‘INDIcators for Reliability and Variability of Bus Systems’ (INDIRA-B) Project

- Transportation Research and Injury Prevention Programme (TRIPP), IIT Delhi
- GRETTIA (Transport Network and Advanced Software Engineering) / COSYS (Components and Systems)

  IFSTTAR (French Institute of Science and Technology for transport, spatial planning, development and networks)
- Delhi Integrated Multi-Modal Transit System Ltd.(DIMTS), Delhi, India

PROFILE OF PARTICIPATING ORGANISATIONS

Indian Institution

- The Transportation Research and Injury Prevention Programme (TRIPP) at the Indian Institute of Technology (IIT) Delhi, is an interdisciplinary programme
- Focuses on the reduction of adverse health effects of road transport
- Introduction of BRTS projects in India was initiated by TRIPP members as advisor to Delhi government

French Institution

- GRETTIA is a research laboratory on *Transport Network and Advanced Software Engineering* in the department COSYS (Components and Systems) at IFSTTAR
- IFSTTAR is the French Institute of Science and Technology for transport, spatial planning, development and networks

Indian Industry

- Delhi Integrated Multimodal Transit System Ltd. (DIMTS) is a 50:50 joint venture between Government of Delhi and Infrastructure Development and Finance Company (IDFC)
- DIMTS has rich experience in the following verticals of transportation –
  - Transport planning and modelling
  - Advisory services
  - Design
  - Project Management and Independent Engineer
  - Transport operations
  - Intelligent Transport System technology
  - Automatic Vehicle Location Systems
  - Payments – Digital wallets
  - Mobile Applications

Need for Study

- Analysis of integration of bus systems in existing city roads and PT network requires research based on
  - Performance-related indicators
  - Patterns of traffic and mobility flows
- Current Automatic Vehicle Location (AVL) systems provide very accurate data concerning the buses' position, headways, etc.
- Need to supervise, on-line and off-line, the performance of the system, based on
  - Indicators and goals assigned at city level
  - Performance regarding level of investment

Objectives

- To assess some of the existing well known quality-of-service indicators of bus performance, and to develop new performance indicators
- To develop a computer-based research tool consisting of different modules/ performance indicators

Objectives

- Performance indicators will further help in giving information about
  - Revenue
  - Heavily used routes and bus-stops
- To design a bus fleet "supervision cockpit" for both operators and PT authorities

Market Research

- INDIRA B tool is being pilot tested by DIMTS.
- This can be used by city bus operators collecting GPS and EVM data.
- Potentially relevant for most ASRTUs and bus operators in metro cities.

Expected Commercial Impact

- May improve bus market in cities.
- Public and Private operators, both can be assisted for improving financial and economic performance.

Expected Commercial Impact

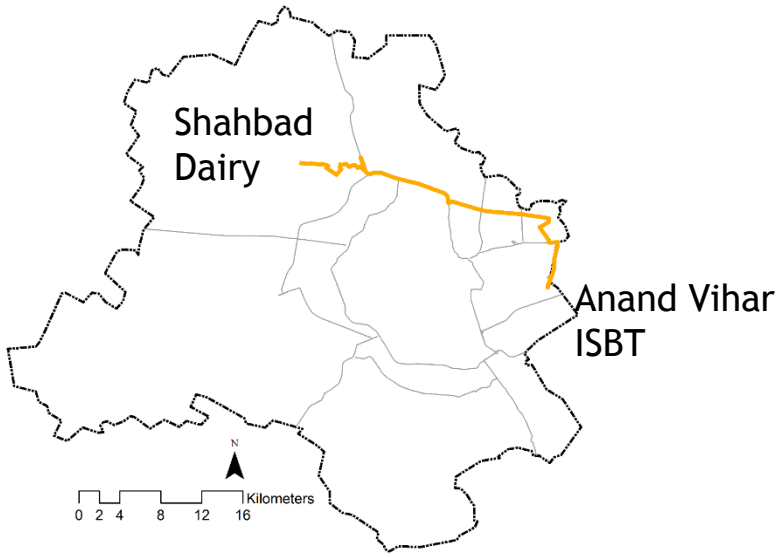
- Will include an explanation and analysis procedure to improve operating conditions
- Tool could also be used for benchmarking performance of PT systems
- Users could be provided with information necessary to ensure a reliable time course

