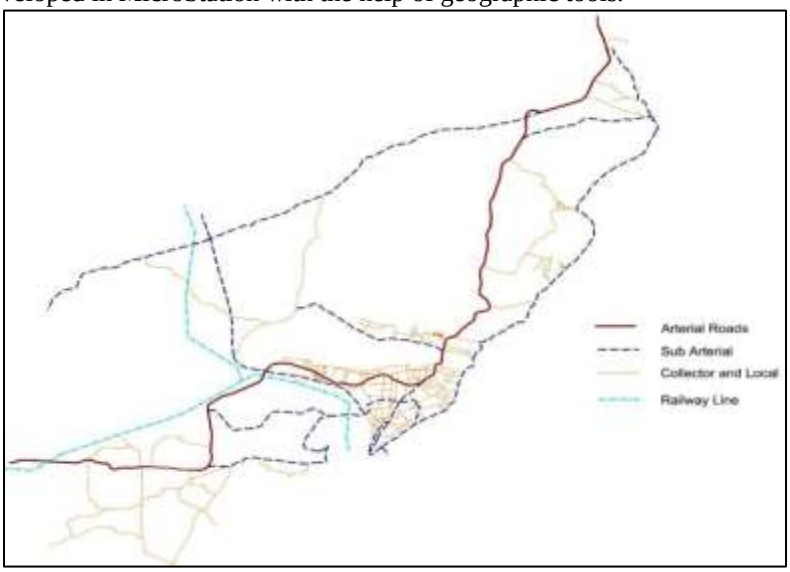

Fig. 2: Existing road network of Visakhapatnam city developed in MicroStation

The vehicle growth pattern of two-wheelers and auto rickshaws are shown in Fig. 3 [13]. It is clearly observed that the two wheeler growth is much higher compared to auto rickshaws.

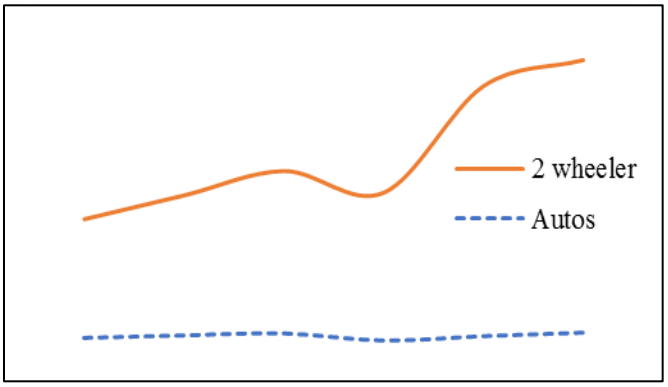

Fig. 3: Visakhapatnam vehicle growth pattern of two wheeler and auto rickshaw (autos)

V. SELECTION OF KPIS AND SERVICE ATTRIBUTES

KPIs have been chosen based on performance areas considered [1],[4],[8],[9]. The evaluation methods of KPIs are considered from various handbooks and performance reports as mentioned below in the Table I. Service attributes considered are shown in Table IX.

Table - 1
KPIs for Benchmarking

Performance measure	*Performance indicators*	*Method of evaluation of KPI*	*Methodology adopted from*
Availability	*Extent of supply of IPT*	*Supply of IPT vehicles/1000 population*	*[9]*
	Service coverage	*Total length in route kms on which IPT ply to the total urban area specified by the city authorities.*	*[1]*
Convenience	*Average waiting time*	*Average waiting time from trip maker survey.*	*Author*
	Vehicular occupancy of IPT	*Percentage of vehicle with more than their capacity at selected locations.*	*Author*
	Travel Time Ratio (TTR)	*Travel time of IPT to the Travel time of two-wheeler along selected Origin and Destinations.*	*[4]*
Comfort	*Based on service attributes- behavior of driver, behavior of co-passengers, cleanliness of vehicle, seating beside the driver*	*Index of acceptability*	*Author*
Mobility	*Travel speed*	*Travel speed of IPT along Major corridors.*	*[9]*
Safety	*Accident rate for IPT*	*Total accidents by IPT to the total number of accidents recorded for the given calendar year.*	*Author*
Affordability	*Affordability*	*Ratio of income spent on travel by IPT in the given month to their monthly income from trip maker survey*	*[9]*
ITS Facility	*GPS for IPT*	*Percentage of IPT vehicle with GPS facilities to total IPT vehicles.*	*[9]*

