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W21259

ATAL INDORE CITY TRANSPORT: MANAGING VEHICLE SCHEDULING IN PUBLIC TRANSPORTATION

Saurabh Chandra, Sanyam Maheshwari, and Amit Kumar Vatsa wrote this exercise solely to provide material for class discussion. The authors do not intend to illustrate either effective or ineffective handling of a managerial situation. The authors may have disguised certain names and other identifying information to protect confidentiality.

In March 2020, Sanyam Maheshwari, an intern at Atal Indore City Transport Service Limited (AICTSL), met with the technical and operations manager, Rahul Shrouti. He wanted Maheshwari to use the management science tools he had learned in his engineering course to determine the bus frequencies and number of buses required to meet passenger demand between various stops. Maheshwari needed to consider reliability, cost, and safety and how these aspects might be improved. Shrouti suggested that Maheshwari begin by studying the operational planning used by the Indore Bus Rapid Transit System (Indore BRTS).

URBAN TRANSIT IN INDIA

India was one of the fastest growing economies of the world with a gross domestic product (GDP) growth rate of 5.024 per cent per year.[1] The majority of India's population lived in rural areas (68.8 per cent), although the share of the urban population was expected to increase substantially, rising to 58 per cent of the population (875 million people) by 2050, according to 2011 estimates.[2]

With urbanization increasing, improving public transport was a priority, especially because ownership of private vehicles was also increasing in India, leading to city congestion and pollution. In urban areas, buses were the most efficient and easiest mode of transport. India was reported to have over 1.75 million registered buses in 2016.[3] Of those, the public sector operated 170,000, which transported approximately 70 million people per day.[4]

In an annual survey of household spending on utility and sustainable products in India, both rural and urban buses were reported as the most used form of transport with 62 per cent of urban households and 66 per

[1] "GDP Growth (Annual %)—India," as reported by World Bank National Accounts Data and OECD National Accounts Data Files, World Bank, accessed July 25, 2020, https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=IN.
[2] C. Chandramouli, "Census of India 2011: Rural Urban Distribution of Population," slide presentation, Ministry of Home Affairs, July 15, 2011, https://censusindia.gov.in/2011-prov-results/paper2/data_files/india/Rural_urban_2011.pdf.
[3] "India Number of Buses: 2005–2016," as reported by the Ministry of Road Transport and Highways, CEIC Data, accessed July 25, 2020 https://www.ceicdata.com/en/india/number-of-buses-by-public-and-private-sector/number-of-buses.
[4] Jaspal Singh, "City Public Transportation Developments in India," Intelligent Transport, December 14, 2016, https://www.intelligenttransport.com/transport-articles/21458/city-public-transportation-india.

cent of rural spending on this form of transit. Auto rickshaw was noted as the second most common means of transportation in both urban (47 per cent) and rural households (38 per cent).[5]

Public bus transport was not responding quickly to the rising travel demand. India's Ministry of Housing and Urban Affairs provided financial assistance to 11 cities for the construction of 504 kilometres of bus rapid transit (BRT), of which about 245 kilometres were operational and the remaining still under construction.[6]

BUS RAPID TRANSIT

BRT was the most common mode of public transportation in mid-size cities around the world. The system relied on a segregated infrastructure with dedicated lanes, busways, and stations, efficient fare collection, rapid and frequent bus operations, and easy boarding and alighting facilities for the passengers. BRT vehicles travelled in exclusive lanes—a corridor, "where busses run on a dedicated right-of-way, such as a bus lane reserved for busses on an arterial road or a freeway."[7] The exclusive travel lanes and fewer stations than used in standard networks helped the buses to escape congestion on mixed roads, considerably reducing their travel times, variability in scheduling, and rate of accidents. The bus service blended the efficiency of rail with the versatility of buses, making the system fast and safe, yet cost effective. BRT was also a flexible system, which could be enhanced incrementally.[8]

The BRT could be an effective transport service particularly for cities in developing countries with large transit-dependent populations and minimal financial capital. Many urban centres around the world—for example, Bogotá, Colombia; Guangzhou, China; Jakarta, Indonesia; and Delhi, Pune, and Ahmedabad, India—had developed BRT networks. The system also helped to address environmental concerns. One-fourth of greenhouse gas emissions were attributable to the transport industry. To reduce the associated environmental and health challenges and to decrease energy consumption in travel, public transport services needed to be provided as an alternative to private cars, providing a service that was safer, more accessible, convenient, and economically attractive. Another advantage to public transit systems was that they allowed economically vulnerable sections of society who could not afford their own vehicles to travel safely and comfortably at affordable rates.

