A project entitled

PRIORITISATION OF BUS ROUTES AND TRANSFER OPTIMIZATION OF THE BUS-TRAIN-TRANSIT NETWORK VIA SCHEDULE CLUSTERING

is submitted in partial fulfilment of requirement for the degree of
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Certificate

This is to certify that the project titled “PRIORITISATION OF BUS ROUTES AND TRANSFER OPTIMIZATION OF THE BUS-TRAIN-TRANSIT NETWORK VIA SCHEDULE CLUSTERING” is the bonafide work carried out by **ABHISHEK SHRIVASTAVA (18114003), CHEEKATLA RATNA MOUNIKA (18114015), NITISHA GUPTA (18114044)**, **TRIPTI YADAV (18114072)** students of B-Tech (Civil Engineering) of National Institute of Technology, Raipur in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology and that the project has not formed the basis for the award previously of any other degree, diploma, fellowship or any other similar title under my guidance.

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Prioritisation of bus routes and transfer optimization of the bus-train-transit network via schedule clustering.

Abstract: Growth of population and land-use is very sensitive thus making route prioritization and efficient transferability for public transport systems is a daunting task in developing countries like India. The measure of effectiveness and profitable ridership of the city bus transit system is primarily governed by its intermodal coordination with transfer success, especially at the Railway station. The purpose of this paper is to select the routes of time and cost-effectiveness and development of favourable bus schedule coordination with the train schedule of a developing city like Raipur. This paper adopted Dijkstra's algorithm for identifying the unique routes and prioritizing routes based on profitability in terms of trip length and population density. Further, timed transfer and transfer optimization was carried out to obtain the optimal bus schedules to coordinate with the train schedule clustered for maximizing the bus-and-train intermodal transfers. A case study consisting of 10 existing routes and 12 proposed unique destined to the railway station of Raipur city has been selected. The results of route prioritizing depicted that 7 proposed and 4 existing routes depict maximum profitability with sensitivity to the travel time and cost. Further, the transfer success rate has been improved substantially by reducing bus trip failure cases from 7 to 1 at the Railway station upon coordinating by optimizing the clustered train schedule with bus arrival timings with no blockage. Thus, this study assists quick and robust solutions to the system operators for improving the ridership and better level of service to the users.

Keywords: Intermodal transfer, bus schedule coordination, Dijkstra's algorithm, prioritization of routes, transfer optimization.

1. Introduction

Public transport systems like buses and trains play a significant role in the day to day lives of many people in developing economies like India. Commuters and non-commuters often choose intermodal transfer for their diverse intra-city and inter-city travel movements. The average footfalls during peak hours in Raipur railway station were found to be 50000 (Survey of major railway stations for cleanliness ranking by IRCTC, 2016). These inter-city travel movements are primarily governed by robust and efficient coordination between the intra-city public transport system and the inter-city regional transit system. Intermodal transferability is a typical characteristic for improving system performance in terms of ridership enhancement. The reliability of the public transport system is often been evaluated based on the success percentage of transfer operations.

Transfers between these two modes are therefore vital to a public transport system giving access to numerous potential destinations at an adequate operating cost to the public transport operators. This results in triggering the need for the development of a coordinated network of dominant modes like city buses and inter-city rail transit systems. Fig.1 depicts a typical illustrative intermodal bus-and-rail transit network.

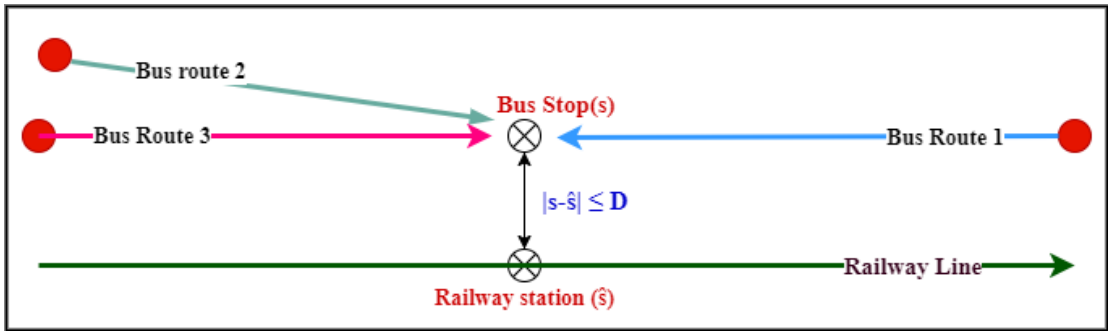


Fig. 1. Intermodal bus-rail-transit network

In contrast to metro or large cities, developing capital cities like Raipur in India, growth of population and land-use is very sensitive. Providing a sustainable public transportation system in terms of route prioritisation and efficient transferability at terminal points in these dynamic cities is a daunting task. The reliability of public transport system in these dynamic cities pre-requisites to significant aspects: (i) Identifying and prioritising the principal feeding routes connecting different parts of the city to the terminal points such as inter-city railway stations, (ii) Improving transferability success rate by intermodal coordination and reduction in congestion level at terminal points. Numerous researchers have made several attempts in addressing the significant challenges related to route prioritisation, timed transfer, transfer optimisation by various mathematical formulations. (Niu et al., 2015; S. Saunders,2001; M.H. Xu,2006;Chowdhury and Chien, 2002; Ibarra-Rojas and Rios-Solis, 2012; Hadas and Ceder, 2010; Shafahi and Khani, 2010).Xuet.al. 2007, have attempted to optimize the route by Dijkstra shortest path algorithm for sparse networks. Ciafi et.al. 2012, attempted to develop a feeder bus network that generates routes and frequencies for every route skeleton by meta-heuristic approach. Related to transfer optimization, various researchers made significant efforts to minimize the cumulative waiting time for transfer operation by altering the time offset various lines upon considering uniformly spaced departure times of each train (Shafahi and Khani, 2010; Cevallos and Zhao, 2006; Hadas and Ceder, 2010).Few researchers attempted coordinating the schedules of feeder bus services for suburban rail transit systems by minimizing the transfer time and operating cost of bus services (Shrivastava and Dhingra, 2002).

Ceder et.al. 2001, optimised the routes by synchronizing the existing bus timetable with the arrival time of the train at the terminal nodes for various sets of clusters. Dessouky et.al. 2003, attempted to coordinate and forecast the bus arrival time with long headways using a simulation technique that has zero-time slack. Currently, various studies were reported on schedule coordination by minimizing transfer waiting times (Parbo et al.,2014; Wu et al.,2015a).Dou, 2015 made a significant attempt in co-ordinating the

last train service with bus schedule for improving the overall transfer success rate. However, these approaches focused on individual train-to-train or train-to-bus coordination in terms of timed transfer or transfer optimisation distinctly in a selected schedule. Thus, this study is an attempt to improve smooth and successful timed transfers and transfer optimisation by clustering the departure timings of long-distance trains with calibrated bus arrival schedules. This study also attempts toprioritising the terminal point feeding bus routes by the shortest path algorithm for enhancing ridership.

2.Study methodology, Notations, Data Input and Assumptions

2.1. Prioritisation of bus routes

The bus route prioritisation for this study has been done to find the shortest and most profitable bus routes arriving at the railway station from different selected parts of the study area. The bus route prioritisation involves two significant steps: (i) Identification of principal feeding bus routes using the Dijkstra algorithm, (ii) Prioritisation of selected bus routes. The detailed flow chart is shown in Fig. 2.

2.1.1 Identification of principal feeding bus routes using Dijkstra algorithm

The principal bus routes from the study area have been selected by using the Dijkstra algorithm (DIJKSTRA, E W.,1959;M.H. Xu,2006) as shown below. The detailed results have been depicted in the subsequent sections.

Pseudo-code for Dijkstra's shortest path algorithm:

Dist[s]←0	(distance to source vertex is zero)
For all vϵ V – {s}	
do dist[v] ←∞	(set all other distances to infinity)
S←θ	(S, the set of visited vertices is initially empty)
Q←V	(Q, the queue initially contains all vertices)
While Q≠θ	(while the queue is not empty)
Do u ←min distance (Q,dist)	(select the element of Q with the min. distance)
S←S∪{u}	(add u to list of visited vertices)
For all vϵneighbors[u]	
Do if dist[v] >dist[u] + w(u,v)	(if new shortest path found)
Then d[v] ←d[u] + w(u,v)	(set new value of shortest path) (if desired, add traceback code)

2.1.2 Prioritisation of selected bus routes

Prioritisation of selected bus routes has been carried out by considering perspective route traffic volume, average passenger trip distance, passenger turnover, travel population behaviour, expected income, route expenses and route profitability. Perspective route traffic volume is calculated using regression analysis.

For the study, population size P_i is constant due to source as railway station and population size P_j of terminal route nodal points. Model parameter values are defined based on regression analysis. For calculation of perspective route traffic volume (Q_{ij}) relation is derived between nodal traffic volume, population and route length as shown in equation(1).

$$Q_{ij} = a + b*P_j + c*R_{ij} \quad (1)$$

Where, a,b,c are coefficients obtained after regression analysis and i and j are nodal points of the network perspective route traffic volume(Q_{ij}), the distance between populated localities(R_{ij}), population size at a starting route populated locality(P_i), population size at a terminal route populated locality(P_j).

Average passenger trip distance

$$L_{av} = L_{me} \quad (2)$$

In equation (2), L_{me} is route length (R_{ij}) to the power 'e', and 'e' is determined by plotting a graph between route length and trip distribution to various nodes. L_{av} is the Average passenger trip distance

Passenger turnover calculation of a route

$$P = L_{av} * Q_{ij} = L_{me} * Q_{ij} \quad (3)$$

In equation(3), P = Passenger turnover calculation of a route *Travel*

population behaviour calculation

$$b = Q_{ij} / P_i \quad (4)$$

In equation (4), P_i = Size of the population that live in all populated localities through which route passes.

Expected income calculation of a route

$$D_i = f * P \quad (5)$$

In equation (5), f is the bus fare of one passenger per km, D is expected income and P is the route passenger turnover.

Calculation of route expenses

$$C = s * q * L_m \quad (6)$$

In equation (6), C is route expenses, L_m is route length, s is vehicle operation cost per km, q is the capacity of a vehicle used for traffic.

Route profitability calculation

$$R = (D_i\text{-}C)/C * 100 \quad (7)$$

In equation (7), R is the route profitability after calculation of profitability routes are derived which gives maximum revenue with the minimum expenses.

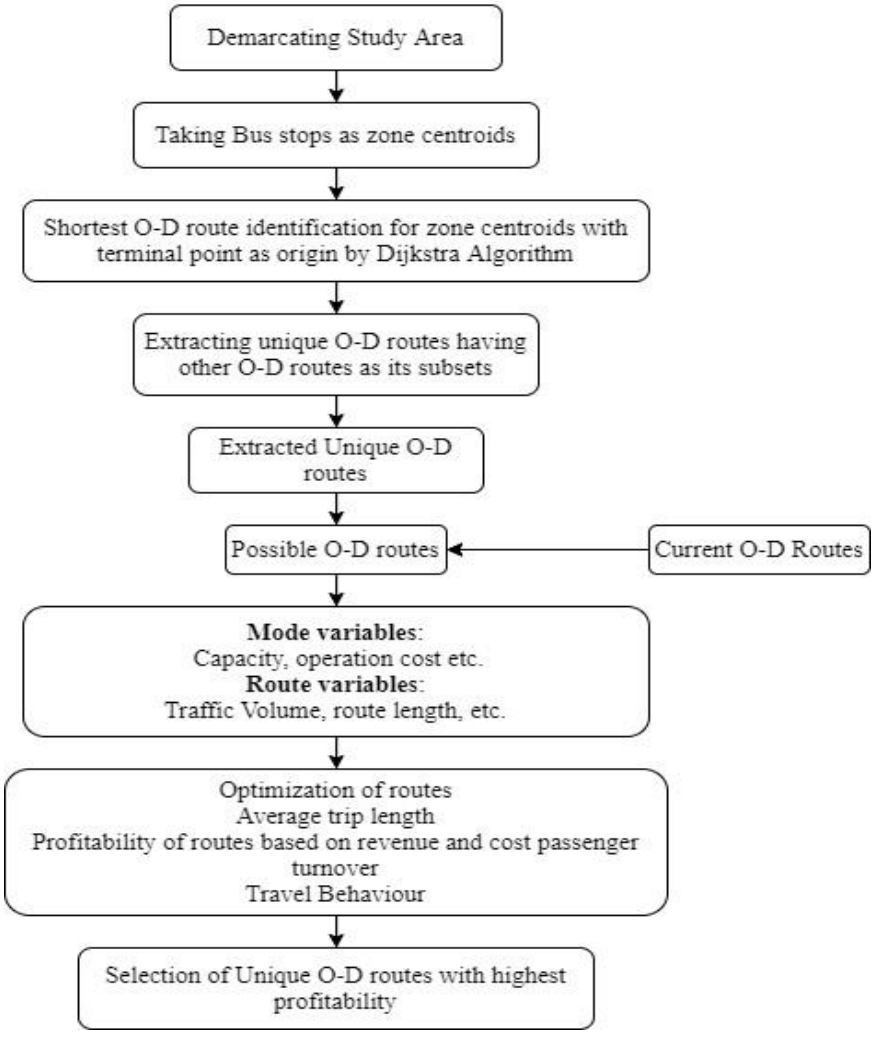


Fig.2: Flow-chart for Dijkstra's algorithm

2.2. Transfer optimisation of the bus schedule.

The main objective of transfer optimisation of bus schedule is to maximise the number of smooth transfers. Thus, the objective is sub-divided into two sections:

- To find the minimum offset and additional shift required to maximize the number of success clusters.
- After applying offset and additional time shifts, the new schedule obtained is maximised by changing the value of travel time, according to the number of transfer bus successes.