VI. DATA COLLECTION AND EXTRACTION

The primary surveys conducted for the study are the trip maker survey, passenger attitude survey, speed and delay survey, vehicular occupancy survey of IPT. The main objective of conducting trip maker survey is to find the trip maker characteristics and their service quality rating of IPT. Trip maker survey is a questionnaire based survey containing various questions related to fare, waiting time, monthly income, etc. for benchmarking and questions related to service quality rating of IPT based on the individual experience were put before them. They were asked to rate against the five point Likert scale ranging from very good (5) to poor (1) for numerical rating as shown in Table XIX. The main objective of conducting passenger attitude survey is to assess acceptable waiting time and the relative weightage of the service attributes scored on a five point Likert scale ranging from extremely important (5) to not at all important (1) was put before passengers as shown in table XVIII. 250 passengers have been interviewed at various locations, all over the city for conducting trip maker survey and passenger attitude survey. The main objective of conducting speed and delay survey of IPT and two-wheeler is to estimate the average travel speed on the major corridors and to estimate the travel times between each of the origin and destination (O-D). The methodology of conducting the speed and delay survey is that the enumerator travels along the traffic stream by a particular mode (IPT or two-wheeler), by noting down the stop and start time of the vehicle at the locations where the vehicle stops. The travel time to reach the fixed control points are noted in

this study. The corridors for conducting the speed and delay study of IPT were considered based on the criteria of corridors having a shared IPT system with fixed routes. For two-wheeler, corridors are taken such that a major portion of arterial and sub arterial road is covered. Two runs are made in either direction during peak periods (8.00 AM to 11.00 AM & 4.30 PM to 7.30 PM) on working days and average journey speeds are worked for both the modes. Similarly, travel times for the 18 selected O-D for both the modes are calculated. The main objective of conducting vehicular occupancy survey of IPT is to assess the percentage of IPT vehicles travelling with more than their capacity. For this vehicular occupancy survey is conducted at 14 important locations at morning and evening peak hours. Accident data were collected from city traffic police. The data sources are shown in the Table II below.

Table - 2
Data Collection for Benchmarking and Numerical Rating

Data	*Type*	*Source*
Vehicle strength and growth	*Secondary*	*Andhra Pradesh transport department, RTA, Visakhapatnam*
Accident data	*Secondary*	*Traffic police*
Waiting time, comfort, affordability, passenger details and service rating	*Primary*	*Trip maker survey*
Acceptable waiting time, relative weightage of indicators	*Primary*	*Passenger attitude survey*
Travel speed, travel time ratio	*Primary*	*Speed and delay survey by conducting trail runs*
Percentage of IPT vehicles exceeding their capacity	*Primary*	*Vehicular occupancy survey of IPT*

VII. RESULTS AND DISCUSSION

The average trip length for IPT in the study area is found to be 5.9 Km from the trip maker survey. It is observed that 50 percent of the trips are less than 4 Km in length and 70 percent of the trips are less than 6 Km in length. The average monthly expenditure for using IPT is found to be 8.12 percent of their monthly income for all income groups. The population less than 5000 monthly income is found to spend about 16 percent of their monthly income for using IPT service. From the vehicular occupancy survey of IPT, it is observed that, during the morning and evening peak hours, the auto rickshaws are overloaded with school children, which is very unsafe for them. Here the load factor observed is more than 2. It is also observed that the auto rickshaw drivers are stopping haphazardly to pick up/ drop passengers adding to the traffic congestion.
The performance of IPT by benchmarking and NRA is individually evaluated as discussed below

A. Performance of IPT by Benchmarking Method:

Each KPI has significant impact on the overall performance of the IPT system. The Calculated Level of Service (CLOS), which indicates the present performance level for each indicator, has been found out using the data collected in the previous section. The CLOS calculation for each KPI has been described below:

1) Extent of Supply:

Extent of supply is measured in terms of number of IPT vehicles per thousand population. Uncontrolled supply will lead to traffic congestion, and in contrast the absence of IPT will lead to shifting of IPT users to private mode. So, extent of supply is important for both mobility and traffic management. In Visakhapatnam IPT vehicles constitute of 37313 auto rickshaws and 2006 maxi cabs. Total number of IPT vehicles (a) = 39319, the data are collected from RTA, Visakhapatnam. Total population (a) = 2035922.