To make public transit attractive, government agencies needed to plan and manage the infrastructure so the service could cope with increasing demand. However, according to studies, an ability to accommodate passenger capacity at peak hours was the most significant issue in developing countries. The dilemma could be resolved by increasing fleet size and service frequency at peak hours,[9] but the solution required a trade-off between public service and increased expenses for the operator. Sustainability of the service required that both be taken care of. When planning operations for BRT networks, many of the options concerned how the public bus service was developed: (1) sufficient capacity to handle expected passenger demand, (2) speed of service to minimize travel times, and (3) frequency of service to limit waiting time.

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[5] National Sample Survey Office, "NSSO Data: Key Indicators of Household Expenditure on Services and Durable Goods," Hindu Centre for Politics and Public Policy, July 1, 2016, https://www.thehinducentre.com/resources/article8792114.ece.

[6] Minister of Housing and Urban Affairs, "National Urban Transport Policy," Question No. 3721, Parliament of India, August 9, 2017, https://loksabha.nic.in/Members/QResult16.aspx?qref=57236.

[7] Quang Thuan Nguyen and Nguyen Ba Thang Phan, "Scheduling Problem for Bus Rapid Transit Routes," in *Advanced Computational Methods for Knowledge Engineering* 358 (2015): 69–79.

[8] "What is BRT?," Institute for Transportation and Development Policy, accessed March 18, 2021, https://www.itdp.org/library/standards-and-guides/the-bus-rapid-transit-standard/what-is-brt.

[9] Huseyin Ceylan and Tayfun Ozcan, "Optimization of Headways and Departure Times in Urban Bus Networks: A Case Study of Çorlu, Turkey," in "Artificial Intelligence Applications in Civil Engineering," ed. Tayfun Dede, special issue, *Advances in Civil Engineering* 2018 (2018), https://doi.org/10.1155/2018/7094504.

Meticulous scheduling was needed to maintain the high quality of a BRT service. BRT operations managers usually scheduled the frequency of service for each of the bus routes. To achieve a certain frequency, the *headway*—the time between two consecutive buses leaving the initial station—was calculated at periodic intervals for specified periods of time and operators decided on and maintained this headway on each bus route. The important performance characteristics for a BRT were *reliability, frequency, capacity, safety,* and *costs*. Reliability was measured as a percentage of bus arrivals within a stipulated delay time and was dependent on traffic conditions on the route. Frequency was the main factor in maintaining reliability and was managed by keeping an appropriate headway. Capacity utilization was the third performance characteristic; optimal capacity utilization could reduce operating costs. The fourth performance characteristic was the total cost of operations, which comprised both the investment and operating costs. Operating costs included transportation (the direct costs of operating the buses, vehicle maintenance, and garages), general and administration costs, marketing and advertising, taxes and licences, and insurance.[10] Last but not least, safety was a high priority performance characteristic.

INDORE BRTS: BACKGROUND

The Indore BRTS, branded as iBUS, was started in 2007 under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM), a city modernization scheme launched by the Government of India.[11] The city of Indore, the commercial and educational hub of the central Indian state of Madhya Pradesh, was plagued with poor traffic conditions, including modest road infrastructure, erratic traffic, and insufficient public transportation. Increasing commercial and trade-related activities had resulted in a remarkable growth in population and a consequent demand for efficient and reliable public transportation (see Exhibit 1). The BRTS was thus launched to enhance the city's roads, improve traffic conditions, encourage the public to use public transportation, and reduce the reliance on private vehicles.[12]

AICTSL initiated the development of Indore BRTS on a public–private partnership model through the legal entity known as a special purpose vehicle. AICTSL submitted the proposal for approval to India's Ministry of Housing and Urban Affairs. In August 2007, the Indore Development Authority issued a construction work order for the selected bidder after funding of ₹984.5 million[13] was approved. A single BRT corridor was constructed on the Agra–Bombay (AB) Road in Indore—a project that experienced several delays. Reasons for the delay included acquiring the land for the corridor's development, completing the parallel underground drinking water trunk line and sewage trunk line, and dealing with encroachments and the need to remove illegal constructions on the proposed corridor. After the deadline was extended eight times, the corridor was completed in May 2013.

