Urban Public Transport **Bus Scheduling Strategies** considering Resource availability constraints for day-to-day application.

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Problem Statement

- Public Transport agencies face challenges arising from unforeseen changes in bus availability which may be due to a variety of reasons such as vehicle breakdowns and unexpected crew absences.

- This leads to missing scheduled trips which ultimately adversely affects the waiting times of commuters and revenues collected by operators.

- A scientific data driven approach is needed to make the best decision possible in this situation.

Aim

- The aim of this study is to create practical and effective rescheduling strategies for bus-based urban public transport systems to mitigate the decrease in quality of service for the commuters arising from unforeseen changes in bus and crew with a focus on quick computational processing times.

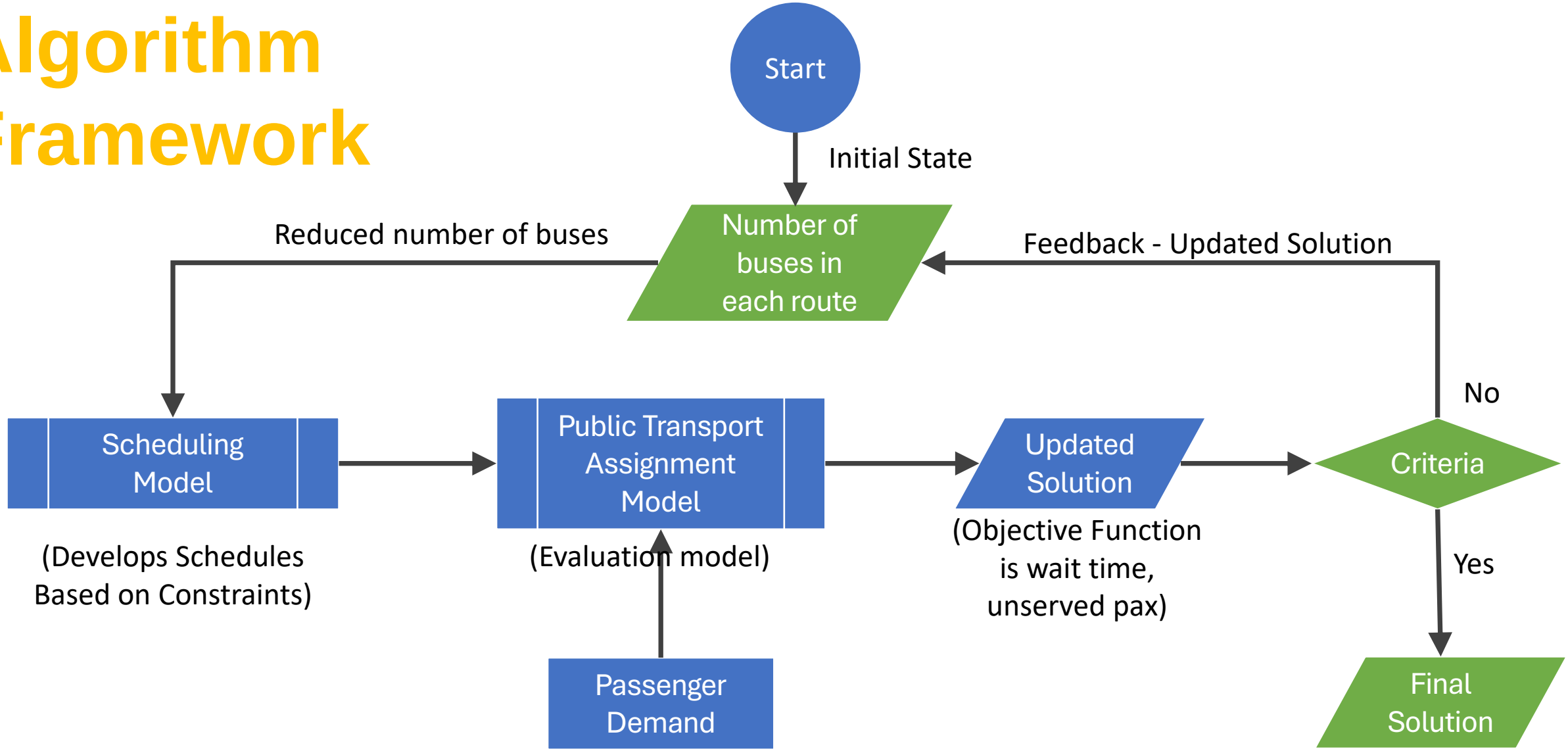
Objectives

1. Developing an algorithm to reallocate buses in a bus route network.