Presence of IPT vehicles/1000 population =39319/(2035922/1000) =19.3126. The CLOS is found to be 4 based on Table V.

2) Service Coverage:

Service coverage is measured as the ratio of the total length of road on which IPT ply to the urban area limits as provided by the city authorities. The presence or absence of transit service near the origin and destination is a key factor in choosing the service. Service coverage measures the ease at which the service can be provided at different locations, the better the service coverage more will be the mode choice. The total length of the road network that IPT ply is 46.2 kms of arterial road, the sub-arterial length of 54.3 kms, collector and local streets of 60 kms within the study area.

Total length in route kms of the corridors on which IPT ply in the city (a) =160. 5 kms, Area of the urban limits of the city in sq. kms (b) = 534 km^2, Service coverage of IPT = (a/b) = 0.3. The respective CLOS is 3 (Table V).

3) Average Waiting Time:

Longer waiting times indicate poor adequacy. Passengers' opinion regarding their experience to avail the service is considered for computing the LOS criteria of the waiting time. 250 Passengers were asked about the maximum waiting times acceptable to them. The reported acceptable waiting times were plotted against the cumulative percentage of passengers and is shown in Fig. 4.

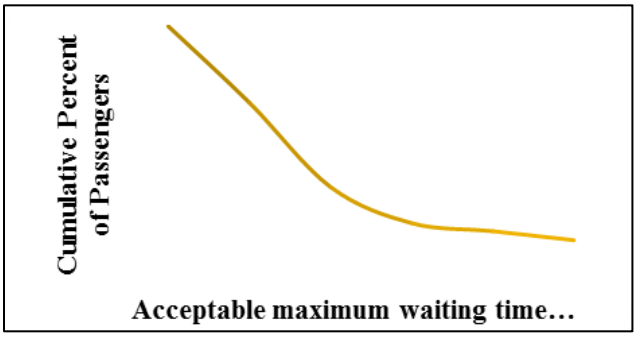

Fig. 4: Maximum waiting times acceptable to passengers

Based on acceptable levels of waiting time (Fig. 4), the LOS criteria were considered viz. for 100, 75, 50, 50 percent and the acceptable waiting times were obtained to be <3, 3-6, 6-10, 10 minutes respectively as indicated in Table V.
The average waiting time is found to be 6.44 minutes from trip maker survey and thus CLOS is found to be 3 (Table V).

4) Vehicular occupancy of IPT:

Vehicle occupancy is a convenience measure of the IPT system. Overloaded vehicles are unsafe for the passengers. The vehicular occupancy of IPT is calculated by conducting vehicular occupancy survey of IPT at 14 different locations. Then the IPT vehicles carrying passengers more than their capacity are considered in computing LOS criteria as shown in Table V.

For each location LOS is found using the ranges in Table V and CLOS of the city is taken as the median of the cumulative LOS frequency distribution of 14 locations as shown in Table III and is obtained to be 2.

Table - 3
Cumulative LOS frequency distribution of Vehicular occupancy of IPT

LOS	*Frequency of locations*	*Percentage*	*Cumulative percentage*
1	*0*	*0*	*0*
2	*8*	*57.145*	*57.145*
3	*6*	*42.86*	*100*
4	*0*	*0*	*100*

5) TTR:

Travel time or journey time is the total time spent to reach a destination from a given origin.Excessive journey time reflects the poor scheduling or routing, it indirectly represents the route directness from a particular origin to a destination. Between a particular origin and destination, TTR shall be the ratio of travel time by IPT vehicle to travel time by two-wheeler. TTR reflects the time competitiveness of IPT service with respect to two-wheeler, which is an important factor in a passenger's decision to use the service as it includes, in-vehicle time, number of transfer's from a particular origin to a destination. TTR among each pair of 18 chosen O-D locations were calculated using All-or-nothing model by considering in- vehicle time and transfer time (6 minutes for each transfer based on the average waiting time). For the LOS criteria for TTR were considered referring to TCQSM [4] as indicated in Table V.