Indore BRTS started from Niranjanpur, a locality on the northern edge of Indore, and ran to Rajiv Gandhi Square in south central Indore. The route ran along the AB Road, which connected vital business and residential locations. Hence, the route was strategically critical and carried the most city traffic (see Exhibit 2). The corridor was 11.57 kilometres long, with 21 bus stops (see Exhibits 3–4). The BRT buses travelled one route, in two directions: from Niranjanpur to Rajiv Gandhi and in the opposite direction from Rajiv Gandhi to Niranjanpur (see Exhibit 3).

[10] Mohammad Hesam Hafezi, Amiruddin Ismail, and Ramez A. Al-Mansob, "Bus Scheduling Model: A Literature Review," paper presented to Regional Engineering Postgraduate Conference, January 2011, https://www.researchgate.net/profile/ramez_al-mansob2/publication/260034430_bus_scheduling_model_a_literature_review/links/0c96052f24398b0e8b000000/bus-scheduling-model-a-literature-review.pdf.

[11] "Jawaharlal Nehru National Urban Renewal Mission," Government of India: Ministry of Housing and Urban Affairs, accessed March 18, 2021, http://mohua.gov.in/cms/jawaharlal-nehru-national-urban-renewal-mission.php.

[12] Private vehicles in Indian cities consisted of cars and motorized two-wheelers such as scooters and motorbikes. Those who could not afford cars made extensive use of inexpensive two-wheelers for daily commutes, which put a many people at risk of accidents.

[13] ₹ = INR = Indian rupee; US$1 = ₹75.62 on March 20, 2020; all currency amounts are in ₹ unless otherwise specified.

BUS SCHEDULING AT INDORE BRTS

Maheshwari met with Shrouti to learn about the operation of Indore BRTS. Maheshwari learned that Indore BRTS had a dedicated team that managed the schedules for buses that ran from 6:00 a.m. to 10:00 p.m. Operations started with dispatching five buses from each end of the route at 6:00 a.m. Initially, within the first one to two hours, they tried to dispatch enough buses running both directions on the BRT corridor to achieve the desired frequency. At any given time, 25–35 buses were in active operation; the remaining buses were used to keep operations running smoothly. Some of the buffer buses were kept at intermediate stops so that if a running bus went out of service on the corridor, a buffer bus could replace the out of service bus as soon as possible.

The schedulers determined peak and non-peak hours of demand based on data from the previous few days (see Exhibits 5–6). The hourly demand for transit followed a normal distribution with a standard deviation close to 20 per cent of the mean. Ridership on weekdays was greater than it was on weekends.

All buses had a global positioning system (GPS) for navigation with radio-frequency identification (RFID). Information from the RFID tags and from live cameras at each bus stop allowed the schedulers to continuously track all buses from the control station. A headway of approximately 3–5 minutes was maintained during peak hours and 7–10 minutes during non-peak hours. Based on the live information, the scheduling team could coordinate bus dispatch from their respective depots and guide the drivers in maintaining appropriate headway. The bus drivers were also trained to adjust their speeds to align with the bus ahead to maintain the required headway.

Indore BRTS had two groups of bus drivers: one group worked in 12-hour shifts and the other worked 8-hour shift. Drivers on the 12-hour shifts normally began their day at 8:00 a.m., specifically to work peak hours. Drivers who worked 8-hour shifts began at 6:00 a.m. on most days. Drivers worked approximately six days a week, getting four days of leave each month.

At the end of each day, the buses were docked at the Niranjanpur depot where crews washed and sanitized the buses, then did a general technical and safety checkup. If an issue arose with a bus while in operation, a team of mechanics was available at each end of the BRT corridor to respond to the problem and carry out small repairs. According to the company's contract with the bus leasing agency, each bus could be operated up to 1,200 kilometres per week.