2. Application of the algorithm on test network to assess efficiency of the algorithm.

3. Assessment of the run time of the algorithm for practical application.

Algorithm Framework

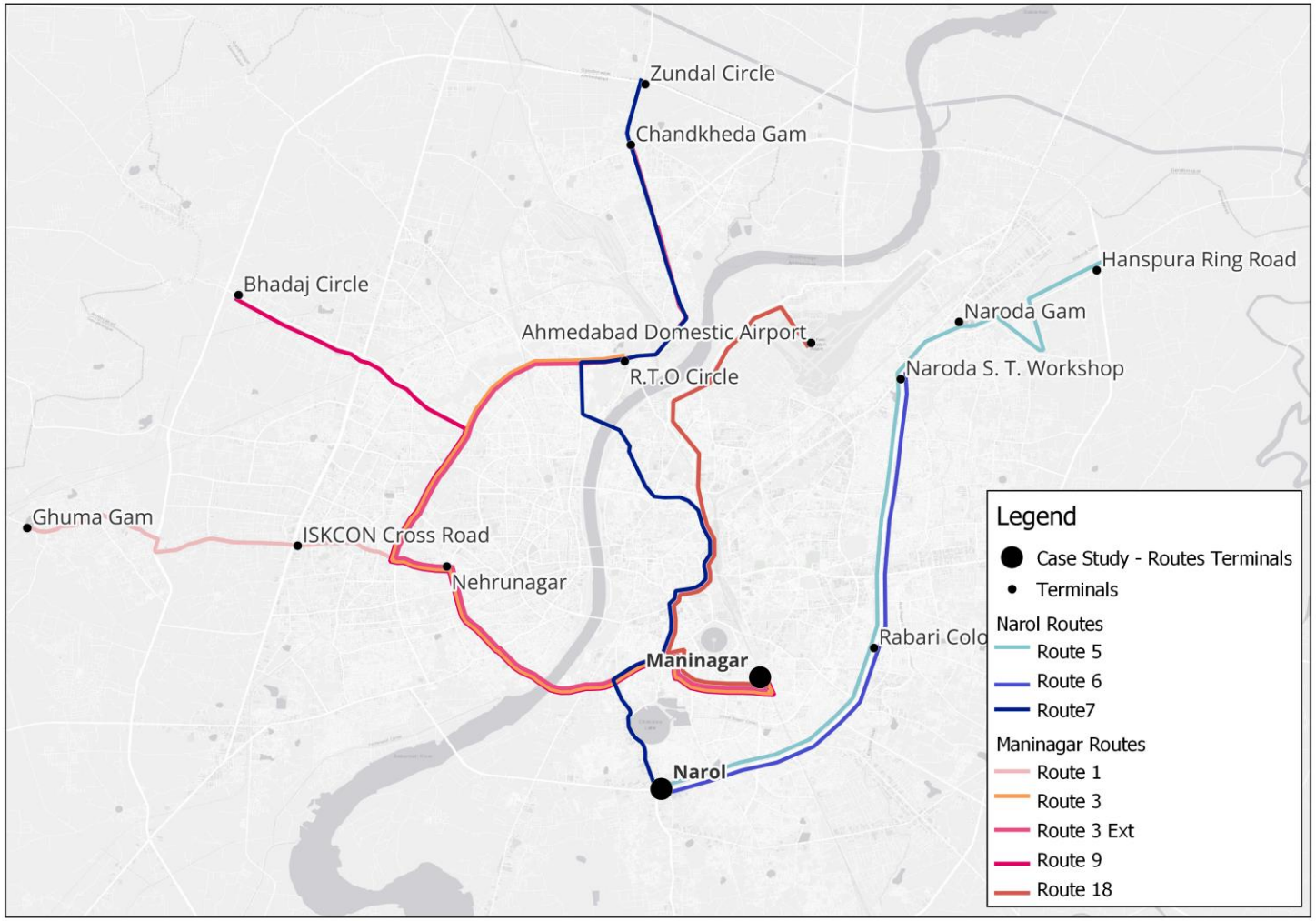


Criteria: Total number of buses available is equal to total number of buses in the updated solution

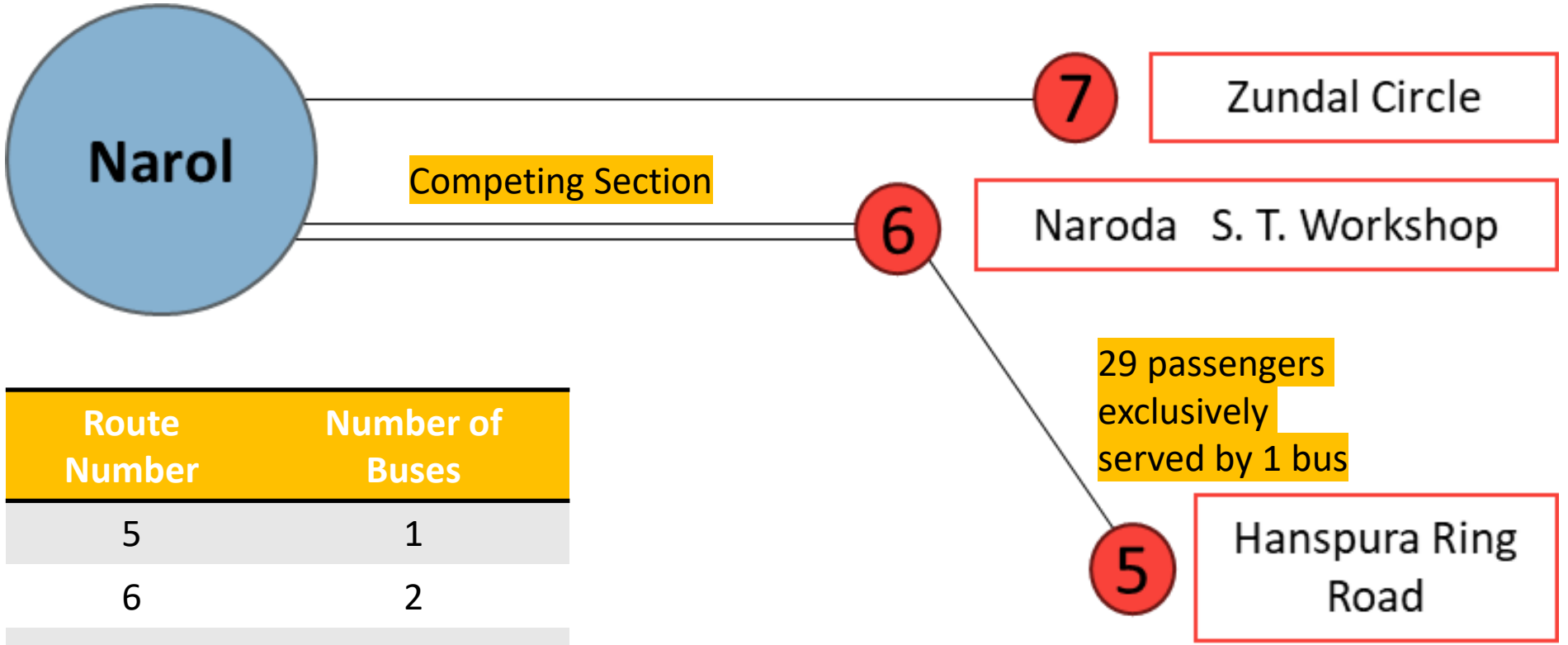
Test Cases

The formulated algorithm is tested with two cases

- Routes terminating at **Narol**.
- Routes terminating at **Maninagar**.