The LOS for TTR of each pair of 18 O-D locations is determined using Table V and the CLOS of the city is taken as the median of the cumulative LOS frequency distribution of all pairs as shown in Table IV and is obtained to be 3.

Table - 4
Cumulative LOS Frequency Distribution of TTR for All Pairs of 18 O-D Locations

LOS	*Frequency*	*Percentage*	*Cumulative percentage*
1	*10*	*6.54*	*6.54*
2	*37*	*24.18*	*30.72*
3	*56*	*36.6*	*67.32*
4	*50*	*32.68*	*100*

The LOS criteria for the above mentioned five KPIs is indicated below

Table - 5
LOS Criteria for KPIs extent of supply, service coverage, waiting time, vehicular occupancy and TTR for IPT

LOS criteria	*Presence of IPT/ 1000 population*	*Service coverage*	*Average waiting time (Minutes)*	*Occupancy; IPT vehicles with more than their capacity (%)*	*TTR*
1	*<4*	*>= 1*	*<3*	*0*	*< =1*
2	*5-6*	*0.7 – 1*	*3 - 6*	*<20*	*1-1.25*
3	*7-8*	*0.3 – 0.7*	*6 – 10*	*20 – 50*	*1.25-1.5*
4	*>8*	*< 0.3*	*>10*	*>50*	*>1.5*

6) Comfort:

Comfort is the major KPI which attracts the passengers to use the IPT service. Even when transit service is available to someone, if a trip by transit is inconvenient or uncomfortable, a person with a choice will choose another mode. While a person without a choice may be greatly inconvenienced and be less likely to continue to use transit once another choice becomes available [6]. This performance indicator was defined to be consisting of four service attributes, namely driver behavior, co-passenger behavior,

cleanliness of the vehicle, seating beside the driver. Each of these elements were placed before the passengers for evaluation on a 5-point Likert scale where 1 indicate the least acceptance and 5 indicate the extreme acceptance. Individual acceptability for each element was then calculated for all respondents with the help of the following equation

$$I_a = \sum(S_i \times f_i) \div N \qquad (3)$$

Where,
I_a = Index of acceptability for the service attribute 'a',
f_i= frequency of respondents giving rating i to service attribute 'a',
s_i= scale value of the rating i,
N = summation of frequencies of respondents giving lowest to highest rating
$= \sum f_i$

The index values for each attribute are calculated and the geometric mean value of all the relative values of the attributes gives an indication of overall acceptability of comfort as a whole. The relative value lies between 0 and 1. This span was divided into four LOS categories, to define LOS criteria as indicated in Table VII.
Using equation (3), the index of acceptability is calculated for each service attribute as shown in Table VI.

Table - 6
Index of Acceptability of the Service Attributes of Comfort

S_i	*Driver behavior*	*Co-passengers behavior*	*Cleanliness of the IPT vehicle*	*Seating beside the driver*
5	*76*	*70*	*17*	*52*
4	*50*	*72*	*83*	*38*
3	*21*	*8*	*50*	*18*
2	*0*	*0*	*0*	*12*
1	*3*	*0*	*0*	*30*
I_a	*4.307*	*4.4133*	*3.78*	*3.467*
Relative value	*0.8614*	*0.88266*	*0.756*	*0.6934*

The geometric mean of relative values for the four attributes of the comfort is 0.7945. Thus, CLOS for comfort of passengers is found to be 2 (Table VII).

7) Travel Speed:

Travel speed provides an indication of Traffic congestion, LOS may be measured along key corridors for IPT and then the overall LOS of the city is reported based on the average speed of IPT along the corridors. The LOS along each corridor is determined for IPT mode from LOS criteria as indicated in Table VII and is shown in Fig. 5; the average speed of IPT is obtained to be 20.93 kmph (speed and delay survey conducted by the authors), which indicates CLOS of IPT for the city is 1.