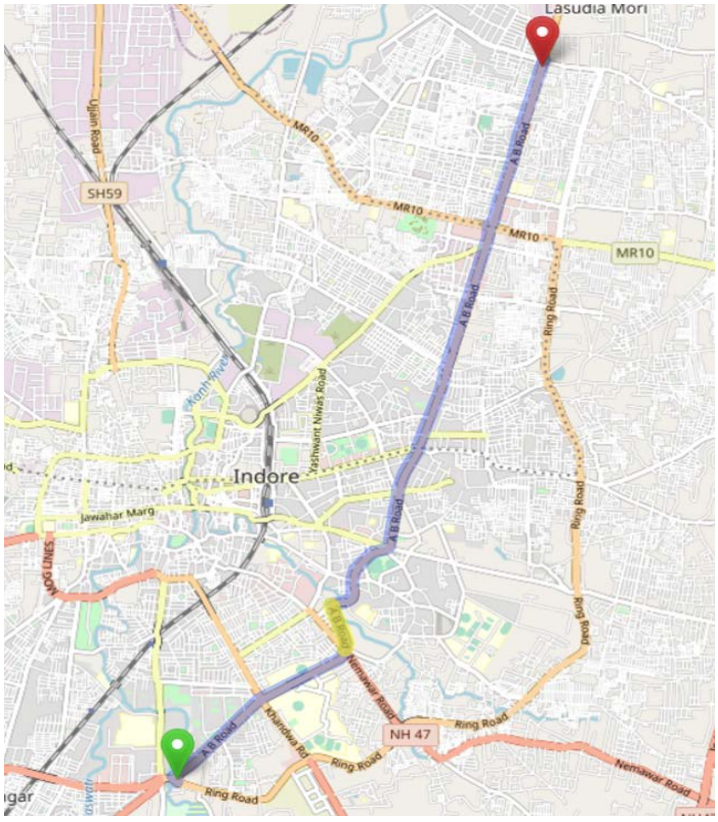
Maheshwari was satisfied with the information he gathered. He was excited to develop workable solutions for Indore BRTS's operational problems, although the complexity of the problem did worry him. His priority was to develop a solution based on management science using the sample demand data he was given to estimate headway and bus deployment for both directions of the route.

EXHIBIT 1: INDORE BUS RAPID TRANSIT SYSTEM DETAILS

Project Initiation Date	2007
Route Length	11.57 kilometres
Road Section (Road Width)	31.6–60.0 metres
System Type	Closed roadway with median stations; open for feeder buses
Stops	21
Buses in the System	46
Bus Capacity	36 (seating) + 15 (standing)
Ridership	Over 52,000 passengers per day (on average)
Bus Specifications	12 metres long; air conditioned; 900 mm floor height from ground; 245 BHP BS III engine

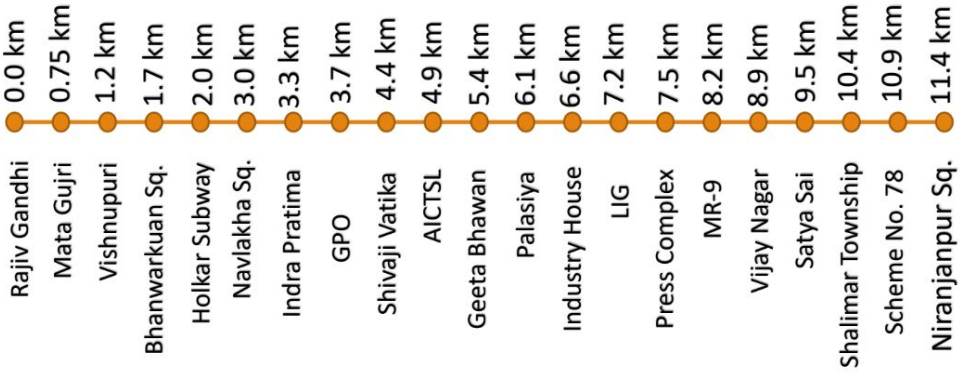
Note: mm = millimetres; BHP = brake horsepower; BS = Bharat Stage
Source: Company files.

EXHIBIT 2: INDORE BUS RAPID TRANSIT SYSTEM MAP



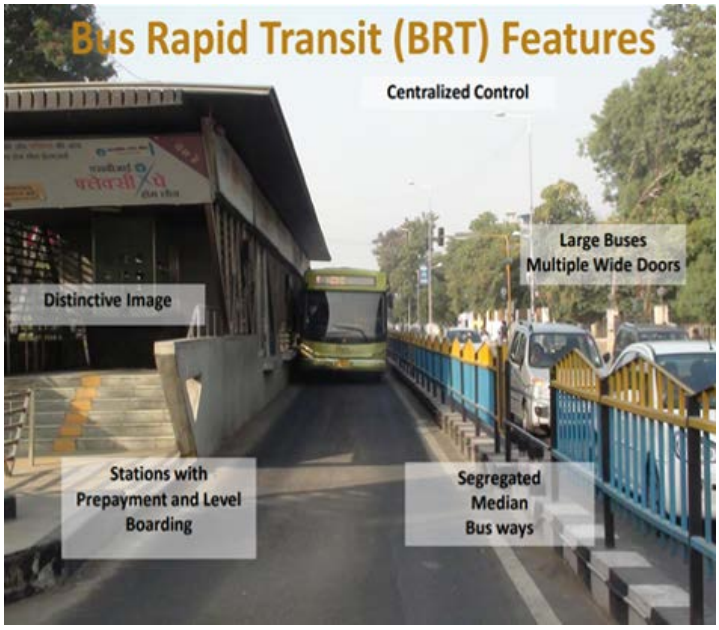
Note: The yellow-coloured stretch of the Bus Rapid Transit corridor indicates slow moving traffic.
Source: Open Street Map contributors, Open Street Map, under Creative Commons licence CC BY-SA 2.0, accessed March 22, 2021, https://www.openstreetmap.org/directions? engine=fossgis_osrm_car&route=22.6828%2C75. 8574%3B22. 7708%2C75. 9015#map=13/22.7282/75.8848.