The bus schedule optimisation for this study has been done to rectify potential transferability failure between bus and train services. The assessment involves: (i) Clustering of train schedule (ii) Evaluation of existing bus schedule, (iii) Timed transfer and transfer optimisation for maximizing smooth transfer.

2.2.1 Clustering of train schedule

Clustering of time is done as per train schedule depending on the number of trains arriving at the particular duration of time. Starting of the cluster shows the departure time of the first train of cluster duration and the ending of the cluster shows the departure of the last train of the cluster time duration.The departure time of the train S_T and peak hour (p) is taken as the input for the formation of the cluster.

2.2.2 Evaluation of existing bus schedule

Evaluation of the existing bus schedule has been done by writing an algorithm for the intermodal bus-and-train transport network, defined by a directed graph G (S_b,l) where S_b is the set of bus stops and l is the set of routes. Consider $s \in S_b$ and $\hat{s}$ as railway station, then the inequality $|s-\hat{s}| \leq D$ means walking distance between the railway station and bus stop should not be greater than D meters, the value accepted by passengers as maximum transfer walking distance which is covered in w minutes. This process is defined as a smooth transfer from bus service to train service. The typical equation for the same is shown in equations (8) and (9). For ease of presentation, the above-described problem is defined as the transfer problem in an intermodal bus-and-train transport network.

For each bus route, a fixed operational schedule in the time horizon of study is considered and is referred to as the original bus schedule. For every bus line l, the number of buses that depart from the terminal stop is denoted by NB_l, headway h, the terminal departure time of kl^{th}bus, denoted as SD_{kl}, travel time of kl^{th} bus is denoted by ST_{kl}. The earliest and latest terminal departure times of the first bus are T_{min} and T_{max} respectively. The number of bus berths at bus stop s is denoted by B^s and the dwelling time d_l. For a particular bus route, circle time is denoted as C_t.

Arrival time of different bus for each route

$$SA_{[m][n]} = SA_{[0][0]} + (m * h) + (n*C_t) \tag{8}$$

Where, m denotes the bus number and n denotes the circle number.

Check for success transfer

$$C_{sn} - w - w_t \leq SA_{[i][j]} \leq C_{en} - w \tag{9}$$

Where, C_{sn} and C_{en} are starting time and ending time of n^{th} cluster and $w_t$is the average accepted waiting time by passengers at the railway station.

2.2.3 Timed transfer and transfer optimisation for maximizing smooth transfer

In this study, it is proposed that in the bus schedule coordination principle, atleast one bus provide success at every cluster duration and then we maximize the number of buses at each cluster. For maximizing the number of susses group the time transfer is used in strategy 1 and then for transfer optimisation strategy 2 and 3 are used. Although our main focus of the study is not for maximizing the number of bus co-ordinations, rather it is for maximizing the number of success clusters so that the bus service should be able to serve the train service throughout the day. The detailed flow chart explaining all the strategies is shown in Fig.5.

*Strategy 1***:** *An overall offset is applied on the bus schedule uniformly to the departure time of all the buses, keeping headway constant, if the scheduled terminal departure time of the bus cannot fulfil the smooth connection with the associated train cluster at each transfer node.*

If the smooth connection is not established at transfer nodes, then instead of redesigning the entire bus schedule we can offset the departure time of the first bus keeping headway constant resulting in a new bus schedule, which may increase the smooth transfer.

$$x_{el} = SD_{kl} - t_e \tag{10}$$

$$T_{min} \leq x_{el} \leq T_{max} \quad (11)$$

In equation (10), for any bus line l having constant headway h and terminal departure time $SD_{kl,}$ an overall offset $t_e$is deployed resulting in new terminal departure time x_{el} having constant headway h; where x_{el} must lie between earliest departure time T_{min} and latest departure time $T_{max}$of particular bus as shown in equation (11). The above strategy is applied iteratively to find the minimum offset time providing the maximum number of smooth transfers.

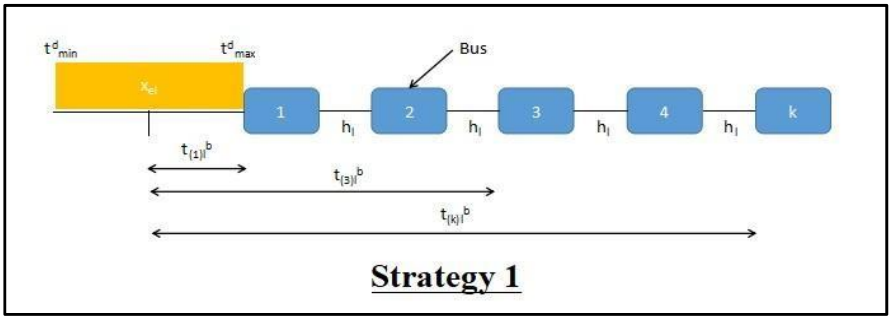


Fig. 3: Strategy 1 for even offset in bus schedule co -ordination

Strategy 2: After applying overall offset if failure remains, we apply an additional time shift to the terminal departure time of an individual bus denoted by y_{kl} as shown in equation (12).

$$x_{el} = SD_{kl} - t_e + y_{kl} \quad (12)$$

$$-0.5*h \leq y_{kl} \leq 0 \quad (13)$$

Equation (13) sets the limit of time-shift y_{kl} within 50% of the existing headway. This implies that there is not much change in even bus headways.

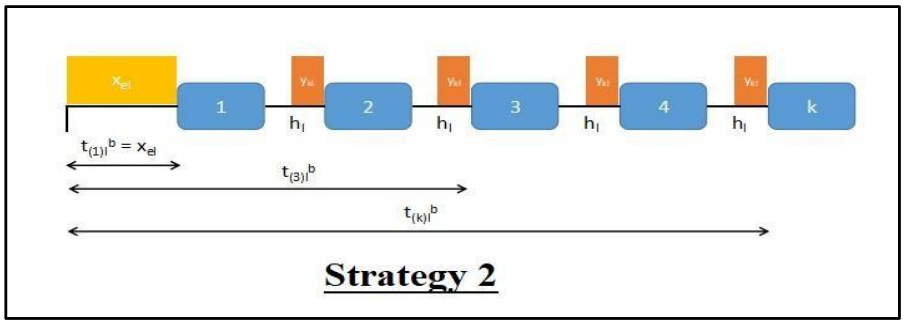


Fig. 4: Strategy 2 for additional time shift in bus schedule co-ordination

*Strategy 3***:** *The bus travel time also can be calibrated according to traffic conditions to minimize the number of intermodal transfer failures.*

As road traffic conditions are good due to low traffic volume early in the morning and late at night, bus travel time can be reduced by accelerating the bus speed to provide a smooth transfer. The range of variable z_{kl} is shown in equation (14).

$$-\frac{\eta}{1+\eta} * ST_{kl} \leq z_{kl} < d_l + w \quad (14)$$

Where η is a predefined calibration factor applied to travel speed and can be manipulated according to real-time situations. The value of η lies within $0 \leq \eta < 1$ and this value is inversely proportional to traffic density. For safety requirements, it is suggested that calibrated travel time should not be greater than $(1+\eta)$ times the scheduled average bus travel speed. Let SA_{kl} denotes the arrival time of kl^{th} bus, then a new schedule is obtained by equation (15).

$$SA_{kl} = SD_{kl} + ST_{kl} + t_e + y_{kl} + z_{kl} \quad (15)$$

*Strategy 4***:** *Blockage due to buses at the terminal station should be avoided during the bus scheduling process for different routes as buses may arrive at the terminal stop which has limited berths.*

There is a possibility of bus blockage, as different routes have their schedules leading to the arrival of more than n buses at the terminal station. There will be difficult during the dwelling process for buses at the terminal station due to limited berths available.

$$n_t = \begin{cases} 1, & if\, arrival\, time\, of\, bus\, is\, at\, t^{th}\, time \\ 0, & otherwise \end{cases} \quad (16)$$

$$\sum_{i=1}^{n_l} n_t = N_t \quad (17)$$

$$\sum_{t=0}^{dl-1} \sum_{j=1}^{l} N_t \leq B^s \quad (18)$$

In equation (16), $n_t$is the binary variable which defines the presence of bus at node junction for a particular time t. In equation (17), N_t signifies the total number of the bus arriving at time t for each route. In equation(18), for a unique time point t belonging to set of time T, at every target bus station, no more than B^s bus should arrive for (t^{th}+ d_l) duration. Here, T is a set of continuous-time points in sequential order, spanning the overall time horizon of the study, and t denotes a particular time point in set T.

It should be noted that any change in the schedule of one bus route may influence other relevant bus routes which require blockage analysis to be carried out over the entire bus network without increasing the model complexity.

The objective of maximising the number of success clusters is achieved by C++ code where strategy-1 gives the offset which is evenly applied to all buses and then strategy-2 is applied providing the value of additional time shift. The new bus schedule obtained is maximised using VBA by applying Strategy 3 to the failed buses. The two objectives fulfil our main goal to maximise the bus-train-transit smooth transfer and hence increase the use of public transport system.

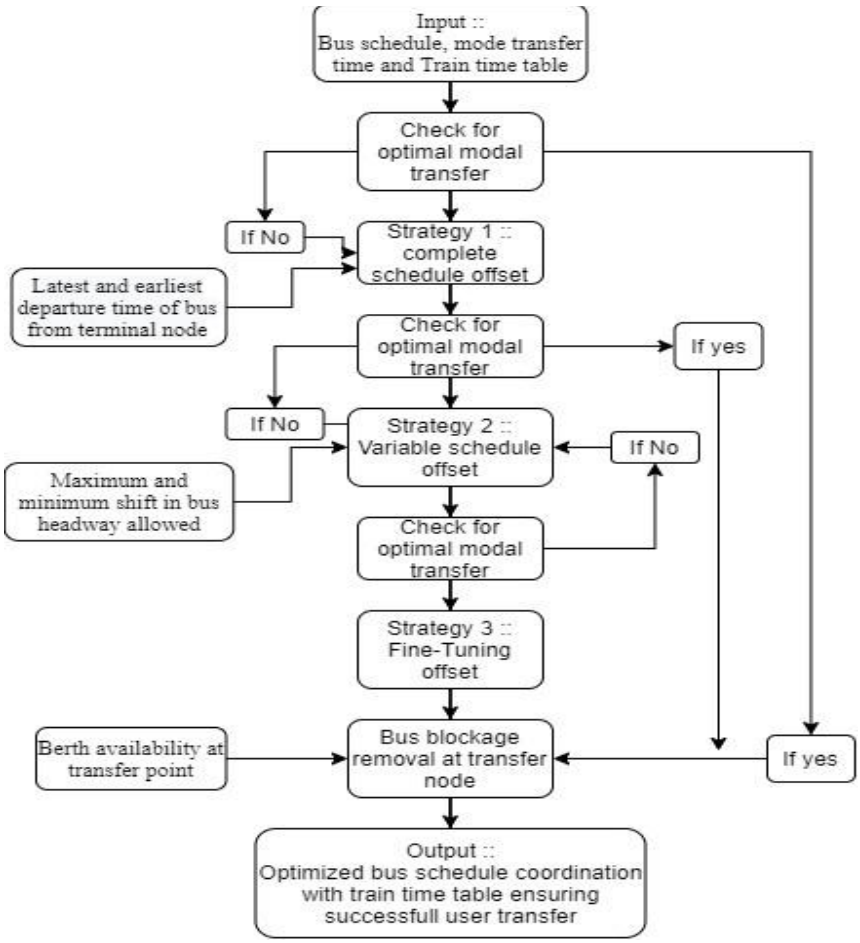


Fig. 5: Flow-chart for Bus schedule co-ordination

3.Case Study

3.1 Study Area

Raipur is the capital state of Chhattisgarh and is geographically located at the centre.Its coordinates are 21.25° N 81.63° E having an area of 226 $km^2$with a population of1,010,087as per census 2011. Raipur Railway Station is situated at an elevation of 3141.35 meters and coordinates 21°15’23” N and 81° 37’47” E. At present 2021, 157 trains are running. Train schedules have been taken from Indian rail info (https://indiarailinfo.com/departures/raipur-junction-r/185). The existing bus schedules are taken from the city bus Sevawebsite accessed on June 17, 2021. The study area is shown in Fig.6. A total of 44 nodes have been considered denoting important locations of the city concerning population density and containing the maximum number of passengers opting bus to travel to Raipur railway junction is shown in Fig.7. There are 10 existing routes connecting these nodes which serve the Raipur Railway station. Details of the nodes, names and their number are given in Annexure 1.