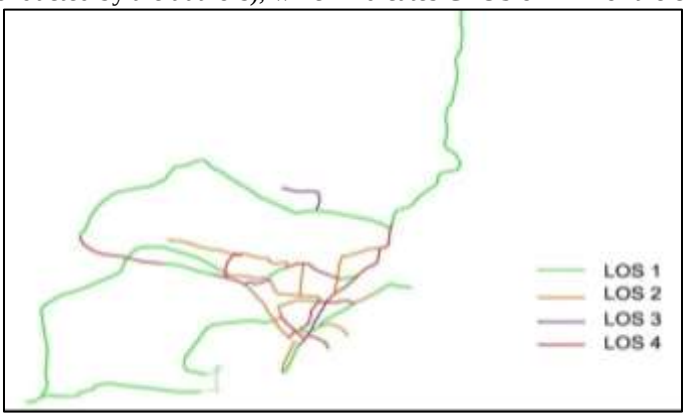

Fig. 5: Travel speed of IPT along major corridors

8) Accident rate for IPT:

Accident rate is a measure of safety of IPT users. The LOS criteria for accident rate is based on accident data of Visakhapatnam city for the years 2012-2015 as shown in Table VII. The total number of road accidents within the city limits for the year 2015 are considered, out of 981 accidents recorded (a), IPT is responsible for 143 (b). The accident rate $\frac{(b \times 100)}{a}$ is found to be 14.57% and the corresponding CLOS is 2 based on Table VII.

9) Affordability:

Affordability is the percentage share of monthly income used for transportation. It is measured as follows:

$$Affordbility\ (\%) = \frac{(\text{Total expenditure on transportation by IPT} \times 100)}{Monthly\ \ income}$$

From the trip maker survey, average affordability of trip makers of all classes of income is obtained to be 8.12%. The corresponding CLOS is found to be 1 based on Table VII.

10) GPS for IPT:

With the GPS installed in the vehicles, the operators can regulate the IPT movements, ensuring smoother running of services. For the study area, the IPT does not have GPS facilities.

Total number of IPT vehicles (a) = 39319, Total number of IPT with GPS (b) = 0

IPT vehicles with GPS facilities = $\frac{(b\times100)}{a} = 0$. The respective CLOS is 4 from Table VII.

The LOS criteria for the above mentioned five KPIs is indicated below.

Table - 7

LOS Criteria for KPIs comfort, travel speed, accident rate, affordability and GPS for IPT

LOS criteria	*Comfort (Geometric mean of relative values)*	*Average speed of IPT (kmph)*	*Accident rate for IPT (%)*	*Affordability (%)*	*GPS for IPT (%)*
1	*>0.85*	*>20*	*<10*	*<10*	*>=75*
2	*0.85-0.5*	*18-20*	*10-15*	*11 – 14*	*50 – 75*
3	*0.5-0.25*	*16-18*	*15-20*	*15 – 19*	*25 – 50*
4	*<0.25*	*<16*	*>20*	*>20*	*<25*

The Overall Level of Service of the IPT system for the Visakhapatnam city is the average of CLOS of all the KPIs. The overall level of service is found to be 2.5, which shows poor performance of the IPT system. The performance report of IPT for the study area is summarized and indicated in Table VIII. The targeted LOS and the suggestions to achieve the target are also indicated in the Table VIII.

Table - 8

IPT Performance Report Card for the City of Visakhapatnam by Benchmarking Process

Indicator	*CLOS*	*LOS Targeted*	*Suggestions to achieve target*
Extent of supply	*4*	*2*	*Registration of new IPT vehicles should not be allowed, confined to operate zone wise and the city bus system should be encouraged.*
Service coverage	*3*	*2*	*Making IPT available in the routes where the trips by city bus are not feasible.*
Affordability	*1*	*1*	*Flexibility in fare collected should be checked and standardized by Government for shared services.*
Comfort	*2*	*1*	*The traffic police should check that no driver allows the commuters to sit next to them.*
Average waiting time	*3*	*2*	*Based on the corridor demand, the frequency may be increased in peak hours.*
Vehicle occupancy	*2*	*1*	*Shifting of trip maker's to high capacity conventional city bus transit.*
Travel Time Ratio	*3*	*2*	*IPT should be used as public transport in the outgrowth areas and should be integrated with city bus routes to act as feeder.*
Travel speed	*1*	*1*	*The speed can be further increased by reducing the overloading, as the delay by passengers alighting and boarding decreases.*
GPS for IPT	*4*	*3*	*IPT vehicles should be upgraded with technology for sustainable transport.*
Accident rate	*2*	*1*	*Checking the over speeding of IPT vehicles on NH-16 by speed laser gun as there are 75 hot spots, organizing drunk drive check posts.*