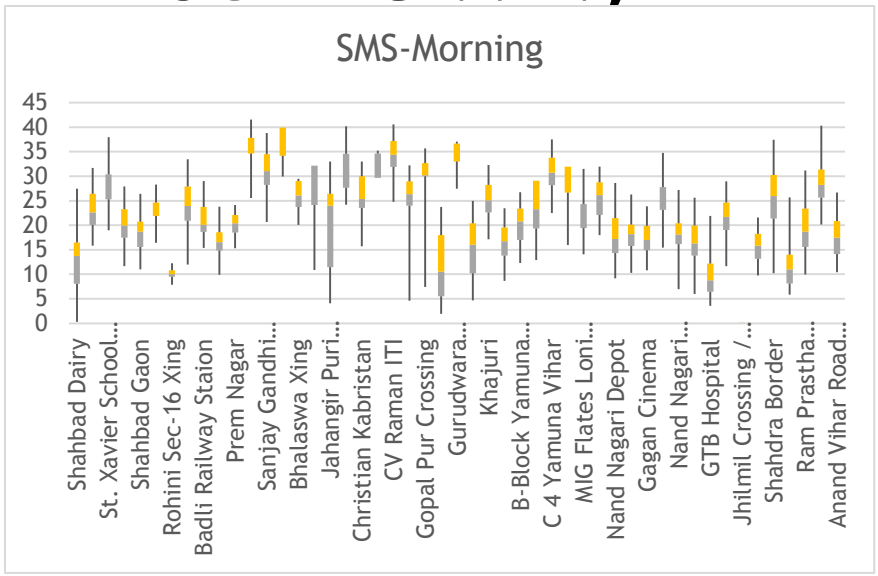
SALIENT ACHIEVEMENTS – WP2

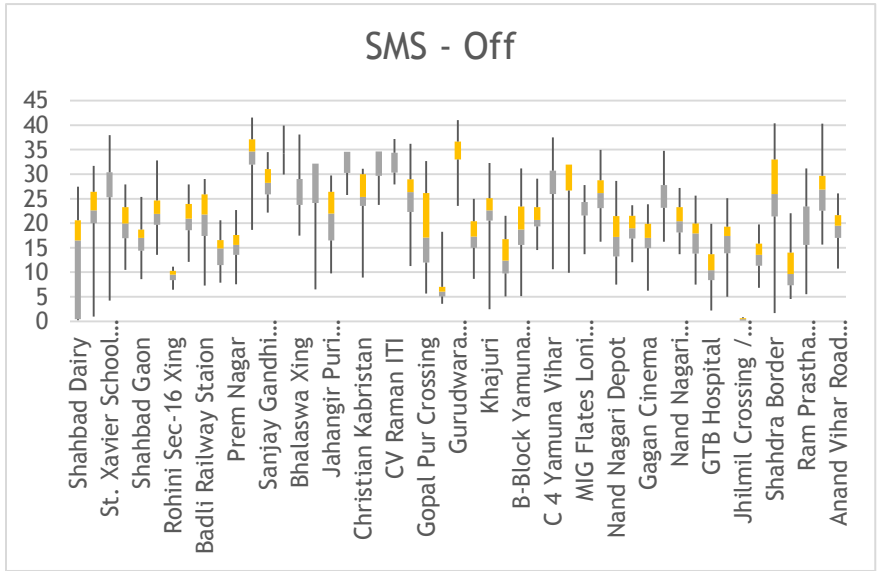
GPS-based indicators developed

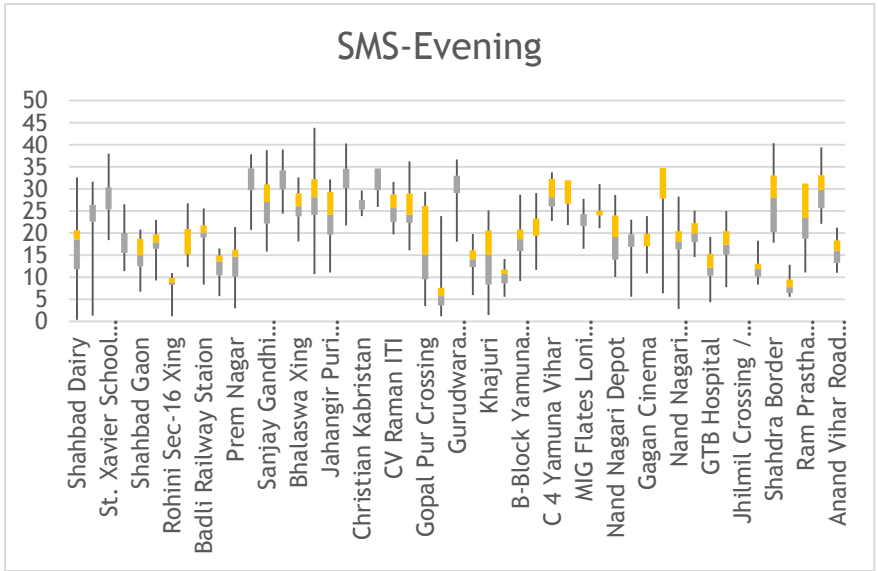
ETM-based indicators developed

Link-based speed estimates (sample route – 165 DOWN)