Narol Network – Schematic Diagram of Competing routes



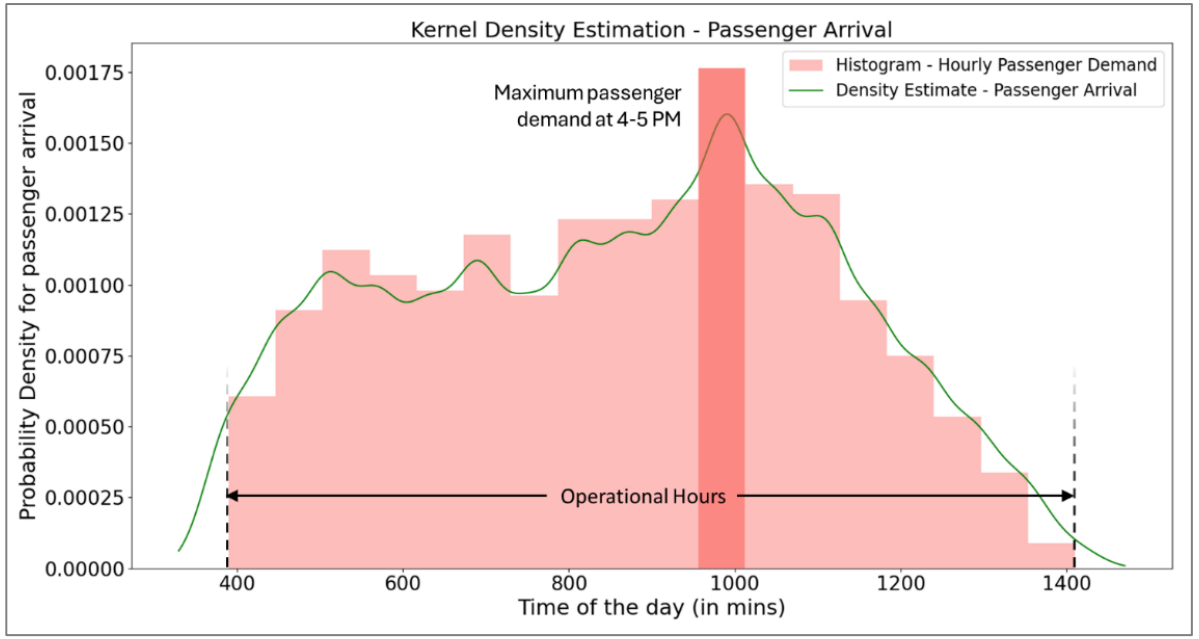
Route Number	Number of Buses
5	1
6	2
7	8

Problem to solve - Two of the eleven buses are unavailable for operations.