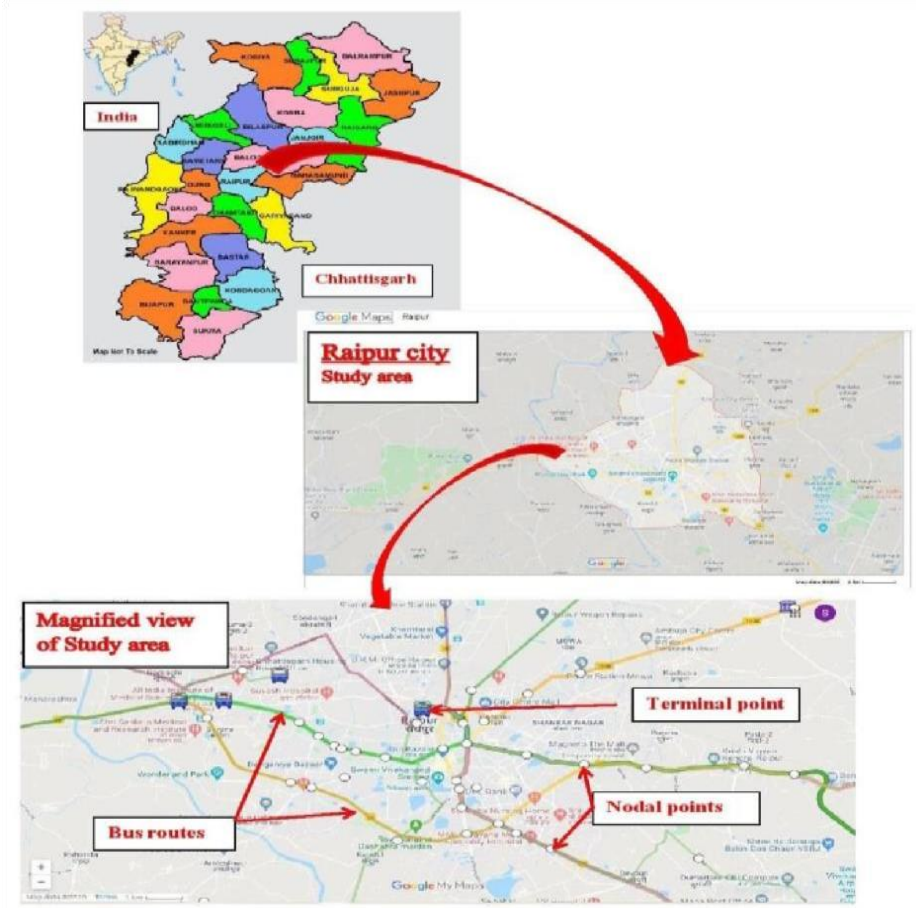
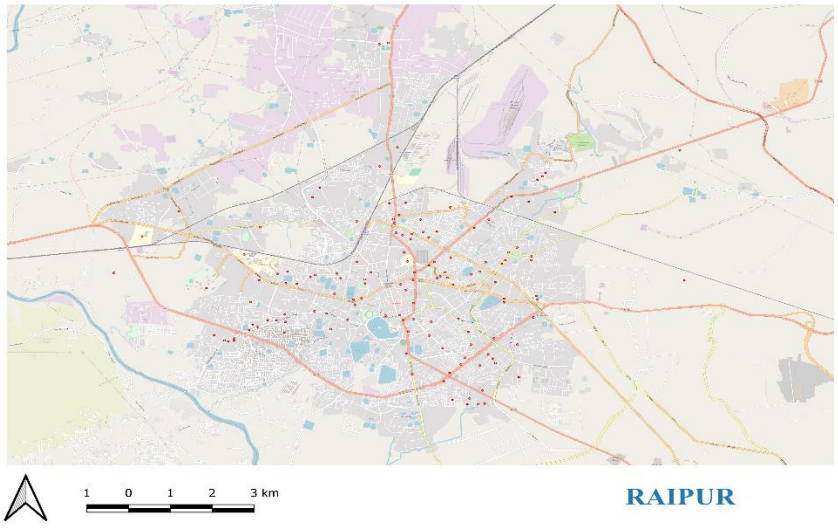


Fig. 6: Map showing area for case study



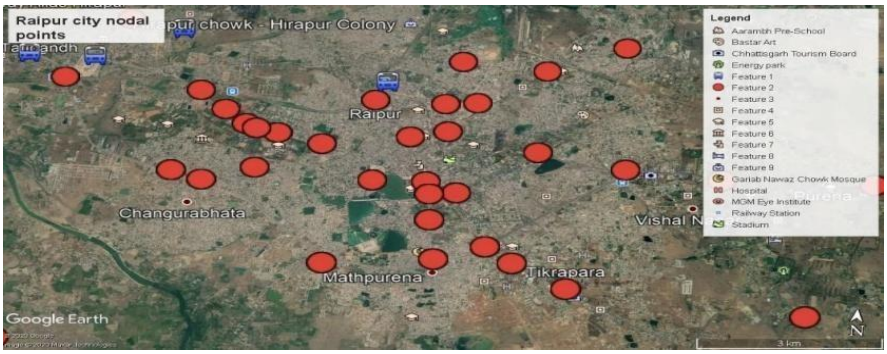


Fig. 7: Nodes considered for the study

Table 1: Nodes considered for the study

Node No.	Node Name	Node No.	Node Name	Node No.	Node Name
0	Raipur Railway Station	15	Sundar Nagar Bus Stop	30	City Mall Bus Stop
1	Tehghani Naka Chowk	16	Raipura Chowk Bus stop	31	Labhandi
2	Jail Road	17	SaronaRing road	32	Jora
3	Ghadi chowk	18	santoshi chowk	33	Mandir Hasaud
4	Jaistambh Chowk	19	Kalibari Bus stop	34	Pandri Bus Stop
5	Asharam Bus stop	20	Pension Bada Bus Stop	35	Awanti Bai Chowk Bus Stop
6	RKC Bus Stop	21	Siddhart chowk	36	Mowa
7	Anupam park bus stop	22	Panchpedi Naka Bus Stop	37	Vidhan Sabha
8	Ayurvedic college bus stop	23	Ramkrishna Care Hospital	38	Fafadih
9	NIT Raipur Bus stop	24	Lalpur	39	Bhanpuri
10	amanaka Bus stop	25	Raipur Airport	40	Urla
11	Aiims Raipur	26	Mana Basti	41	Hirapur Chowk
12	Tatibandh Chowk	27	Dumartarai	42	Nandan van
13	Vivekanand sarovar bus stop	28	Gaurav Path	43	DDU Nagar
14	Bhatagaon	29	Telibandha Bus Stop		

3.2. Prioritisation of bus routes.

There were existing 10 routes where the city bus transit service was available with railway station as one terminal point. The bus route prioritisation for terminal bound trips was done through the following two steps:

3.2.1 Identification of principal feeding bus routes using Dijkstra algorithm

Dijkstra's shortest path algorithm has been applied as discussed in section 2.1 and 43 node points were proposed for operation. Out of those 43 node points, 12 routes are identified to be the unique routes as other routes obtained from Dijkstra's shortest path algorithm are the subsets of these 12 routes. The 12 proposed routes are shown in Table 3.

3.2.2 Prioritisation of selected bus routes:

These 12 proposed routes along with the current operational 10 routes are then optimized based on factors affecting travel behaviour i.e., nodal traffic volume, average passenger trip distance, passenger turnover, travel population behaviour, expected income, route expenses and route profitability. It has been found that for the same nodal points the profitability of the routes does not vary significantly. With the increase in the length of the route, the profitability of the routes decreases as on the outskirts of the Raipur the population is less and hence the demand is less.

The 10 existing routes are shown in Fig.8 and the 12 shortest unique routes are shown in Fig.9. These are prioritised collectively by statistical analysis to get the more profitable routes if public transport operates on those routes. For prioritisation, the total residential population of the nodal points were taken from census 2011.

Fig. 8: Existing routes

Fig. 9: Dijkstra's Unique Routes

Table 2: Nodal station traffic volume calculation

Location	PCU (Passenger car units)	Pj (Nodal household numbers)	Lm (Route length)
Vidhan Sabha	3976	2628	7.2
Awanti bai	1861	450	4.1
Telibhandha	6181	3021	23.1
Tatibandh	8298	4581	8.5
Kalibadi	3700	3050	4
Jaistamb	2914	400	3.2
Pachpedinaka	6701	510	5.6
Santoshi Nagar	5209	750	8.4
Raipura Chowk	1982	4050	8.3
Telghani naka	10626	7418	0.75
Vivekanad sarovar	2772	2450	4
Gadhi Chowk	10136	8996	2.5

Table 3: Route definition of Existing and Dijkstra's Routes

Existing Routes	
Route Name	**Existing Routes**
Route 1	0->2->3->19->21->22->23->24->25
Route 2	0->2->3->19->21->22->23->24->26
Route 3	0->2->3->28->29->30->31->32->33
Route 4	0->2->3->34->35->36->37
Route 5	0->38
Route 6	0->39
Route 7	0->1->41->42
Route 8	0->2->3->4->5->6->7->8->9-> 10->11->12
Route 9	0->1->13->14
Route 10	0->2->3->28->29->30->31->32
Dijkstra's Routes	
Route Name	**Dijkstra's Routes**
Route A	0->2->3->19->21->22->23->24->25
Route B	0->1->5->6->7->8->9->10->11->12->17
Route C	0->2->3->19->21->22->23->24->27->29->28
Route D	0->2->3->19->21->22->23->24->27->29->28->24->27->29->30->31->32->33
Route E	0->34->35->36->37
Route F	0->39->40
Route G	0->2->3->4->15->16->43
Route H	0->2->3->4->13
Route I	0->2->3->19->21->18->14
Route J	0->2->3->19->21->22->23->24->26
Route K	0->38
Route L	0->1->41->42

Major travel behaviour factors in the intra-municipal passenger traffic model are marked in the following way:

Prospective traffic volume between two nodal points

The results obtained from the regression analysis are depicted in the table. 4.