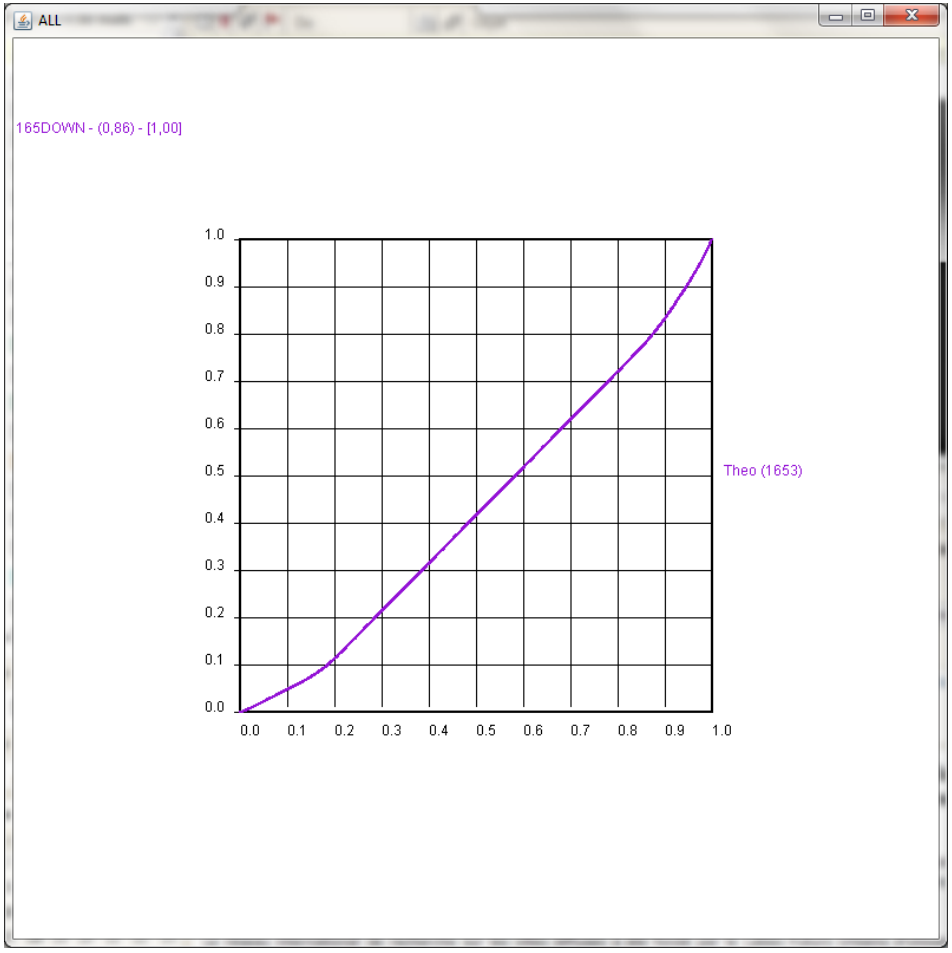




Travel time based indicators

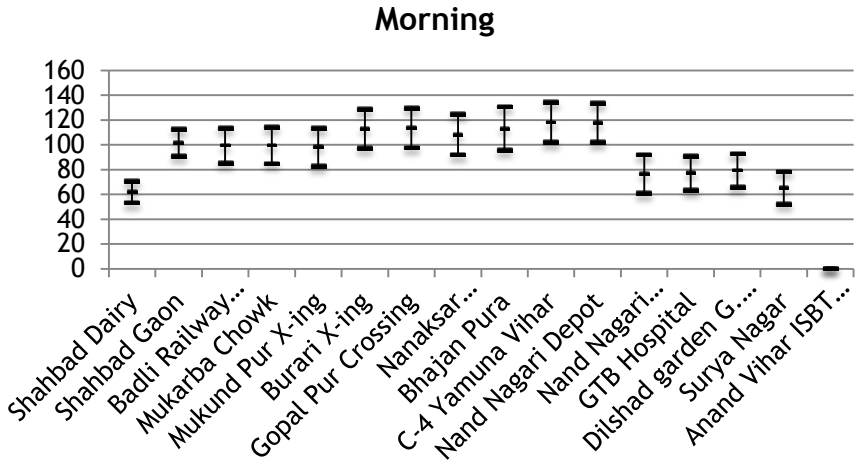
Research Work	Measure of Reliability	Remarks
Polus (1978)	Inverse of standard deviation of travel times or wait times	Reliability was first studied by fitting Beta distribution to travel time, rather than using linear regression
Liu and Sinha (2007)	Ratio of mean travel time to standard deviation	Extension to Polus' estimate (1978) to incorporate differences in mean over differing bus routes or route sections