B. Performance of IPT by Numerical Rating Approach:

Eleven service attributes have been considered for evaluating the performance of IPT. The relative weightage of the attributes computed from the passenger attitude survey is shown in the Table IX. The service quality rating of the attributes obtained from trip maker survey is shown in the Table X. $QIPTS_i$ is calculated for each service attribute using equation (2). The overall quality of service, QIPTS, is the summation of $QIPTS_i$ as indicated in equation (1) and is shown in the Table XI.

Table - 9

Relative Weightage of Service Attributes for IPT

S.No.	*Service attribute*	*Number of Passengers Putting Weights on*					*Average Weightage (X)*	*Relative weightage $W_i = X/\Sigma X$*
		*5**	*4***	*3****	*2*****	*1******		
1	*Safety while travelling*	*136*	*86*	*28*	*0*	*0*	*4.432*	*0.1118*
2	*Travel Cost*	*69*	*85*	*40*	*23*	*3*	*3.536*	*0.0891*
3	*Time saving*	*19*	*23*	*78*	*72*	*58*	*2.492*	*0.0628*
4	*Behavior of Driver*	*122*	*62*	*45*	*18*	*3*	*4.128*	*0.104*
5	*Behavior of Co-passenger*	*92*	*40*	*32*	*43*	*43*	*3.38*	*0.0852*
6	*Cleanliness of vehicle*	*62*	*53*	*60*	*62*	*13*	*3.356*	*0.0846*
7	*Seating beside the driver*	*89*	*57*	*48*	*18*	*38*	*3.564*	*0.0899*
8	*Route directness*	*77*	*47*	*12*	*43*	*71*	*3.064*	*0.0773*
9	*Waiting time*	*120*	*72*	*38*	*20*	*0*	*4.168*	*0.1051*
10	*Travel speed*	*77*	*68*	*72*	*25*	*8*	*3.724*	*0.0939*
11	*Vehicular occupancy*	*98*	*50*	*68*	*22*	*12*	*3.8*	*0.0958*

*Extremely important, **very important, ***important, ****important to some extent, *****not at all important

It is clearly observed from Table IX that passengers put more weightage on Safety while travelling, waiting time and less weightage on time saving and route directness.

Table - 10
Service Quality with Respect to Unity of the Service Attributes

S. NO	*Service attribute*	*Number of passengers putting weights on*					*Average weightage (X)*	*Service quality w.r.t unity (X divided by 5)R_i*
		*5**	*4***	*3****	*2*****	*1******		
1	*Safety while travelling*	*66*	*82*	*65*	*37*	*0*	*3.708*	*0.7416*
2	*Travel Cost*	*145*	*47*	*38*	*12*	*8*	*4.236*	*0.8472*
3	*Time saving*	*73*	*40*	*70*	*40*	*27*	*3.368*	*0.6736*
4	*Behavior of Driver*	*127*	*83*	*35*	*0*	*5*	*4.308*	*0.8616*
5	*Behavior of Co-passenger*	*117*	*120*	*13*	*0*	*0*	*4.416*	*0.8832*
6	*Cleanliness of vehicle*	*28*	*138*	*83*	*1*	*0*	*3.772*	*0.7544*
7	*Seating beside the driver*	*87*	*63*	*30*	*20*	*50*	*3.468*	*0.6936*
8	*Route directness*	*119*	*2*	*35*	*22*	*2*	*4.136*	*0.8272*
9	*Waiting time*	*45*	*27*	*53*	*87*	*38*	*2.816*	*0.5632*
10	*Travel speed*	*68*	*50*	*65*	*43*	*24*	*3.38*	*0.676*
11	*Vehicular occupancy*	*33*	*28*	*37*	*92*	*60*	*2.528*	*0.5056*

*very good, **good, ***fair, ****satisfactory, *****poor

It is clearly observed from Table X that the service quality rating by the passengers is more for the attributes behavior of co-passengers, behavior of driver and less for the attributes vehicle occupancy, waiting time.