Table 4: Traffic volume forecast model

Regression Statistics	
Multiple R	0.72477893
R Square	0.5253045
Adjusted R Square	0.47783495
Standard Error	2207.68198
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	53934794.6	53934794.6	11.066136	0.007661931
Residual	10	48738597.4	4873859.74		
Total	11	102673392			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*

Intercept	2799.13044	1000.08392	2.79889556	0.01883019	570.8046085	5027.45627
pj	0.80321728	0.24145435	3.32658022	0.00766193	0.265223452	1.34121111

Therefore, Final equation is:

$$Q_{ij} = 2799.13 + 0.81*Pj \quad (19)$$

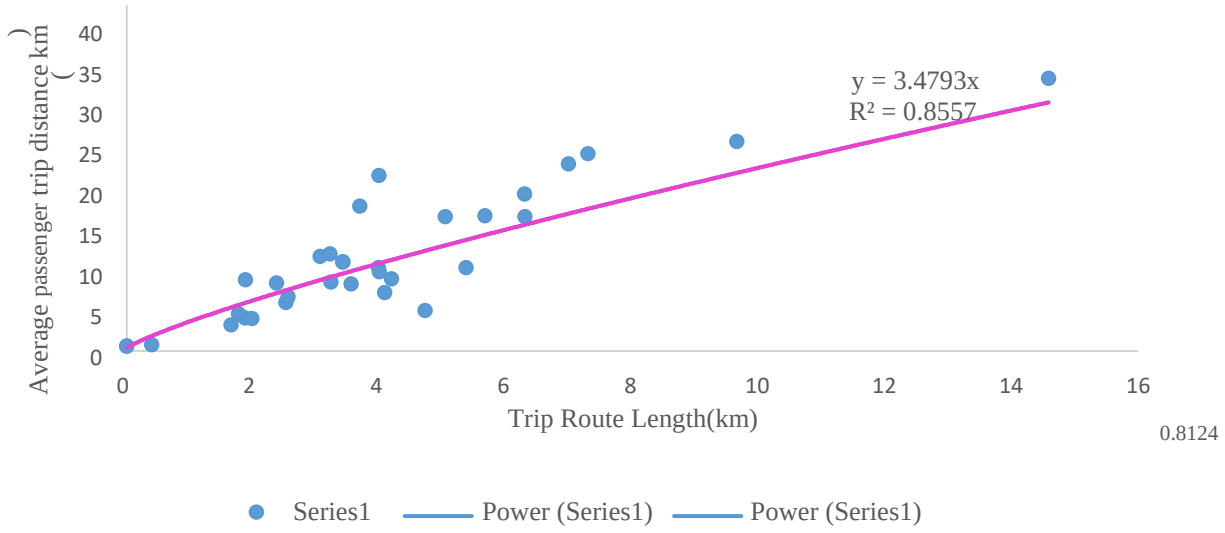


Fig 10. Calculation of Average passenger trip distance

Profitability and length of the routes was the decisive factor to select the best route of operation and routes are to select such that at least one bus route should be providing services to each nodal point. Profitability is dependent on the trip demand of nodal points, trip time and average passenger trip distance. These ensure that the optimum route will be shortest thus will decrease trip distance and trip time, also it should be profitable for bus service.

It is observed that few current operation routes were the same as are derived through Dijkstra's shortest path algorithm and therefore shares the same percentage of profitability. The proposed short route 6 and existing route 6 were the same, therefore were having the same profitability of 25.78%. Based on profitability the optimum routes were extracted out, such that there should be at least one route serving each nodal point. Therefore, the final optimized result gave 7 proposed short routes and 4 existing routes together were optimal for City Bus service operation table 5.

Table 5: Final optimum routes

Route	Length(km)	Profitability(%)	Nodes										
Route B	10.3	25.67	0	1	5	6	7	8	9	10	11	12	17
Route C	24.4	20.65	0	2	3	19	21	22	23	24	27	29	28
Route F	10.3	27.78	0	39	40								
Route G	9.8	23.13	0	2	3	4	15	16	43				
Route H	4	27.78	0	2	3	4	13						
Route I	11.5	23.74	0	2	3	19	21	18	14				
Route 1	21.7	21.5	0	2	3	19	21	22	23	24	25		
Route 2	16.7	21.57	0	2	3	19	21	22	23	24	26		
Route 3	25.9	21.95	0	2	3	28	29	30	31	32	33		
Route 4	8.9	26.67	0	2	3	34	35	36	37				
Route 5	0.6	26.55	0	38									

From analysis, it is found that the profitability of routes having similar nodal points doesn't vary significantly. There is a decrease in the profit of routes as its length increases, it is because the routes extend beyond the outskirts of Raipur city were lower population density thus overall demand to the end of the route will be lesser which will generate lesser revenue for same transit operating cost per km. Zonal population and route length haveasignificant influence on the potential demand of routes. It is also observed from

the study that the most profitable route may not be the best route for operation and the short route may not be the best route for operation. However, a shorter route will reduce trip time, increases average passenger trip distance and hence ensures more favourable conditions for increasing ridership and reliability of the public transit.

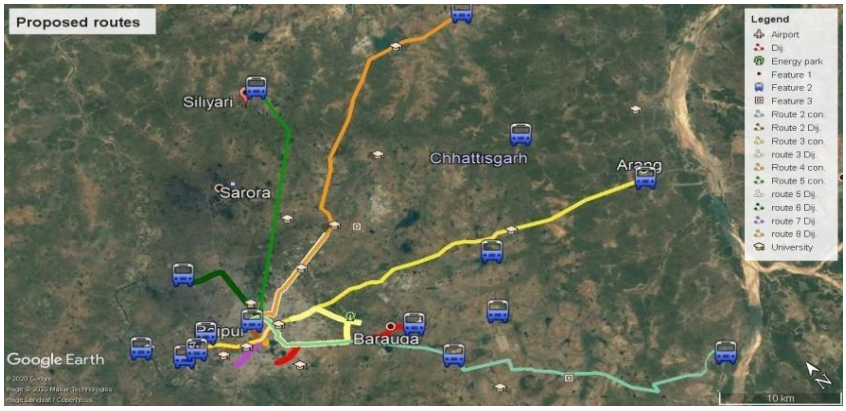


Fig.11.Proposed routes

3.3. Co-ordination of Bus-Train schedule

The total number of trains reaching the Raipur Railway Station is 159 which are clustered for analysis. In this study, clustering of trains has been done based on the arrival time and peak hour of trains as shown in Table 6. The majority of the trains arriving at the station were from 04:50 to 23:25.

Five operating routes Urla, Silyari, Nandanvan, Kharora,Chandkhuri were selected for study as shown in Fig.12. The number of buses available at each route, their circle time and headway between the buses is shown in Table 7. The walking time from the bus stop to the railway station is considered as 15 minutes and the dwelling time of the buses at the bus stop is taken like 5 minutes. The maximum waiting time at the platform for a train is considered to be 15 minutes. The maximum fine-tuning factor (ɳ) considered is 0.10. Notations and calculations for this study are referred from section 2.2.

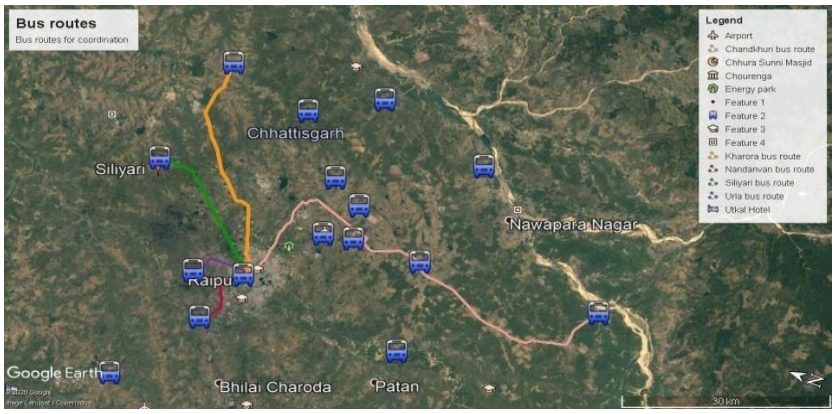


Fig. 12. Bus routes

Table 6: Cluster times

Cluster No.	No. of trains in a cluster	First train arrival time	Last train arrival time
1	8	04:50:00	05:38:00
2	15	06:00:00	07:00:00
3	12	07:15:00	08:10:00
4	15	09:00:00	10:05:00
5	14	10:15:00	11:15:00
6	8	11:20:00	12:05:00
7	14	12:30:00	13:35:00
8	11	13:50:00	14:45:00
9	9	15:10:00	16:10:00
10	10	16:30:00	17:30:00
11	12	17:45:00	18:50:00
12	10	19:00:00	19:55:00

13	12	20:05:00	21:05:00
14	5	21:40:00	22:35:00
15	4	22:55:00	23:25:00

Table 7: Details of bus route

	Silyari	Nandanvan	**Kharora**	**Chandkhuri**	**Urla**
No. of buses	1	1	7	4	3
Headway (min.)	0	0	20	36	30
Circle time(min.)	150	90	170	144	90
No. of Trips	6	8	5	6	9

The calculations done in the ms excel are shown in the tables given below. The calculations are done for each of the 5 bus routes separately.

Table 8: Excel calculations for Nandanvan route bus schedule

Cluster	First train	Next	Next	Next	Last train	Walking time 15 minutes					Waiting time 15 minutes				
1	4:50 AM	5:05 AM	5:25 AM	5:25 AM	5:38 AM	4:35 AM	4:50 AM	5:10 AM	5:10 AM	5:23 AM	4:20 AM	4:35 AM	4:55 AM	4:55 AM	5:08 AM
2	6:00 AM	6:30 AM	6:35 AM	6:40 AM	7:00 AM	5:45 AM	6:15 AM	6:20 AM	6:25 AM	6:45 AM	5:30 AM	6:00 AM	6:05 AM	6:10 AM	6:30 AM
3	7:15 AM	7:15 AM	7:35 AM	7:55 AM	8:10 AM	7:00 AM	7:00 AM	7:20 AM	7:40 AM	7:55 AM	6:45 AM	6:45 AM	7:05 AM	7:25 AM	7:40 AM
4	9:00 AM	9:20 AM	9:30 AM	9:55 AM	10:05 AM	8:45 AM	9:05 AM	9:15 AM	9:40 AM	9:50 AM	8:30 AM	8:50 AM	9:00 AM	9:25 AM	9:35 AM
5	10:15 AM	10:25 AM	10:35 AM	11:05 AM	11:15 AM	10:00 AM	10:10 AM	10:20 AM	10:50 AM	11:00 AM	9:45 AM	9:55 AM	10:05 AM	10:35 AM	10:45 AM
6	11:20 AM	11:30 AM	11:45 AM	11:55 AM	12:05 PM	11:05 AM	11:15 AM	11:30 AM	11:40 AM	11:50 AM	10:50 AM	11:00 AM	11:15 AM	11:25 AM	11:35 AM
7	12:30 PM	12:35 PM	1:00 PM	1:10 PM	1:35 PM	12:15 PM	12:20 PM	12:45 PM	12:55 PM	1:20 PM	12:00 PM	12:05 PM	12:30 PM	12:40 PM	1:05 PM
8	1:50 PM	1:55 PM	2:05 PM	2:20 PM	2:45 PM	1:35 PM	1:40 PM	1:50 PM	2:05 PM	2:30 PM	1:20 PM	1:25 PM	1:35 PM	1:50 PM	2:15 PM
9	3:10 PM	3:30 PM	3:50 PM	4:10 PM	4:20 PM	2:55 PM	3:15 PM	3:35 PM	3:55 PM	4:05 PM	2:40 PM	3:00 PM	3:20 PM	3:40 PM	3:50 PM
10	4:30 PM	4:45 PM	4:55 PM	5:00 PM	5:30 PM	4:15 PM	4:30 PM	4:40 PM	4:45 PM	5:15 PM	4:00 PM	4:15 PM	4:25 PM	4:30 PM	5:00 PM
11	5:45 PM	6:00 PM	6:25 PM	6:35 PM	6:50 PM	5:30 PM	5:45 PM	6:10 PM	6:20 PM	6:35 PM	5:15 PM	5:30 PM	5:55 PM	6:05 PM	6:20 PM
12	7:00 PM	7:05 PM	7:20 PM	7:30 PM	7:55 PM	6:45 PM	6:50 PM	7:05 PM	7:15 PM	7:40 PM	6:30 PM	6:35 PM	6:50 PM	7:00 PM	7:25 PM
13	8:05 PM	8:20 PM	8:40 PM	8:55 PM	9:05 PM	7:50 PM	8:05 PM	8:25 PM	8:40 PM	8:50 PM	7:35 PM	7:50 PM	8:10 PM	8:25 PM	8:35 PM
14	9:40 PM	10:05 PM	10:25 PM	10:25 PM	10:35 PM	9:25 PM	9:50 PM	10:10 PM	10:10 PM	10:20 PM	9:10 PM	9:35 PM	9:55 PM	9:55 PM	10:05 PM
15	10:55 PM	11:10 PM	11:10 PM	11:10 PM	11:25 PM	10:40 PM	10:55 PM	10:55 PM	10:55 PM	11:10 PM	10:25 PM	10:40 PM	10:40 PM	10:40 PM	10:55 PM

Raipur R St.	Telghani	Hirapur	Nandanvan	Nandanvan	Hirapur	Telghani	Raipur R St.	Check	Cluster no.
7:24 AM	7:30 AM	7:48 AM	8:04 AM	8:09 AM	8:25 AM	8:43 AM	8:49 AM	1	4
8:54 AM	9:00 AM	9:18 AM	9:34 AM	9:39 AM	9:55 AM	10:13 AM	10:19 AM	1	5
10:24 AM	10:30 AM	10:48 AM	11:04 AM	11:09 AM	11:25 AM	11:43 AM	11:49 AM	1	6
11:54 AM	12:00 PM	12:18 PM	12:34 PM	12:39 PM	12:55 PM	1:13 PM	1:19 PM	1	7
1:49 PM	1:55 PM	2:13 PM	2:29 PM	2:34 PM	2:50 PM	3:08 PM	3:14 PM	1	9
3:19 PM	3:25 PM	3:43 PM	3:59 PM	4:04 PM	4:20 PM	4:38 PM	4:44 PM	1	10
4:49 PM	4:55 PM	5:13 PM	5:29 PM	5:34 PM	5:50 PM	6:08 PM	6:14 PM	1	11
6:19 PM	6:25 PM	6:43 PM	6:59 PM	7:04 PM	7:20 PM	7:38 PM	7:44 PM	1	13
								8	

Table 9: Excel calculations for Urla route bus schedule.