Mazloumi et al. (2009)	Travel time variability (TTV) $TTV = (T_{97.5} - T_{2.5})/T_{50}$	• Based on Bates (2001) who reported that that median and TT distribution are better measures of performance than mean • We have used the 2.5th percentile and 97.5th percentile values, as this covers 95% of the data

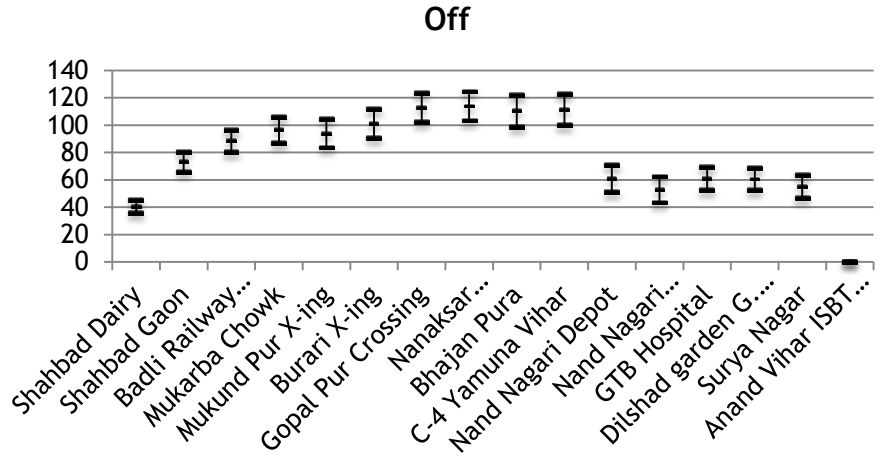
Lorenz curve headway indicators (sample route – 165 DOWN)

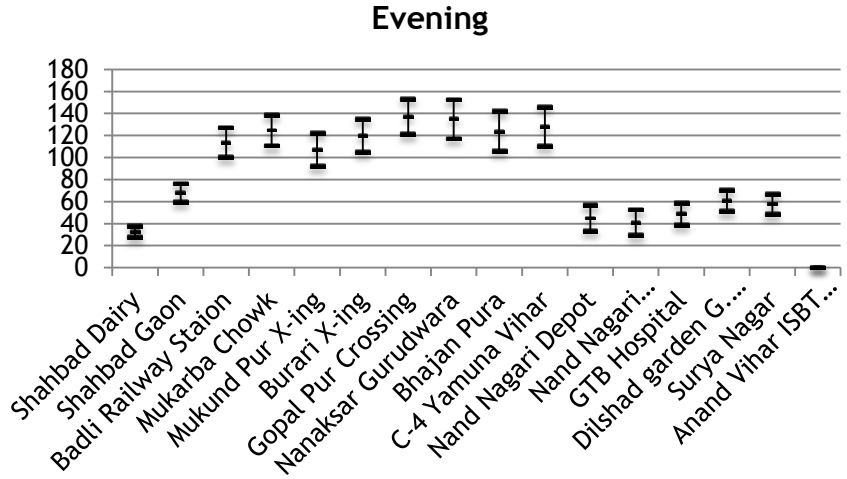


- Mostly regular headways
  - ~ 20% shorter headways
  - ~ 15% longer headways
  - ~ 65% headways equal to the average headway