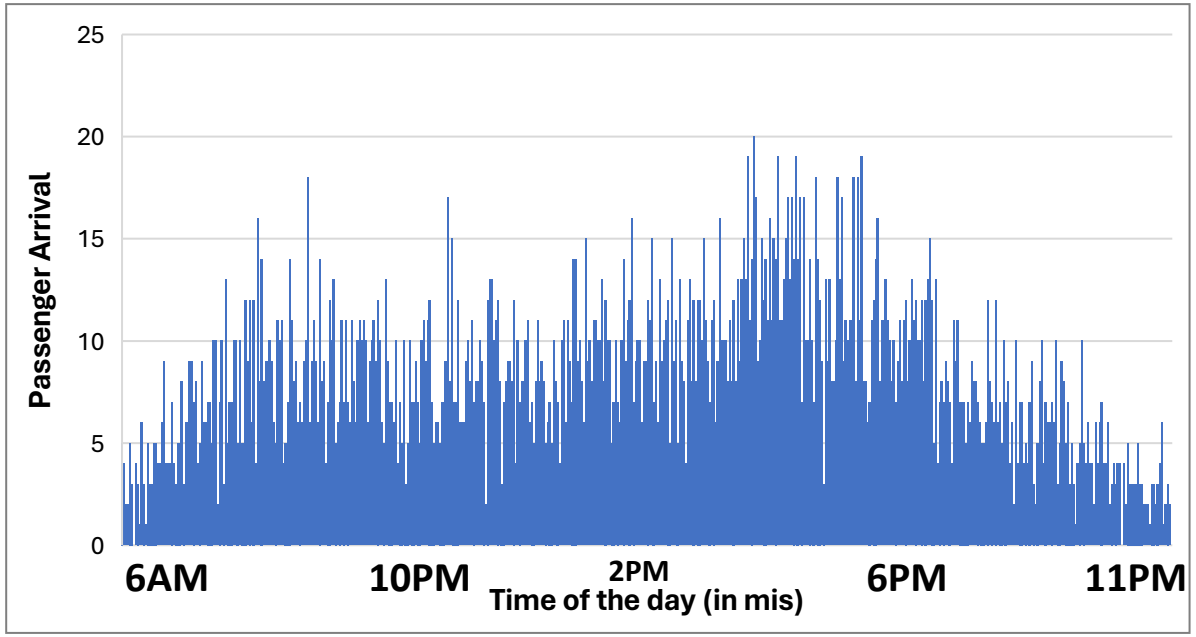
Narol Network – Passenger Demand

The Kernel Density Function is used to determine the probability density for arrival rates for each minute of the day based on hourly passenger demand.