Cluster	First train	Next	Next	Next	Last train	Walking time 15 minutes					Waiting time 15 minutes				
1	4:50 AM	5:05 AM	5:25 AM	5:25 AM	5:38 AM	4:35 AM	4:50 AM	5:10 AM	5:10 AM	5:23 AM	4:20 AM	4:35 AM	4:55 AM	4:55 AM	5:08 AM
2	6:00 AM	6:30 AM	6:35 AM	6:40 AM	7:00 AM	5:45 AM	6:15 AM	6:20 AM	6:25 AM	6:45 AM	5:30 AM	6:00 AM	6:05 AM	6:10 AM	6:30 AM
3	7:15 AM	7:15 AM	7:35 AM	7:55 AM	8:10 AM	7:00 AM	7:00 AM	7:20 AM	7:40 AM	7:55 AM	6:45 AM	6:45 AM	7:05 AM	7:25 AM	7:40 AM
4	9:00 AM	9:20 AM	9:30 AM	9:55 AM	10:05 AM	8:45 AM	9:05 AM	9:15 AM	9:40 AM	9:50 AM	8:30 AM	8:50 AM	9:00 AM	9:25 AM	9:35 AM
5	10:15 AM	10:25 AM	10:35 AM	11:05 AM	11:15 AM	10:00 AM	10:10 AM	10:20 AM	10:50 AM	11:00 AM	9:45 AM	9:55 AM	10:05 AM	10:35 AM	10:45 AM
6	11:20 AM	11:30 AM	11:45 AM	11:55 AM	12:05 PM	11:05 AM	11:15 AM	11:30 AM	11:40 AM	11:50 AM	10:50 AM	11:00 AM	11:15 AM	11:25 AM	11:35 AM
7	12:30 PM	12:35 PM	1:00 PM	1:10 PM	1:35 PM	12:15 PM	12:20 PM	12:45 PM	12:55 PM	1:20 PM	12:00 PM	12:05 PM	12:30 PM	12:40 PM	1:05 PM
8	1:50 PM	1:55 PM	2:05 PM	2:20 PM	2:45 PM	1:35 PM	1:40 PM	1:50 PM	2:05 PM	2:30 PM	1:20 PM	1:25 PM	1:35 PM	1:50 PM	2:15 PM
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11	5:45 PM	6:00 PM	6:25 PM	6:35 PM	6:50 PM	5:30 PM	5:45 PM	6:10 PM	6:20 PM	6:35 PM	5:15 PM	5:30 PM	5:55 PM	6:05 PM	6:20 PM
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13	8:05 PM	8:20 PM	8:40 PM	8:55 PM	9:05 PM	7:50 PM	8:05 PM	8:25 PM	8:40 PM	8:50 PM	7:35 PM	7:50 PM	8:10 PM	8:25 PM	8:35 PM
14	9:40 PM	10:05 PM	10:25 PM	10:25 PM	10:35 PM	9:25 PM	9:50 PM	10:10 PM	10:10 PM	10:20 PM	9:10 PM	9:35 PM	9:55 PM	9:55 PM	10:05 PM
15	10:55 PM	11:10 PM	11:10 PM	11:10 PM	11:25 PM	10:40 PM	10:55 PM	10:55 PM	10:55 PM	11:10 PM	10:25 PM	10:40 PM	10:40 PM	10:40 PM	10:55 PM

Strategy 1 : 0:04:00

BUS NO -1

Raipur R. Stn	Khamtarai	Bhanpuri	Urla	Urla	Bhanpuri	Khamtarai	Raipur R. Stn	Check	Cluster no
6:09 AM	6:21 AM	6:29 AM	6:49 AM	6:54 AM	7:14 AM	7:22 AM	7:34 AM	1	3
7:39 AM	7:51 AM	7:59 AM	8:19 AM	8:24 AM	8:44 AM	8:52 AM	9:04 AM	1	4
9:09 AM	9:21 AM	9:29 AM	9:49 AM	9:54 AM	10:14 AM	10:22 AM	10:34 AM	1	5
10:39 AM	10:51 AM	10:59 AM	11:19 AM	11:24 AM	11:44 AM	11:52 AM	12:04 PM	1	7
12:09 PM	12:21 PM	12:29 PM	12:49 PM	12:54 PM	1:14 PM	1:22 PM	1:34 PM	1	8
1:39 PM	1:51 PM	1:59 PM	2:19 PM	2:24 PM	2:44 PM	2:52 PM	3:04 PM	1	9
3:09 PM	3:21 PM	3:29 PM	3:49 PM	3:54 PM	4:14 PM	4:22 PM	4:34 PM	1	10
4:39 PM	4:51 PM	4:59 PM	5:19 PM	5:24 PM	5:44 PM	5:52 PM	6:04 PM	1	11
6:09 PM	6:21 PM	6:29 PM	6:49 PM	6:54 PM	7:14 PM	7:22 PM	7:34 PM	1	12
								9	

Strategy 1		
7:30 AM	1	3
9:00 AM	1	4
10:30 AM	1	5
12:00 PM	0	-
1:30 PM	1	8
3:00 PM	1	9
4:30 PM	1	10
6:00 PM	1	11
7:30 PM	1	12

BUS NO -2

Raipur R. Stn	Khamtarai	Bhanpuri	Urla	Urla	Bhanpuri	Khamtarai	Raipur R. Stn	Check	Cluster no.
8:09 AM	8:21 AM	8:29 AM	8:49 AM	8:54 AM	9:14 AM	9:22 AM	9:34 AM	1	4
9:39 AM	9:51 AM	9:59 AM	10:19 AM	10:24 AM	10:44 AM	10:52 AM	11:04 AM	1	6
11:09 AM	11:21 AM	11:29 AM	11:49 AM	11:54 AM	12:14 PM	12:22 PM	12:34 PM	1	7
12:39 PM	12:51 PM	12:59 PM	1:19 PM	1:24 PM	1:44 PM	1:52 PM	2:04 PM	1	8
2:09 PM	2:21 PM	2:29 PM	2:49 PM	2:54 PM	3:14 PM	3:22 PM	3:34 PM	1	9
3:39 PM	3:51 PM	3:59 PM	4:19 PM	4:24 PM	4:44 PM	4:52 PM	5:04 PM	1	10
5:09 PM	5:21 PM	5:29 PM	5:49 PM	5:54 PM	6:14 PM	6:22 PM	6:34 PM	1	11
6:39 PM	6:51 PM	6:59 PM	7:19 PM	7:24 PM	7:44 PM	7:52 PM	8:04 PM	1	13
8:09 PM	8:21 PM	8:29 PM	8:49 PM	8:54 PM	9:14 PM	9:22 PM	9:34 PM	1	14
								9	

Strategy 1		
9:30 AM	1	4
11:00 AM	1	6
12:30 PM	1	7
2:00 PM	1	8
3:30 PM	1	9
5:00 PM	1	10
6:30 PM	1	11
8:00 PM	1	13
9:30 PM	1	14

BUS NO -3

Raipur R. Stn	Khamtarai	Bhanpuri	Urla	Urla	Bhanpuri	Khamtarai	Raipur R. Stn	Check	Cluster no.	Correction
8:39 AM	8:51 AM	8:59 AM	9:19 AM	9:24 AM	9:44 AM	9:52 AM	10:04 AM	1	5	
10:09 AM	10:21 AM	10:29 AM	10:49 AM	10:54 AM	11:14 AM	11:22 AM	11:34 AM	1	6	
11:39 AM	11:51 AM	11:59 AM	12:19 PM	12:24 PM	12:44 PM	12:52 PM	1:04 PM	1	7	
1:09 PM	1:21 PM	1:29 PM	1:49 PM	1:54 PM	2:14 PM	2:22 PM	2:34 PM	0	-	0:04:00
2:39 PM	2:51 PM	2:59 PM	3:19 PM	3:24 PM	3:44 PM	3:52 PM	4:04 PM	1	9	
4:09 PM	4:21 PM	4:29 PM	4:49 PM	4:54 PM	5:14 PM	5:22 PM	5:34 PM	1	11	
5:39 PM	5:51 PM	5:59 PM	6:19 PM	6:24 PM	6:44 PM	6:52 PM	7:04 PM	1	12	
7:09 PM	7:21 PM	7:29 PM	7:49 PM	7:54 PM	8:14 PM	8:22 PM	8:34 PM	1	13	
8:39 PM	8:51 PM	8:59 PM	9:19 PM	9:24 PM	9:44 PM	9:52 PM	10:04 PM	1	14	
								8		

Strategy 1		
10:00 AM	1	5
11:30 AM	1	6
1:00 PM	1	7
2:30 PM	1	8
4:00 PM	1	9
5:30 PM	1	11
7:00 PM	1	12
8:30 PM	1	13
10:00 PM	1	14
	9	

Table 10: Excel calculations for Silyari route bus schedule.

Cluster	First train	Next	Next	Next	Last train	Walking time 15 minutes					Waiting time 15 minutes				
1	4:50 AM	5:05 AM	5:25 AM	5:25 AM	5:38 AM	4:35 AM	4:50 AM	5:10 AM	5:10 AM	5:23 AM	4:20 AM	4:35 AM	4:55 AM	4:55 AM	5:08 AM
2	6:00 AM	6:30 AM	6:35 AM	6:40 AM	7:00 AM	5:45 AM	6:15 AM	6:20 AM	6:25 AM	6:45 AM	5:30 AM	6:00 AM	6:05 AM	6:10 AM	6:30 AM
3	7:15 AM	7:15 AM	7:35 AM	7:55 AM	8:10 AM	7:00 AM	7:00 AM	7:20 AM	7:40 AM	7:55 AM	6:45 AM	6:45 AM	7:05 AM	7:25 AM	7:40 AM
4	9:00 AM	9:20 AM	9:30 AM	9:55 AM	10:05 AM	8:45 AM	9:05 AM	9:15 AM	9:40 AM	9:50 AM	8:30 AM	8:50 AM	9:00 AM	9:25 AM	9:35 AM
5	10:15 AM	10:25 AM	10:35 AM	11:05 AM	11:15 AM	10:00 AM	10:10 AM	10:20 AM	10:50 AM	11:00 AM	9:45 AM	9:55 AM	10:05 AM	10:35 AM	10:45 AM
6	11:20 AM	11:30 AM	11:45 AM	11:55 AM	12:05 PM	11:05 AM	11:15 AM	11:30 AM	11:40 AM	11:50 AM	10:50 AM	11:00 AM	11:15 AM	11:25 AM	11:35 AM
7	12:30 PM	12:35 PM	1:00 PM	1:10 PM	1:35 PM	12:15 PM	12:20 PM	12:45 PM	12:55 PM	1:20 PM	12:00 PM	12:05 PM	12:30 PM	12:40 PM	1:05 PM
8	1:50 PM	1:55 PM	2:05 PM	2:20 PM	2:45 PM	1:35 PM	1:40 PM	1:50 PM	2:05 PM	2:30 PM	1:20 PM	1:25 PM	1:35 PM	1:50 PM	2:15 PM
9	3:10 PM	3:30 PM	3:50 PM	4:10 PM	4:20 PM	2:55 PM	3:15 PM	3:35 PM	3:55 PM	4:05 PM	2:40 PM	3:00 PM	3:20 PM	3:40 PM	3:50 PM
10	4:30 PM	4:45 PM	4:55 PM	5:00 PM	5:30 PM	4:15 PM	4:30 PM	4:40 PM	4:45 PM	5:15 PM	4:00 PM	4:15 PM	4:25 PM	4:30 PM	5:00 PM
11	5:45 PM	6:00 PM	6:25 PM	6:35 PM	6:50 PM	5:30 PM	5:45 PM	6:10 PM	6:20 PM	6:35 PM	5:15 PM	5:30 PM	5:55 PM	6:05 PM	6:20 PM
12	7:00 PM	7:05 PM	7:20 PM	7:30 PM	7:55 PM	6:45 PM	6:50 PM	7:05 PM	7:15 PM	7:40 PM	6:30 PM	6:35 PM	6:50 PM	7:00 PM	7:25 PM
13	8:05 PM	8:20 PM	8:40 PM	8:55 PM	9:05 PM	7:50 PM	8:05 PM	8:25 PM	8:40 PM	8:50 PM	7:35 PM	7:50 PM	8:10 PM	8:25 PM	8:35 PM
14	9:40 PM	10:05 PM	10:25 PM	10:25 PM	10:35 PM	9:25 PM	9:50 PM	10:10 PM	10:10 PM	10:20 PM	9:10 PM	9:35 PM	9:55 PM	9:55 PM	10:05 PM
15	10:55 PM	11:10 PM	11:10 PM	11:10 PM	11:25 PM	10:40 PM	10:55 PM	10:55 PM	10:55 PM	11:10 PM	10:25 PM	10:40 PM	10:40 PM	10:40 PM	10:55 PM