Passenger load indicators (sample routes – 165 DOWN)







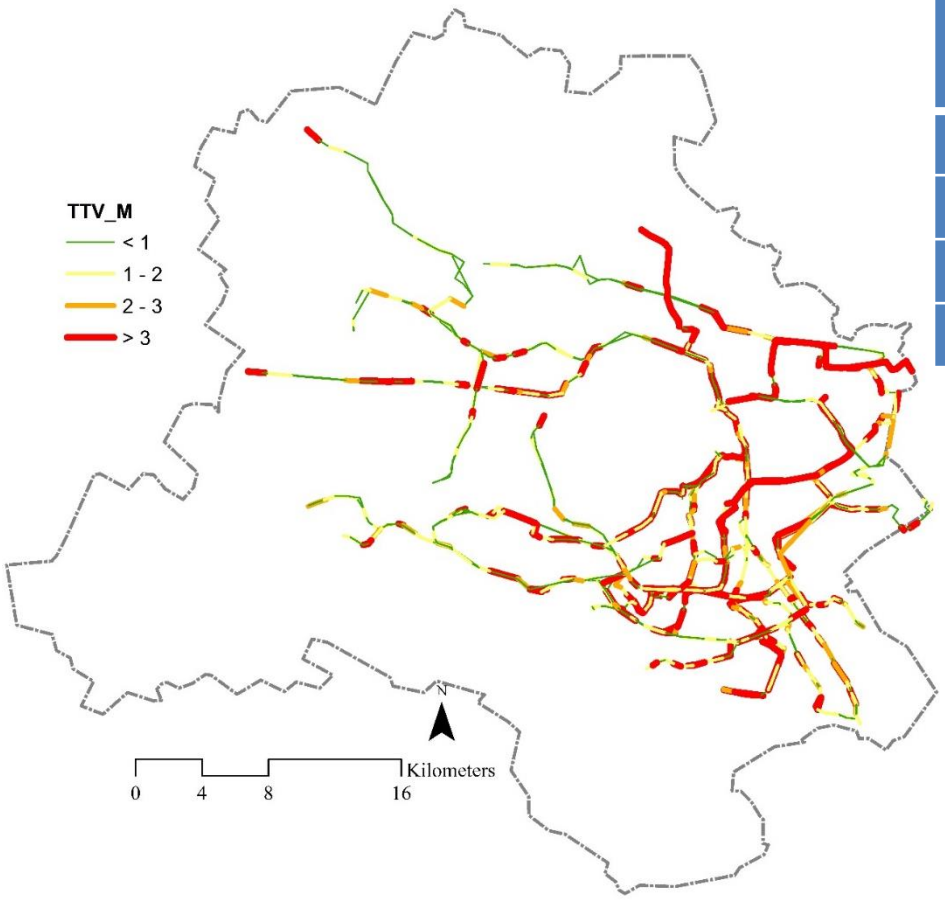
Passenger Variables	Morning	Off-peak	Evening
Average Passenger Volume, P_{avg}	70	53	58
Coefficient of flow variation, $\eta_f = P_{max}/P_{avg}$	1.260	1.128	1.182
Coefficient of passenger exchange, $\eta_x = B_L/(B_L - \Sigma\lvert b_i - a_i\rvert)$	1.077	1.078	1.077