Probability Density Function



Passenger Arrivals

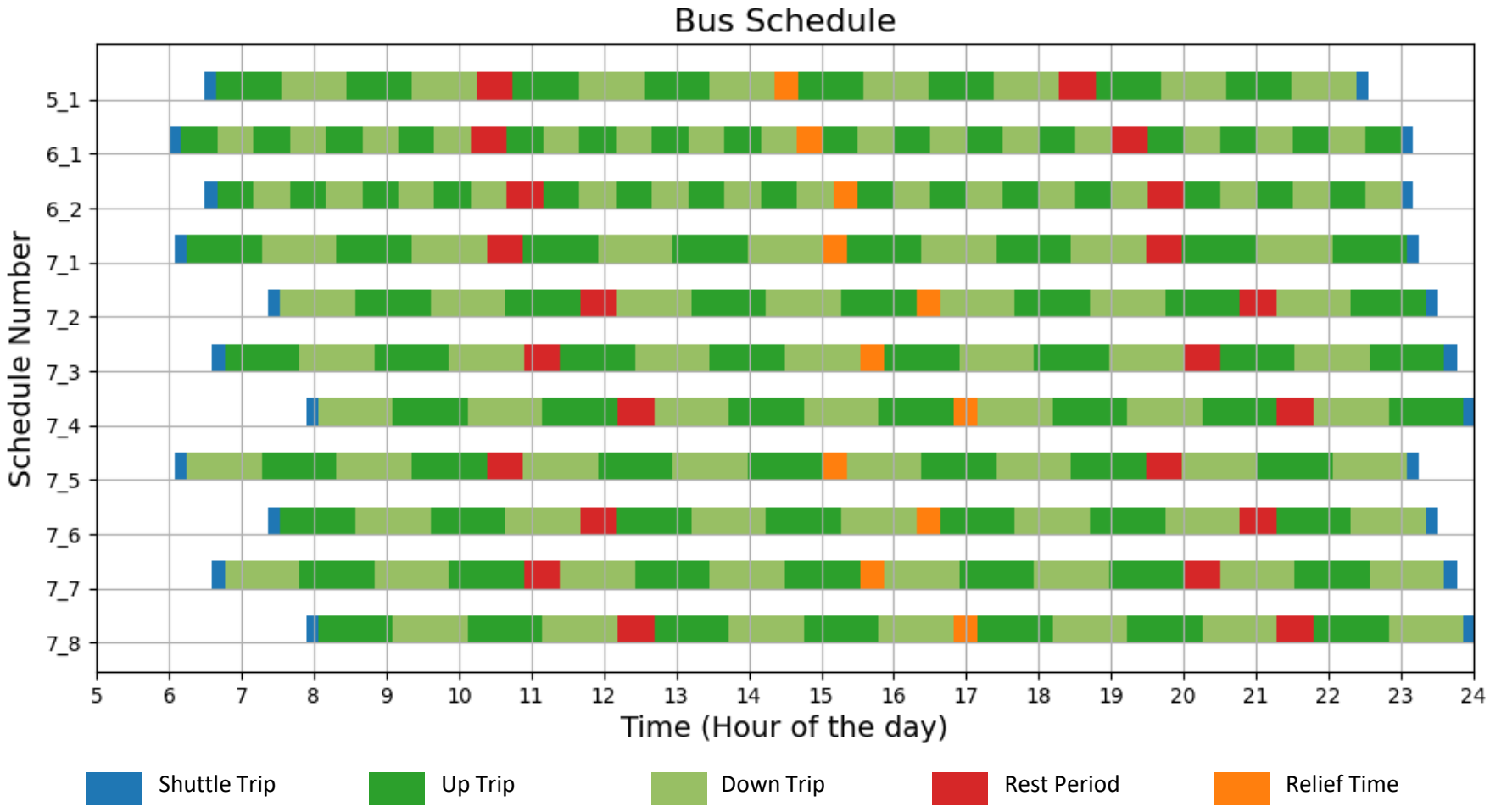


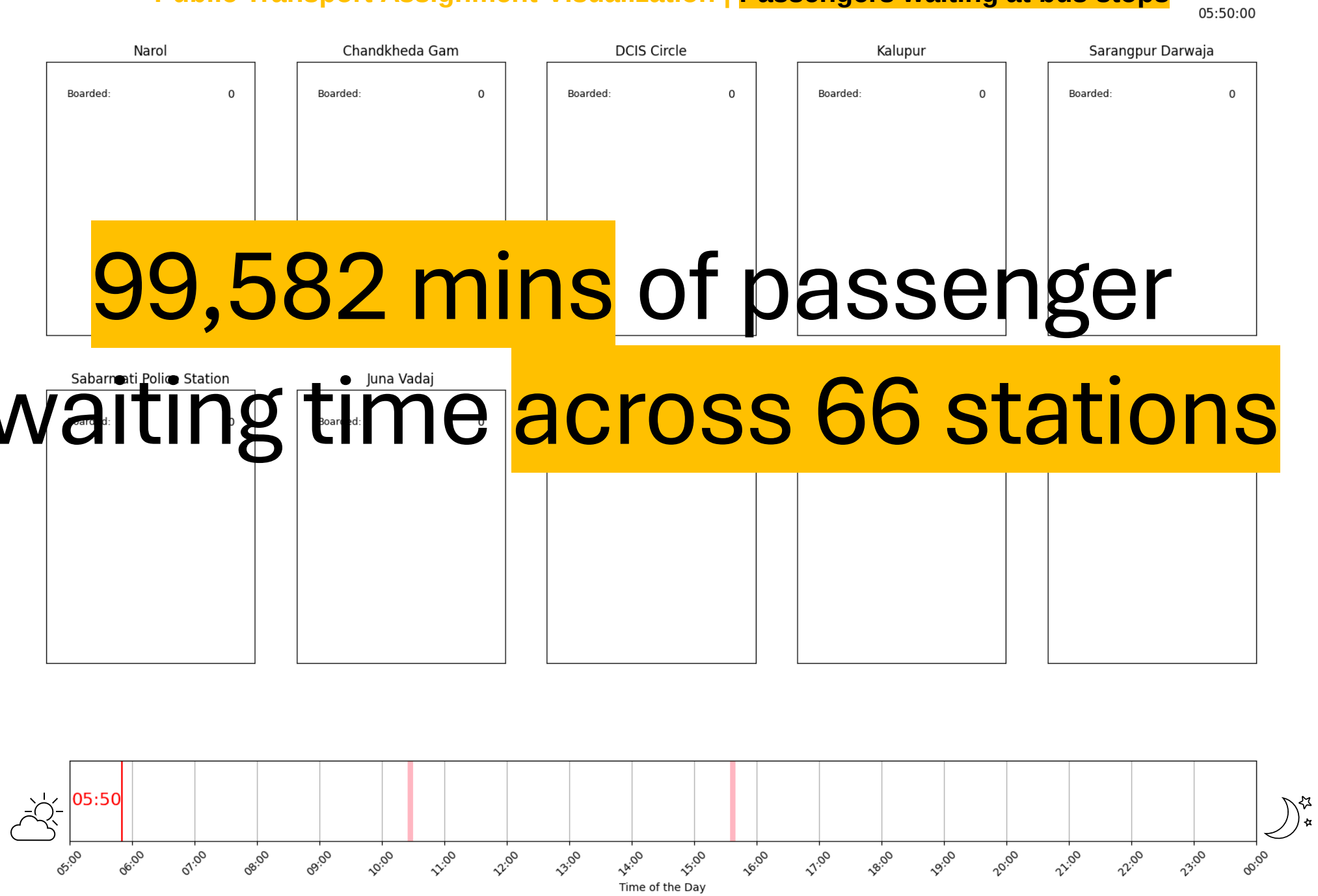
Scheduling Model Output: Narol Network, 11 Bus Schedules

Model Inputs & Constraints:

All details are provided for each route.