BUS-1

Raipur R St.	Fafadih	Mandhar	Silyari	Silyari	Mandhar	Fafadih	Raipur R St.	Check	Cluster no.
5:24 AM	5:30 AM	6:06 AM	6:29 AM	6:39 AM	7:02 AM	7:38 AM	7:44 AM	1	3
7:54 AM	8:00 AM	8:36 AM	8:59 AM	9:09 AM	9:32 AM	10:08 AM	10:14 AM	1	5
10:24 AM	10:30 AM	11:06 AM	11:29 AM	11:39 AM	12:02 PM	12:38 PM	12:44 PM	1	7
12:54 PM	1:00 PM	1:36 PM	1:59 PM	2:09 PM	2:32 PM	3:08 PM	3:14 PM	1	9
3:24 PM	3:30 PM	4:06 PM	4:29 PM	4:39 PM	5:02 PM	5:38 PM	5:44 PM	1	11
5:54 PM	6:00 PM	6:36 PM	6:59 PM	7:09 PM	7:32 PM	8:08 PM	8:14 PM	1	13
								6	

Table 11: Excel calculations for Chandkuri route bus schedule

Cluster	First train	Next	Next	Next	Last train	Walking time 15 minutes					Waiting time 15 minutes				
1	4:50 AM	5:05 AM	5:25 AM	5:25 AM	5:38 AM	4:35 AM	4:50 AM	5:10 AM	5:10 AM	5:23 AM	4:20 AM	4:35 AM	4:55 AM	4:55 AM	5:08 AM
2	6:00 AM	6:30 AM	6:35 AM	6:40 AM	7:00 AM	5:45 AM	6:15 AM	6:20 AM	6:25 AM	6:45 AM	5:30 AM	6:00 AM	6:05 AM	6:10 AM	6:30 AM
3	7:15 AM	7:15 AM	7:35 AM	7:55 AM	8:10 AM	7:00 AM	7:00 AM	7:20 AM	7:40 AM	7:55 AM	6:45 AM	6:45 AM	7:05 AM	7:25 AM	7:40 AM
4	9:00 AM	9:20 AM	9:30 AM	9:55 AM	10:05 AM	8:45 AM	9:05 AM	9:15 AM	9:40 AM	9:50 AM	8:30 AM	8:50 AM	9:00 AM	9:25 AM	9:35 AM
5	10:15 AM	10:25 AM	10:35 AM	11:05 AM	11:15 AM	10:00 AM	10:10 AM	10:20 AM	10:50 AM	11:00 AM	9:45 AM	9:55 AM	10:05 AM	10:35 AM	10:45 AM
6	11:20 AM	11:30 AM	11:45 AM	11:55 AM	12:05 PM	11:05 AM	11:15 AM	11:30 AM	11:40 AM	11:50 AM	10:50 AM	11:00 AM	11:15 AM	11:25 AM	11:35 AM
7	12:30 PM	12:35 PM	1:00 PM	1:10 PM	1:35 PM	12:15 PM	12:20 PM	12:45 PM	12:55 PM	1:20 PM	12:00 PM	12:05 PM	12:30 PM	12:40 PM	1:05 PM
8	1:50 PM	1:55 PM	2:05 PM	2:20 PM	2:45 PM	1:35 PM	1:40 PM	1:50 PM	2:05 PM	2:30 PM	1:20 PM	1:25 PM	1:35 PM	1:50 PM	2:15 PM
9	3:10 PM	3:30 PM	3:50 PM	4:10 PM	4:20 PM	2:55 PM	3:15 PM	3:35 PM	3:55 PM	4:05 PM	2:40 PM	3:00 PM	3:20 PM	3:40 PM	3:50 PM
10	4:30 PM	4:45 PM	4:55 PM	5:00 PM	5:30 PM	4:15 PM	4:30 PM	4:40 PM	4:45 PM	5:15 PM	4:00 PM	4:15 PM	4:25 PM	4:30 PM	5:00 PM
11	5:45 PM	6:00 PM	6:25 PM	6:35 PM	6:50 PM	5:30 PM	5:45 PM	6:10 PM	6:20 PM	6:35 PM	5:15 PM	5:30 PM	5:55 PM	6:05 PM	6:20 PM
12	7:00 PM	7:05 PM	7:20 PM	7:30 PM	7:55 PM	6:45 PM	6:50 PM	7:05 PM	7:15 PM	7:40 PM	6:30 PM	6:35 PM	6:50 PM	7:00 PM	7:25 PM
13	8:05 PM	8:20 PM	8:40 PM	8:55 PM	9:05 PM	7:50 PM	8:05 PM	8:25 PM	8:40 PM	8:50 PM	7:35 PM	7:50 PM	8:10 PM	8:25 PM	8:35 PM
14	9:40 PM	10:05 PM	10:25 PM	10:25 PM	10:35 PM	9:25 PM	9:50 PM	10:10 PM	10:10 PM	10:20 PM	9:10 PM	9:35 PM	9:55 PM	9:55 PM	10:05 PM
15	10:55 PM	11:10 PM	11:10 PM	11:10 PM	11:25 PM	10:40 PM	10:55 PM	10:55 PM	10:55 PM	11:10 PM	10:25 PM	10:40 PM	10:40 PM	10:40 PM	10:55 PM

Strategy 1 :	0:18:00
Strategy 2 :	0:09:00

BUS-1

Raipur R St.	Telibandha	Mandirhasud	Khurud-2	Chandkhuri	Chandkhuri	Khururd-2	Mandirhasud	Telibandha	Raipur R St.	Check	Cluster no.
5:30 AM	5:46 AM	6:08 AM	6:20 AM	6:36 AM	6:40 AM	6:56 AM	7:08 AM	7:30 AM	7:46 AM	1	3
7:54 AM	8:10 AM	8:32 AM	8:44 AM	9:00 AM	9:04 AM	9:20 AM	9:32 AM	9:54 AM	10:10 AM	1	5
10:18 AM	10:34 AM	10:56 AM	11:08 AM	11:24 AM	11:28 AM	11:44 AM	11:56 AM	12:18 PM	12:34 PM	1	7
12:42 PM	12:58 PM	1:20 PM	1:32 PM	1:48 PM	1:52 PM	2:08 PM	2:20 PM	2:42 PM	2:58 PM	1	9
3:06 PM	3:22 PM	3:44 PM	3:56 PM	4:12 PM	4:16 PM	4:32 PM	4:44 PM	5:06 PM	5:22 PM	1	11
5:30 PM	5:46 PM	6:08 PM	6:20 PM	6:36 PM	6:40 PM	6:56 PM	7:08 PM	7:30 PM	7:46 PM	1	13

Strategy 1		
7:28 AM	1	3
9:52 AM	1	5
12:16 PM	1	7
2:40 PM	0	-
5:04 PM	1	10
7:28 PM	1	12

BUS-2

Raipur R St.	Telibandha	Mandirhasud	Khurud-2	Chandkhuri	Chandkhuri	Khururd-2	Mandirhasud	Telibandha	Raipur R St.	Check	Cluster no.	Correction
6:06 AM	6:22 AM	6:44 AM	6:56 AM	7:12 AM	7:16 AM	7:32 AM	7:44 AM	8:06 AM	8:22 AM	0	-	0:27:00
8:30 AM	8:46 AM	9:08 AM	9:20 AM	9:36 AM	9:40 AM	9:56 AM	10:08 AM	10:30 AM	10:46 AM	1	5	
10:54 AM	11:10 AM	11:32 AM	11:44 AM	12:00 PM	12:04 PM	12:20 PM	12:32 PM	12:54 PM	1:10 PM	1	7	
1:18 PM	1:34 PM	1:56 PM	2:08 PM	2:24 PM	2:28 PM	2:44 PM	2:56 PM	3:18 PM	3:34 PM	1	9	
3:42 PM	3:58 PM	4:20 PM	4:32 PM	4:48 PM	4:52 PM	5:08 PM	5:20 PM	5:42 PM	5:58 PM	1	11	
6:06 PM	6:22 PM	6:44 PM	6:56 PM	7:12 PM	7:16 PM	7:32 PM	7:44 PM	8:06 PM	8:22 PM	1	13	

Strategy 1			Correction II	Strategy 2		
8:04 AM	0	-	0:09:00	7:55 AM	0	-
10:28 AM	1	5		10:19 AM	1	5
12:52 PM	1	7		12:43 PM	1	7
3:16 PM	1	9		3:07 PM	1	9
5:40 PM	1	11		5:31 PM	1	11
8:04 PM	1	13		7:55 PM	1	13

BUS-3

Raipur R St.	Telibandha	Mandirhasud	Khurud-2	Chandkhuri	Chandkhuri	Khururd-2	Mandirhasud	Telibandha	Raipur R St.	Check	Cluster no.	Correction	Strategy 1		
6:42 AM	6:58 AM	7:20 AM	7:32 AM	7:48 AM	7:52 AM	8:08 AM	8:20 AM	8:42 AM	8:58 AM	1	4		8:40 AM	1	4
9:06 AM	9:22 AM	9:44 AM	9:56 AM	10:12 AM	10:16 AM	10:32 AM	10:44 AM	11:06 AM	11:22 AM	1	6		11:04 AM	1	6
11:30 AM	11:46 AM	12:08 PM	12:20 PM	12:36 PM	12:40 PM	12:56 PM	1:08 PM	1:30 PM	1:46 PM	1	8		1:28 PM	1	8
1:54 PM	2:10 PM	2:32 PM	2:44 PM	3:00 PM	3:04 PM	3:20 PM	3:32 PM	3:54 PM	4:10 PM	1	10		3:52 PM	1	9
4:18 PM	4:34 PM	4:56 PM	5:08 PM	5:24 PM	5:28 PM	5:44 PM	5:56 PM	6:18 PM	6:34 PM	1	11		6:16 PM	1	11
6:42 PM	6:58 PM	7:20 PM	7:32 PM	7:48 PM	7:52 PM	8:08 PM	8:20 PM	8:42 PM	8:58 PM	0	-	0:08:00	8:40 PM	1	13

BUS-4

Raipur R St.	Telibandha	Mandirhasud	Khurud-2	Chandkhuri	Chandkhuri	Khururd-2	Mandirhasud	Telibandha	Raipur R St.	Check	Cluster no.	Correction	Strategy 1		
7:18 AM	7:34 AM	7:56 AM	8:08 AM	8:24 AM	8:28 AM	8:44 AM	8:56 AM	9:18 AM	9:34 AM	1	4		9:16 AM	1	4
9:42 AM	9:58 AM	10:20 AM	10:32 AM	10:48 AM	10:52 AM	11:08 AM	11:20 AM	11:42 AM	11:58 AM	0	-	0:07:55	11:40 AM	1	6
12:06 PM	12:22 PM	12:44 PM	12:56 PM	1:12 PM	1:16 PM	1:32 PM	1:44 PM	2:06 PM	2:22 PM	1	8		2:04 PM	1	8
2:30 PM	2:46 PM	3:08 PM	3:20 PM	3:36 PM	3:40 PM	3:56 PM	4:08 PM	4:30 PM	4:46 PM	1	10		4:28 PM	1	10
4:54 PM	5:10 PM	5:32 PM	5:44 PM	6:00 PM	6:04 PM	6:20 PM	6:32 PM	6:54 PM	7:10 PM	1	12		6:52 PM	1	12
7:18 PM	7:34 PM	7:56 PM	8:08 PM	8:24 PM	8:28 PM	8:44 PM	8:56 PM	9:18 PM	9:34 PM	1	14		9:16 PM	1	14