EXHIBIT 3: INDORE BUS RAPID TRANSIT SYSTEM BUS STOPS



Note: km = kilometres; AICTSL = Atal Indore City Transport Service Limited; Sq. = Square
Source: Company files.

EXHIBIT 4: INDORE BUS RAPID TRANSIT SYSTEM BUS STOP FEATURES



Source: Company files.

EXHIBIT 5: ORIGIN–DESTINATION DEMAND MATRIX FOR PEAK HOURS (7:30 A.M. TO 11:30 A.M.) IN NUMBER OF PASSENGERS

Bus Stop Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Bus Stop Name	Rajiv Gandhi	Mata Gujri	Vishnupuri	Bhanwarkuan Square	Holkar Subway	Navlakha Square	Indra Pratima	GPO	Shivaji Vatika	AICTSL	Geeta Bhawan	Palasiya	Industry House	LIG	Press Complex	MR-9	Vijay Nagar	Satya Sai	Shalimar Township	Scheme No. 78	Niranjanpur Square
	Distance* (in km)	0	0.75	1.2	1.7	2.0	3.0	3.3	3.7	4.4	4.9	5.4	6.1	6.6	7.2	7.5	8.2	8.9	9.5	10.4	10.9	11.4
1	Rajiv Gandhi	0	7	5	52	19	30	16	71	24	40	100	80	30	61	16	50	39	9	13	16	23
2	Mata Gujri	15	0	4	43	8	24	14	24	15	15	43	37	12	23	5	30	22	8	9	11	10
3	Vishnupuri	8	6	0	21	10	17	9	25	8	16	45	31	0	20	6	21	16	5	4	4	8
4	Bhanwarkuan Square	24	11	7	0	22	53	27	119	32	73	232	176	40	169	13	91	82	12	18	20	26
5	Holkar Subway	8	4	3	31	0	12	5	18	10	11	26	38	14	30	4	9	12	5	6	6	5
6	Navlakha Square	25	20	20	182	47	0	66	145	33	58	299	316	58	223	29	201	133	24	23	42	46
7	Indra Pratima	18	11	9	66	20	52	0	69	21	47	89	78	39	87	13	55	36	15	9	20	25
8	GPO	17	11	6	127	21	72	16	0	30	43	152	131	24	140	12	79	67	8	11	13	15
9	Shivaji Vatika	6	4	3	26	14	13	7	31	0	11	32	20	15	21	4	11	8	4	6	9	7
10	AICTSL	14	5	3	57	19	20	23	39	18	0	61	43	18	47	7	27	21	5	6	16	10
11	Geeta Bhawan	21	10	9	246	34	75	28	102	36	49	0	231	53	169	22	88	36	12	13	17	17
12	Palasiya	30	13	10	243	33	119	31	128	26	44	205	0	35	150	12	112	82	8	13	20	22
13	Industry House	9	5	0	44	14	21	10	40	10	26	53	42	0	41	8	18	13	6	5	10	9
14	LIG	21	11	9	141	22	77	26	95	31	44	186	172	43	0	15	97	75	5	10	19	17
15	Press Complex	13	7	6	43	25	35	18	32	18	24	46	51	15	48	0	26	28	11	10	10	13
16	MR-9	32	20	17	150	40	220	60	146	27	58	364	188	77	268	26	0	124	26	30	37	50
17	Vijay Nagar	30	23	13	220	39	122	46	201	50	49	174	287	57	214	27	162	0	16	28	45	43
18	Satya Sai	7	6	9	38	16	21	12	23	11	16	44	29	18	27	4	22	15	0	12	10	10
19	Shalimar Township	15	8	7	30	20	19	11	43	13	25	56	39	12	50	12	32	24	7	0	8	16
20	Scheme No. 78	26	11	7	85	25	42	13	36	17	34	41	70	36	71	10	45	38	8	14	0	22
21	Niranjanpur Square	20	9	9	63	21	29	27	56	16	28	85	45	17	51	16	45	40	10	17	25	0

Note: *distance is measured from the origin (Rajiv Gandhi) to the specified stop; the number of passengers is the total number of passengers travelling between an origin (row) and destination (column) over the measured period; km = kilometres; AICTSL = Atal Indore City Transport Service Limited
Source: Company files.