Table - 11
Service Levels and their Deficiencies of IPT Using Numerical Rating Approach

Service attribute	*Relative weight, W_i (scale value from Table IX) (1)*	*Service quality, R_i (from Table X) (2)*	*$QIPTS_i$ (3) = (1) × (2)*	*Acceptance level (60% of scale value) (4)*	*Deficiency from acceptance level (5) = (3) – (4)*
Safety while travelling	*0.1118*	*0.7416*	*0.0829*	*0.0670*	*0.0158*
Travel Cost	*0.0891*	*0.8472*	*0.0755*	*0.0535*	*0.0220*
Time saving	*0.0628*	*0.6736*	*0.0423*	*0.0377*	*0.0046*
Behavior of Driver	*0.104*	*0.8616*	*0.0896*	*0.0624*	*0.0272*
Behavior of Co-passenger	*0.0852*	*0.8832*	*0.0753*	*0.0511*	*0.0241*
Cleanliness of vehicle	*0.0846*	*0.7544*	*0.0638*	*0.0507*	*0.0130*
Seating beside the driver	*0.0899*	*0.6936*	*0.0623*	*0.0539*	*0.0084*
Route directness	*0.0773*	*0.8272*	*0.0639*	*0.0463*	*0.0175*
Waiting time	*0.1051*	*0.5632*	*0.0592*	*0.0630*	*-0.0038*
Travel speed	*0.0939*	*0.676*	*0.0634*	*0.0563*	*0.0071*
Vehicular occupancy	*0.0958*	*0.5056*	*0.0484*	*0.0575*	*-0.0090*
QIPTS			*0.7270*		

It is observed from Table XI that the QIPTSifor the attributes behavior of driver and safety while travelling are more. Also it is found that the QIPTSi for the attributes time saving and vehicular occupancy is less. A deficiency from acceptance level is observed for the attributes waiting time and vehicular occupancy, which indicates that the passengers require improvement in these attributes.

VIII. CONCLUSION

The performance of IPT has been evaluated by using benchmarking and NRA in the present study. Through benchmarking process it is observed that the IPT system in Visakhapatnam is performing better in the areas of affordability and mobility. The CLOS of the KPIs are found to be 1 in these areas. The performance of IPT is found to be very poor in the areas of availability, convenience and the ITS facilities. Under the performance area of availability, the CLOS of extent of supply and service coverage are found to be 4 and 3 respectively. Similarly, under convenience area, the CLOS of the indicators of average waiting time, TTR and vehicle occupancy are found to be 3, 3 and 2 respectively. No IPT vehicle has GPS facilities which indicate CLOS of 4. The CLOS of comfort based on the driver behavior, co-passenger behavior, cleanliness of the vehicle and seating beside the driver is found to be 2. Under the performance area of mobility and safety, the CLOS of travel speed and accident rate are found to be 1 and 2 respectively. The Overall Level of Service of IPT is obtained to be 2.5, which shows that there is a need for improvement in the performance. Suggestions to improve the IPT system have been presented in the report card.

Eleven service attributes have been considered for evaluating the performance of IPT by NRA. The passenger put more weightage for the attributes safety while travelling, waiting time and behavior of the driver. The deficiencies of the attributes from the acceptable levels are quantified and reported in Table IX. It is observed that passengers are not satisfied with the waiting time and vehicular occupancy. These two attributes need to be improved for better performance. The QIPTS is found to be 0.7270, which indicates only 72% of the users are satisfied with the service.

The benchmarking and the numerical rating methods together evaluate the gaps in performance of IPT from all perspectives.

The IPT system may be regularized and may be operated zone wise for its better functioning and well-coordinated with the city bus system in terms of routes and frequencies. There is an ample scope for improvement of the IPT system in Visakhapatnam as mentioned in the report card in Table VI. The regular monitoring of the IPT system can help in improving the mobility and reducing private motorization of Visakhapatnam.

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