Table 12: Excel calculations for Kharora route bus schedule

Cluster	First train	Next	Next	Next	Last train	Walking time 15 minutes					Waiting time 15 minutes				
1	4:50 AM	5:05 AM	5:25 AM	5:25 AM	5:38 AM	4:35 AM	4:50 AM	5:10 AM	5:10 AM	5:23 AM	4:20 AM	4:35 AM	4:55 AM	4:55 AM	5:08 AM
2	6:00 AM	6:30 AM	6:35 AM	6:40 AM	7:00 AM	5:45 AM	6:15 AM	6:20 AM	6:25 AM	6:45 AM	5:30 AM	6:00 AM	6:05 AM	6:10 AM	6:30 AM
3	7:15 AM	7:15 AM	7:35 AM	7:55 AM	8:10 AM	7:00 AM	7:00 AM	7:20 AM	7:40 AM	7:55 AM	6:45 AM	6:45 AM	7:05 AM	7:25 AM	7:40 AM
4	9:00 AM	9:20 AM	9:30 AM	9:55 AM	10:05 AM	8:45 AM	9:05 AM	9:15 AM	9:40 AM	9:50 AM	8:30 AM	8:50 AM	9:00 AM	9:25 AM	9:35 AM
5	10:15 AM	10:25 AM	10:35 AM	11:05 AM	11:15 AM	10:00 AM	10:10 AM	10:20 AM	10:50 AM	11:00 AM	9:45 AM	9:55 AM	10:05 AM	10:35 AM	10:45 AM
6	11:20 AM	11:30 AM	11:45 AM	11:55 AM	12:05 PM	11:05 AM	11:15 AM	11:30 AM	11:40 AM	11:50 AM	10:50 AM	11:00 AM	11:15 AM	11:25 AM	11:35 AM
7	12:30 PM	12:35 PM	1:00 PM	1:10 PM	1:35 PM	12:15 PM	12:20 PM	12:45 PM	12:55 PM	1:20 PM	12:00 PM	12:05 PM	12:30 PM	12:40 PM	1:05 PM
8	1:50 PM	1:55 PM	2:05 PM	2:20 PM	2:45 PM	1:35 PM	1:40 PM	1:50 PM	2:05 PM	2:30 PM	1:20 PM	1:25 PM	1:35 PM	1:50 PM	2:15 PM
9	3:10 PM	3:30 PM	3:50 PM	4:10 PM	4:20 PM	2:55 PM	3:15 PM	3:35 PM	3:55 PM	4:05 PM	2:40 PM	3:00 PM	3:20 PM	3:40 PM	3:50 PM
10	4:30 PM	4:45 PM	4:55 PM	5:00 PM	5:30 PM	4:15 PM	4:30 PM	4:40 PM	4:45 PM	5:15 PM	4:00 PM	4:15 PM	4:25 PM	4:30 PM	5:00 PM
11	5:45 PM	6:00 PM	6:25 PM	6:35 PM	6:50 PM	5:30 PM	5:45 PM	6:10 PM	6:20 PM	6:35 PM	5:15 PM	5:30 PM	5:55 PM	6:05 PM	6:20 PM
12	7:00 PM	7:05 PM	7:20 PM	7:30 PM	7:55 PM	6:45 PM	6:50 PM	7:05 PM	7:15 PM	7:40 PM	6:30 PM	6:35 PM	6:50 PM	7:00 PM	7:25 PM
13	8:05 PM	8:20 PM	8:40 PM	8:55 PM	9:05 PM	7:50 PM	8:05 PM	8:25 PM	8:40 PM	8:50 PM	7:35 PM	7:50 PM	8:10 PM	8:25 PM	8:35 PM
14	9:40 PM	10:05 PM	10:25 PM	10:25 PM	10:35 PM	9:25 PM	9:50 PM	10:10 PM	10:10 PM	10:20 PM	9:10 PM	9:35 PM	9:55 PM	9:55 PM	10:05 PM
15	10:55 PM	11:10 PM	11:10 PM	11:10 PM	11:25 PM	10:40 PM	10:55 PM	10:55 PM	10:55 PM	11:10 PM	10:25 PM	10:40 PM	10:40 PM	10:40 PM	10:55 PM

Strategy 1 :	0:19:00
Strategy 2 :	0:09:00
Strategy 3 :	0:06:00

BUS-1

Raipur R St.	Pandri bus Stand	Avanti Chowk	Mova Zero Point	Vidhan sabha	DondeKela	Kharora	Kharora	DondeKela	Vidhan sabha	Mova Zero Point	Avanti Chowk	Pandri bus Stand	Raipur R St.	Check	Cluster no.	Strategy 1		
4:59 AM	5:12 AM	5:22 AM	5:28 AM	5:36 AM	5:53 AM	6:19 AM	6:29 AM	6:55 AM	7:12 AM	7:20 AM	7:26 AM	7:36 AM	7:49 AM	1	3	7:30 AM	1	3
7:59 AM	8:12 AM	8:22 AM	8:28 AM	8:36 AM	8:53 AM	9:19 AM	9:29 AM	9:55 AM	10:12 AM	10:20 AM	10:26 AM	10:36 AM	10:49 AM	1	5	10:30 AM	1	5
10:59 AM	11:12 AM	11:22 AM	11:28 AM	11:36 AM	11:53 AM	12:19 PM	12:29 PM	12:55 PM	1:12 PM	1:20 PM	1:26 PM	1:36 PM	1:49 PM	1	8	1:30 PM	1	8
1:59 PM	2:12 PM	2:22 PM	2:28 PM	2:36 PM	2:53 PM	3:19 PM	3:29 PM	3:55 PM	4:12 PM	4:20 PM	4:26 PM	4:36 PM	4:49 PM	1	10	4:30 PM	1	10
4:59 PM	5:12 PM	5:22 PM	5:28 PM	5:36 PM	5:53 PM	6:19 PM	6:29 PM	6:55 PM	7:12 PM	7:20 PM	7:26 PM	7:36 PM	7:49 PM	1	13	7:30 PM	1	12

BUS-2

Raipur R St.	Pandri bus Stand	Avanti Chowk	Mova Zero Point	Vidhan sabha	DondeKela	Kharora	Kharora	DondeKela	Vidhan sabha	Mova Zero Point	Avanti Chowk	Pandri bus Stand	Raipur R St.	Check	Cluster no.	Correction	Strategy 1		
5:19 AM	5:32 AM	5:42 AM	5:48 AM	5:56 AM	6:13 AM	6:39 AM	6:49 AM	7:15 AM	7:32 AM	7:40 AM	7:46 AM	7:56 AM	8:09 AM	0	-	0:14:00	7:50 AM	1	3
8:19 AM	8:32 AM	8:42 AM	8:48 AM	8:56 AM	9:13 AM	9:39 AM	9:49 AM	10:15 AM	10:32 AM	10:40 AM	10:46 AM	10:56 AM	11:09 AM	1	6		10:50 AM	1	5
11:19 AM	11:32 AM	11:42 AM	11:48 AM	11:56 AM	12:13 PM	12:39 PM	12:49 PM	1:15 PM	1:32 PM	1:40 PM	1:46 PM	1:56 PM	2:09 PM	1	8		1:50 PM	1	8
2:19 PM	2:32 PM	2:42 PM	2:48 PM	2:56 PM	3:13 PM	3:39 PM	3:49 PM	4:15 PM	4:32 PM	4:40 PM	4:46 PM	4:56 PM	5:09 PM	1	10		4:50 PM	1	10
5:19 PM	5:32 PM	5:42 PM	5:48 PM	5:56 PM	6:13 PM	6:39 PM	6:49 PM	7:15 PM	7:32 PM	7:40 PM	7:46 PM	7:56 PM	8:09 PM	1	13		7:50 PM	1	13

BUS-4

Raipur R St.	Pandri bus Stand	Avanti Chowk	Mova Zero Point	Vidhan sabha	DondeKela	Kharora	Kharora	DondeKela	Vidhan sabha	Mova Zero Point	Avanti Chowk	Pandri bus Stand	Raipur R St.	Check	Cluster no.	Correction	Strategy 1		
6:19 AM	6:32 AM	6:42 AM	6:48 AM	6:56 AM	7:13 AM	7:39 AM	7:49 AM	8:15 AM	8:32 AM	8:40 AM	8:46 AM	8:56 AM	9:09 AM	1	4		8:50 AM	1	4
9:19 AM	9:32 AM	9:42 AM	9:48 AM	9:56 AM	10:13 AM	10:39 AM	10:49 AM	11:15 AM	11:32 AM	11:40 AM	11:46 AM	11:56 AM	12:09 PM	1	7		11:50 AM	1	6
12:19 PM	12:32 PM	12:42 PM	12:48 PM	12:56 PM	1:13 PM	1:39 PM	1:49 PM	2:15 PM	2:32 PM	2:40 PM	2:46 PM	2:56 PM	3:09 PM	1	9		2:50 PM	1	9
3:19 PM	3:32 PM	3:42 PM	3:48 PM	3:56 PM	4:13 PM	4:39 PM	4:49 PM	5:15 PM	5:32 PM	5:40 PM	5:46 PM	5:56 PM	6:09 PM	1	11		5:50 PM	1	11
6:19 PM	6:32 PM	6:42 PM	6:48 PM	6:56 PM	7:13 PM	7:39 PM	7:49 PM	8:15 PM	8:32 PM	8:40 PM	8:46 PM	8:56 PM	9:09 PM	0	-	0:19:00	8:50 PM	1	13

BUS-5

Raipur R St.	Pandri bus Stand	Avanti Chowk	Mova Zero Point	Vidhan sabha	DondeKela	Kharora	Kharora	DondeKela	Vidhan sabha	Mova Zero Point	Avanti Chowk	Pandri bus Stand	Raipur R St.	Check	Cluster no.	Strategy 1		
6:39 AM	6:52 AM	7:02 AM	7:08 AM	7:16 AM	7:33 AM	7:59 AM	8:09 AM	8:35 AM	8:52 AM	9:00 AM	9:06 AM	9:16 AM	9:29 AM	1	4	9:10 AM	1	4
9:39 AM	9:52 AM	10:02 AM	10:08 AM	10:16 AM	10:33 AM	10:59 AM	11:09 AM	11:35 AM	11:52 AM	12:00 PM	12:06 PM	12:16 PM	12:29 PM	1	7	12:10 PM	1	7
12:39 PM	12:52 PM	1:02 PM	1:08 PM	1:16 PM	1:33 PM	1:59 PM	2:09 PM	2:35 PM	2:52 PM	3:00 PM	3:06 PM	3:16 PM	3:29 PM	1	9	3:10 PM	1	9
3:39 PM	3:52 PM	4:02 PM	4:08 PM	4:16 PM	4:33 PM	4:59 PM	5:09 PM	5:35 PM	5:52 PM	6:00 PM	6:06 PM	6:16 PM	6:29 PM	1	11	6:10 PM	1	11
6:39 PM	6:52 PM	7:02 PM	7:08 PM	7:16 PM	7:33 PM	7:59 PM	8:09 PM	8:35 PM	8:52 PM	9:00 PM	9:06 PM	9:16 PM	9:29 PM	1	14	9:10 PM	1	14

BUS-6

Raipur R St.	³andri bus Stan	Avanti Chowk	Mova Zero Point	Vidhan sabha	DondeKela	Kharora	Kharora	DondeKela	Vidhan sabha	Mova Zero Point	Avanti Chowk	³andri bus Stan	Raipur R St.	Check	Cluster no.	Strategy 1		
6:59 AM	7:12 AM	7:22 AM	7:28 AM	7:36 AM	7:53 AM	8:19 AM	8:29 AM	8:55 AM	9:12 AM	9:20 AM	9:26 AM	9:36 AM	9:49 AM	1	4	9:30 AM	1	4
9:59 AM	10:12 AM	10:22 AM	10:28 AM	10:36 AM	10:53 AM	11:19 AM	11:29 AM	11:55 AM	12:12 PM	12:20 PM	12:26 PM	12:36 PM	12:49 PM	1	7	12:30 PM	1	7
12:59 PM	1:12 PM	1:22 PM	1:28 PM	1:36 PM	1:53 PM	2:19 PM	2:29 PM	2:55 PM	3:12 PM	3:20 PM	3:26 PM	3:36 PM	3:49 PM	1	9	3:30 PM	1	9
3:59 PM	4:12 PM	4:22 PM	4:28 PM	4:36 PM	4:53 PM	5:19 PM	5:29 PM	5:55 PM	6:12 PM	6:20 PM	6:26 PM	6:36 PM	6:49 PM	1	12	6:30 PM	1	11
6:59 PM	7:12 PM	7:22 PM	7:28 PM	7:36 PM	7:53 PM	8:19 PM	8:29 PM	8:55 PM	9:12 PM	9:20 PM	9:26 PM	9:36 PM	9:49 PM	1	14	9:30 PM	1	14