EXHIBIT 6: ORIGIN–DESTINATION DEMAND MATRIX FOR NON-PEAK HOURS (11:30 A.M. TO 14:30 P.M.) IN NUMBER OF PASSENGERS

Bus Stop Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
	Bus Stop Name	Rajiv Gandhi	Mata Gujri	Vishnupuri	Bhanwarkuan Square	Holkar Subway	Navlakha Square	Indra Pratima	GPO	Shivaji Vatika	AICTSL	Geeta Bhawan	Palasiya	Industry House	LIG	Press Complex	MR-9	Vijay Nagar	Satya Sai	Shalimar Township	Scheme No. 78	Niranjanpur Square
	Distance* (in km)	0	0.75	1.2	1.7	2.0	3.0	3.3	3.7	4.4	4.9	5.4	6.1	6.6	7.2	7.5	8.2	8.9	9.5	10.4	10.9	11.4
1	Rajiv Gandhi	0	2	1	10	3	8	5	5	4	4	8	16	6	8	3	10	8	3	4	7	4
2	Mata Gujri	2	0	2	5	1	5	3	6	2	4	4	7	3	5	2	7	4	3	3	2	3
3	Vishnupuri	2	1	0	6	2	4	3	4	2	3	3	7	0	5	1	3	4	1	2	2	2
4	Bhanwarkuan Square	12	7	5	0	6	34	12	34	9	14	44	54	10	47	8	47	40	7	6	17	12
5	Holkar Subway	3	2	2	8	0	5	4	6	2	5	4	7	2	10	1	4	4	2	2	4	4
6	Navlakha Square	10	6	3	60	6	0	16	32	5	13	56	32	13	31	7	70	21	4	7	9	5
7	Indra Pratima	8	3	1	17	3	13	0	11	1	6	11	13	3	17	5	15	7	4	4	5	5
8	GPO	11	4	3	34	7	28	13	0	5	13	33	32	3	20	6	31	25	3	4	9	12
9	Shivaji Vatika	5	1	1	12	3	5	6	6	0	4	10	8	4	8	1	10	3	2	3	3	2
10	AICTSL	4	2	3	12	4	9	11	13	3	0	15	7	6	15	3	12	6	3	4	7	4
11	Geeta Bhawan	3	5	6	71	4	74	19	37	7	12	0	64	7	50	10	81	34	7	8	11	13
12	Palasiya	17	7	6	84	3	47	22	33	9	17	42	0	12	23	10	19	19	9	8	12	10
13	Industry House	3	3	0	15	3	15	4	12	4	6	17	4	0	4	4	8	7	2	5	5	5
14	LIG	15	5	3	55	6	45	9	41	9	14	7	49	11	0	9	25	32	4	7	7	8
15	Press Complex	0	3	2	10	3	8	6	4	3	4	10	6	2	9	0	9	7	3	2	3	4
16	MR-9	10	2	3	41	6	61	10	37	8	13	57	47	11	48	6	0	24	5	10	13	14
17	Vijay Nagar	13	5	2	23	5	30	9	28	6	15	38	48	6	30	5	37	0	3	6	4	8
18	Satya Sai	2	2	1	6	2	6	2	6	1	3	8	6	3	8	3	4	6	0	1	2	2
19	Shalimar Township	5	2	1	7	2	10	4	7	2	2	9	8	3	6	2	5	9	2	0	1	3
20	Scheme No. 78	6	2	2	18	5	8	5	9	6	6	9	10	6	10	5	8	8	3	2	0	5
21	Niranjanpur Square	4	2	3	7	4	9	6	9	4	9	17	12	8	16	3	7	7	2	4	6	0

Note: *distance is measured from the origin (Rajiv Gandhi) to the specified stop; the number of passengers is the total number of passengers travelling between an origin (row) and destination (column) over the measured period; km = kilometres; AICTSL = Atal Indore City Transport Service Limited
Source: Company files.