SALIENT ACHIEVEMENTS – WP3

Benchmarks for cockpit development

Design policy interventions

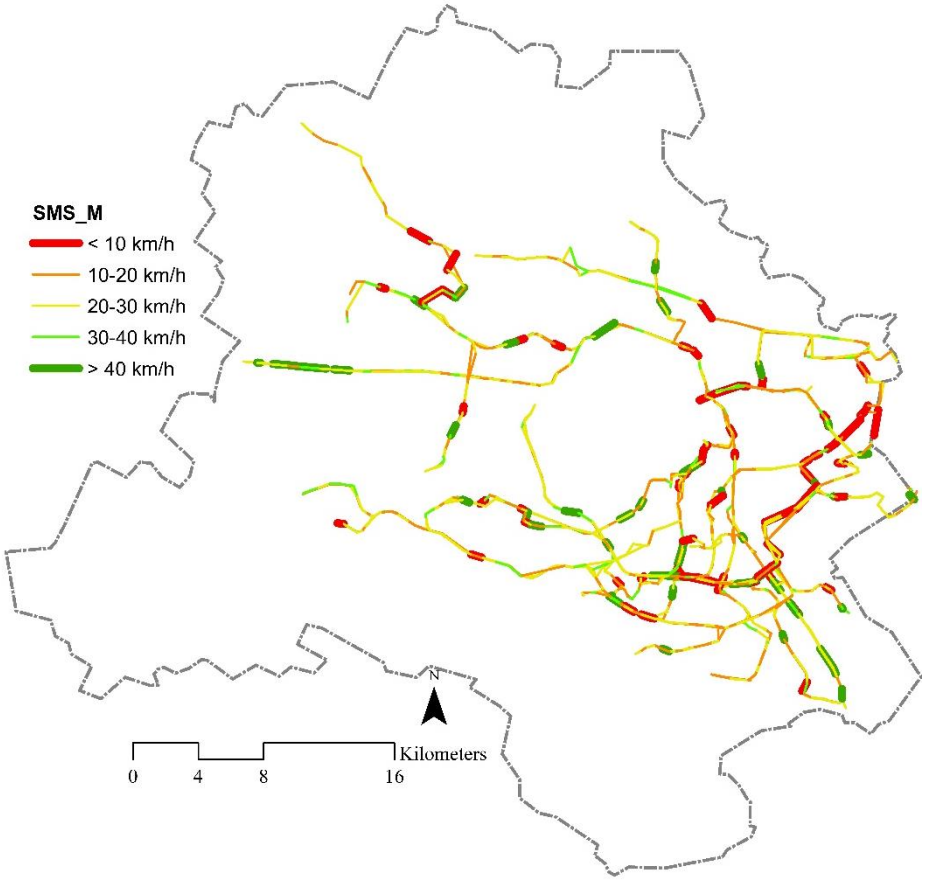
TTV benchmarks



TTV	% of links (morning peak)	% of links (off peak)	% of links (evening peak)
< 1	42	39	57
1 - 2	28	28	22
2 - 3	8	8	5
> 3	22	24	16

- Long routes with high frequency have least proportion of TTV>3 links in peak periods
- Long routes with low frequency have highest proportion of TTV>3 links for off-peak and evening peak
- Short route with high frequency has highest proportion of TTV>3 links for morning peak

Speed benchmarks



Links with low speeds experience higher levels of variability / unreliability

	Morning peak	Off peak	Evening peak
< 10 km/h	4%	8%	11%
10-20 km/h	35%	40%	42%
20-30 km/h	46%	40%	36%
30-40 km/h	12%	10%	9%
> 40 km/h	3%	2%	2%

- Greater congestion observed in off-peak and evening peak
- Weak negative correlation between TTV and speeds (sig. at 99%)
  - Pearson's: -0.2 to -0.1
  - Spearman's ρ: -0.3 to -0.2

Passenger load benchmarks

ROUTE	AVERAGE PASSENGER DEMAND		
	Morning	Off-Peak	Evening
Low freq - short route	33 (±23)	31 (±22)	31 (±18)
Low freq - long route	53 (±27)	39 (±25)	38 (±20)
High freq - short route	34 (±09)	32 (±06)	32 (±05)
High freq - long route	44 (±13)	34 (±10)	36 (±11)

- Maximum load:
  - Immediate attention at cockpit when per bus load increases beyond 70 (theoretical capacity)
  - Focus on low frequency and long routes
- Coefficient of passenger exchange:
  - Monthly assessment of routes where coefficient > 1.5
  - Currently no focus required on any type of route
- Average passenger volume:
  - Monthly assessment of routes where per bus average volume > 70
  - Monthly assessment of routes where per bus average volume < 20
  - Focus on low frequency and long routes for demand > 70
  - Focus on low frequency and short routes for demand < 20

Design policy interventions

- Reliability
  - Links with high TTV
  - Links with high TTV which are persistent daily
  - Links with high delays
  - Links with high delays which are persistent daily
- Passenger demand
  - Average passenger load per bus exceeds 70
  - Average passenger load per bus is less than 20
  - Coefficient of passenger exchange exceeds 1.5

WAY FORWARD

Way forward

- Detailed policy intervention strategies to be developed
- Development of resilience indicators – what happens to the bus service in case of partial/complete breakdown
- Testing of application for Delhi cluster buses