BUS-7

Raipur R St.	³andri bus Stan	Avanti Chowk	Mova Zero Point	Vidhan sabha	DondeKela	Kharora	Kharora	DondeKela	Vidhan sabha	Mova Zero Point	Avanti Chowk	³andri bus Stan	Raipur R St.	Check	Cluster no.	Strategy 1		
7:19 AM	7:32 AM	7:42 AM	7:48 AM	7:56 AM	8:13 AM	8:39 AM	8:49 AM	9:15 AM	9:32 AM	9:40 AM	9:46 AM	9:56 AM	10:09 AM	1	5	9:50 AM	1	5
10:19 AM	10:32 AM	10:42 AM	10:48 AM	10:56 AM	11:13 AM	11:39 AM	11:49 AM	12:15 PM	12:32 PM	12:40 PM	12:46 PM	12:56 PM	1:09 PM	1	7	12:50 PM	1	7
1:19 PM	1:32 PM	1:42 PM	1:48 PM	1:56 PM	2:13 PM	2:39 PM	2:49 PM	3:15 PM	3:32 PM	3:40 PM	3:46 PM	3:56 PM	4:09 PM	1	10	3:50 PM	1	9
4:19 PM	4:32 PM	4:42 PM	4:48 PM	4:56 PM	5:13 PM	5:39 PM	5:49 PM	6:15 PM	6:32 PM	6:40 PM	6:46 PM	6:56 PM	7:09 PM	1	12	6:50 PM	1	12
7:19 PM	7:32 PM	7:42 PM	7:48 PM	7:56 PM	8:13 PM	8:39 PM	8:49 PM	9:15 PM	9:32 PM	9:40 PM	9:46 PM	9:56 PM	10:09 PM	1	14	9:50 PM	1	14

Table 13: Bus blockage calculations by applying different strategies

BUS BLOCKAGE		
BUS 1	BUS 2	Strategy 4
9:30 AM	10:00 AM	1
11:00 AM	11:30 AM	1
12:30 PM	1:00 PM	1
2:00 PM	2:30 PM	1
3:30 PM	4:00 PM	1
5:00 PM	5:30 PM	1
6:30 PM	7:00 PM	1
8:00 PM	8:30 PM	1
9:30 PM	10:00 PM	1

BUS BLOCKAGE				
BUS 1	BUS 2	BUS 3	BUS 4	Strategy 4
7:28 AM	7:55 AM	8:40 AM	9:16 AM	1
9:52 AM	10:19 AM	11:04 AM	11:40 AM	1
12:16 PM	12:43 PM	1:28 PM	2:04 PM	1
2:40 PM	3:07 PM	3:52 PM	4:28 PM	1
5:04 PM	5:31 PM	6:16 PM	6:52 PM	1
7:28 PM	7:55 PM	8:40 PM	9:16 PM	1

BUS BLOCKAGE																
BUS 1	BUS 2	Strategy 4	BUS 2	BUS 3	Strategy 4	BUS 3	BUS 4	Strategy 4	BUS 4	BUS 5	Strategy 4	BUS 5	BUS 6	Strategy 4	BUS 6	BUS 7	Strategy 4
7:30 AM	7:50 AM	1	7:50 AM	7:55 AM	1	7:55 AM	8:50 AM	1	8:50 AM	9:10 AM	1	9:10 AM	9:30 AM	1	9:30 AM	9:50 AM	1
10:30 AM	10:50 AM	1	10:50 AM	11:01 AM	1	11:01 AM	11:50 AM	1	11:50 AM	12:10 PM	1	12:10 PM	12:30 PM	1	12:30 PM	12:50 PM	1
1:30 PM	1:50 PM	1	1:50 PM	2:01 PM	1	2:01 PM	2:50 PM	1	2:50 PM	3:10 PM	1	3:10 PM	3:30 PM	1	3:30 PM	3:50 PM	1
4:30 PM	4:50 PM	1	4:50 PM	5:01 PM	1	5:01 PM	5:50 PM	1	5:50 PM	6:10 PM	1	6:10 PM	6:30 PM	1	6:30 PM	6:50 PM	1
7:30 PM	7:50 PM	1	7:50 PM	8:01 PM	1	8:01 PM	8:50 PM	1	8:50 PM	9:10 PM	1	9:10 PM	9:30 PM	1	9:30 PM	9:50 PM	1

After applying strategies in table 14, the transfer optimisation is done and the result obtained is shown in table 15.

The original schedule of each bus line:

Table 14: Original schedule for each bus line

Bus Line	Bus No.	The terminal Departure time of the first bus from Raipur railway station	Headway (min)	Bus-to-Train connectivity
Silyari	1	5:24 AM	-	1/1/1/1/1/1
Nandanvan	1	7:24 AM	-	1/1/1/1/1/1/1/1
Kharora	1	4:59 AM	20	1/1/1/1/1
	2	5:19 AM		0/1/1/1/1
	3	5:39 AM		0/1/1/1/1
	4	6:19 AM		1/1/1/1/0
	5	6:39 AM		1/1/1/1/1
	6	6:59 AM		1/1/1/1/1
	7	7:19 AM		1/1/1/1/1
Chandkhuri	1	5:30 AM	36	1/1/1/1/1/1
	2	6:06 AM		0/1/1/1/1/1
	3	6:42 AM		1/1/1/1/1/0
	4	7:18 AM		1/0/1/1/1/1
Urla	1	6:09 AM	30	1/1/1/1/1/1/1/1/1
	2	8:09 AM		1/1/1/1/1/1/1/1/1
	3	8:39 AM		1/1/1/0/1/1/1/1/1

Optimal bus schedule coordination solution:

Table 15: Optimal bus schedule co-ordination solution

Bus Line	Bus No.	Terminal Departure time of first bus fromRaipur railway station	T_e(min)	Y_{kl}(min)	Z_{kl}(min)	Headway(min)	Bus-to-Train connectivity
Silyari	1	5:24 AM	0	0	0	0	1/1/1/1/1/1
Nandanvan	1	7:24 AM	0	0	0	0	1/1/1/1/1/1/1/1
Kharora	1	4:40 AM	-19	0	0	20	1/1/1/1/1
	2	5:00 AM		0	0	20	1/1/1/1/1
	3	5:20 AM		-9	0	11	0/1/1/1/1
	4	6:00 AM		0	0	20	1/1/1/1/1
	5	6:20 AM		0	0	20	1/1/1/1/1
	6	6:40 AM		0	0	20	1/1/1/1/1
	7	7:00 AM		0	0	20	1/1/1/1/1
Chandkhuri	1	5:12 AM	-18	0	0	36	1/1/1/1/1/1
	2	5:48 AM		-9	0	27	1/1/1/1/1/1
	3	6:24 AM		0	0	36	1/1/1/1/1/1
	4	7:00 AM		0	0	36	1/1/1/1/1/1
Urla	1	6:05 AM	-4	0	0	30	1/1/1/1/1/1/1/1/1
	2	8:05 AM		0	0		1/1/1/1/1/1/1/1/1
	3	8:35 AM		0	0		1/1/1/1/1/1/1/1/1

4. Results and Discussion

Total 43 potential node points have been selected in this study from the study area to identify the potential unique routes feeding the Raipur railway station. Based on the shortest path algorithm 12 potential unique routes have been identified for route prioritization. The 10 existing routes serving the passengers to the Railway station have been compared and analysed with the proposed 12 potential unique routes to determine the profitability in terms of travel time, travel cost, trip demand, and average passenger trip distance. The results depicted 7 proposed unique routes and 4 existing routes serve with maximum profitability.

The transfer optimization at the railway station was done between the Train departure schedule and bus arrival scheduled for 5 potential routes from 11 prioritized routes. The Urla node contributes maximum trips of 9 per bus and the Kharora node contributes a minimum of 5 trips per bus Further, the Kharora node has the maximum number of buses i.e. 7 and the Syliari and Nandanvan node have theminimum number of buses i.e. serving to the railway station. Total 159 trains per day are departing from the Railway station grouped into 15 clusters. Based on the timed transfer and transfer optimization analysis, the failure transfer cases of bus trips have been reduced from 7 to 1.

5. Conclusion

This study has proposed a methodology for prioritisation and coordination of bus transport networks for the terminal bound trip for enhancing the bus ridership. The prioritisation model was so structured that it will reduce the overall travel time and improve the connectivity of terminal points and various nodal points which was reflected by the potential profitability of the routes. Transfer optimization incorporating the enumerated bus schedule coordination strategies is developed to minimize the number of transfer failures from bus service to train service. Accordingly, Dijkstra's Algorithm, regression analysis, C++ code and MS Excel were prepared for bus route prioritisation and transfer optimisation. The case study conducted in Raipur city, Chhattisgarh, India shows that there are 14 optimal routes of operation in city bus service for increased profitability; also, the bus schedule yielded by the proposed model for coordination increased the number of smooth bus-to-train transfers. The developed model uses distance as the only qualifier for shortest route identification through Dijkstra's shortest path algorithm where time can also be a significant variable. This study focuses on the minimization of transfer failures by adjusting bus schedules in the context of clustered train schedules. The results depicted that the transfer success rate has been improved substantially from 7 failure cases to 1 failure case. Thus the developed approach could be employed as a viable tool to assist bus route prioritisation and schedule coordination for public transport operators. Moreover, if the arrival time of each bus at every cycle of their operation is within the cluster zone, then a smooth connection to the train service will be available to the public.

Annexure-1

a	Traffic Volume.
b	Population.
c	Route length.
i,j	Nodal points of the network.
Q_{ij}	Perspective route traffic volume.
Rij	Distance between populated localities.
P_i	Population size at a starting route populated locality.
Pj	Population size at a terminal route populated locality.
L_{me}	Route length(Rij^e).
L_{av}	Average passenger trip distance.
P	Passenger turnover for a route.
P_i	Size of the population that live in all populated localities through which route passes.
f	Bus fare of one passenger per km.
D_i	Expected income.
C	Route expenses.
L_m	Route length.
s	Vehicle operation cost per km.
q	Capacity of a vehicle used for traffic.
R	Route profitability after calculation.
S_b	Set of bus stops
l	Set of bus routes
s	Bus stop
ŝ	Railway station
NB_l	Number of buses that depart from the terminal stop.
h	Headway between buses.
SD_{kl}	Terminal Departure time of kl^{th}bus.
ST_{kl}	Travel time ofkl^{th}bus.
T_{min}	Earliest terminal departure time of the first bus.
T_{max}	Latest terminal departure time of the first bus.
B^s	Number of bus berths atbus stop s.
d_l	Maximum bus dwell time at stop s.
C_t	Circle time for a particular bus route.
$SA_{[m][n]}$	Arrival time of m^{th} bus of the n^{th} circle.
x_{el}	Terminal departure time of first bus serving particular route after coordination.
η	Maximum fine-tuning factor applied to travel speed.
D	Walking distance between the bus stop and railway station.
w	Walking time between the bus stop and railway station.
w_t	Average accepted waiting time by passengers at the railway station.
t_e	Time shift is allocated to the terminal departure time of the first bus serving a particular route.
y_{kl}	Additional time shift to the terminal departure time of the individual bus.
z_{kl}	Time shift allocated to travel time from station s to s+1 for a particular bus route.
N_t	Total number of the bus arriving at time t for each route.
C_{sn}	Starting time of n^{th} cluster.
C_{en}	Ending time of n^{th} cluster.

Input data taken as reference were obtained from the following websites:

Nandanvan bus route schedule	https://citybusseva.in/rprtonandanvan.html
Chandkhuri bus route schedule	https://citybusseva.in/raipurtochankuri.html
Kharora bus route schedule	https://citybusseva.in/raipurtokharora.html
Urla bus route schedule	https://citybusseva.in/RAIPURRAILWAYSTATIONTOURLA.html
Silyari bus route schedule	https://citybusseva.in/raipurrailwaystationtosiliyarirailwaystation.html
Raipur train schedule	https://indiarailinfo.com/departures/raipur-junction-r/185

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