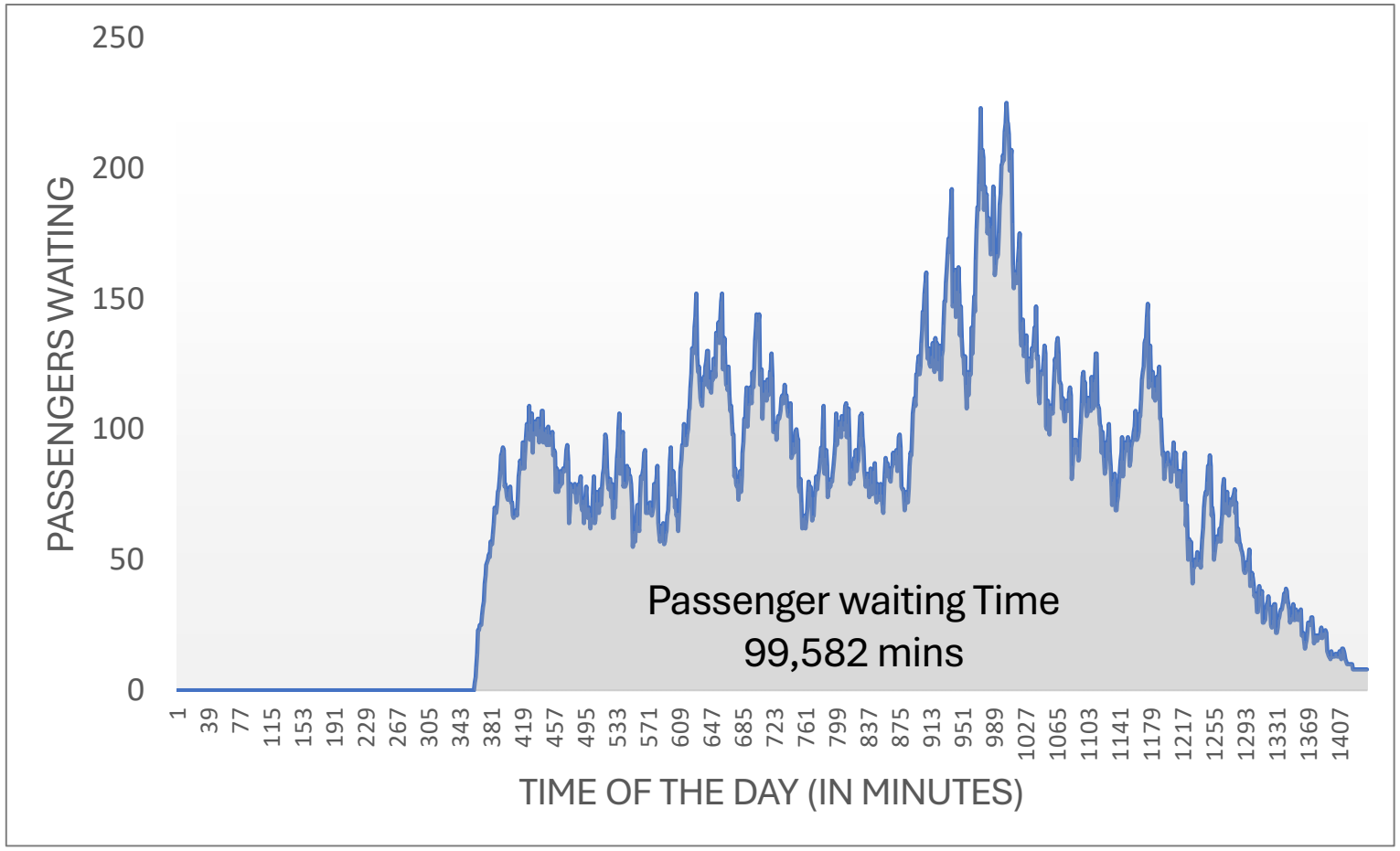
1. Route Number
2. No of buses
3. Trip duration (static)
4. Shuttle duration
5. Crew break duration
6. Crew change duration
7. Max crew work duration
8. Max crew half duration
9. Service start time
10. Depot
11. Terminals





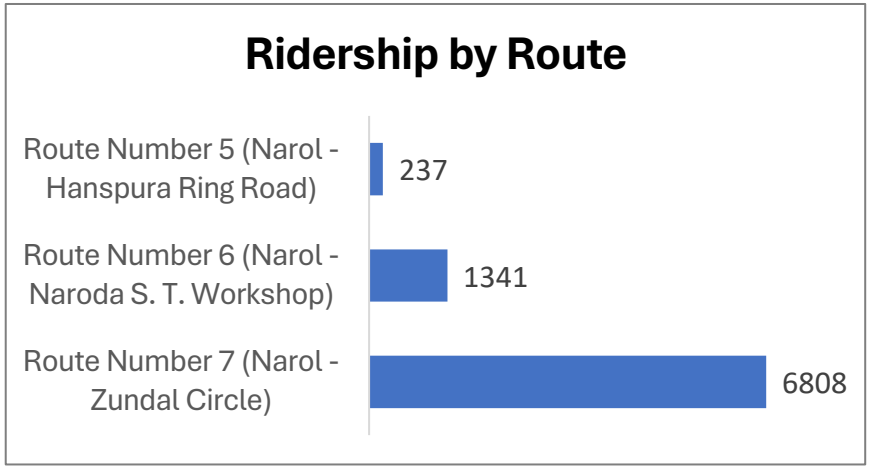
99,582 mins of passenger waiting time across 66 stations

Narol Network – Base Assignment results



Objective Function:

Average Passenger Waiting Time – 11.86
Passengers Unserved - 7



Narol Network – Best Solution for reducing 2 buses

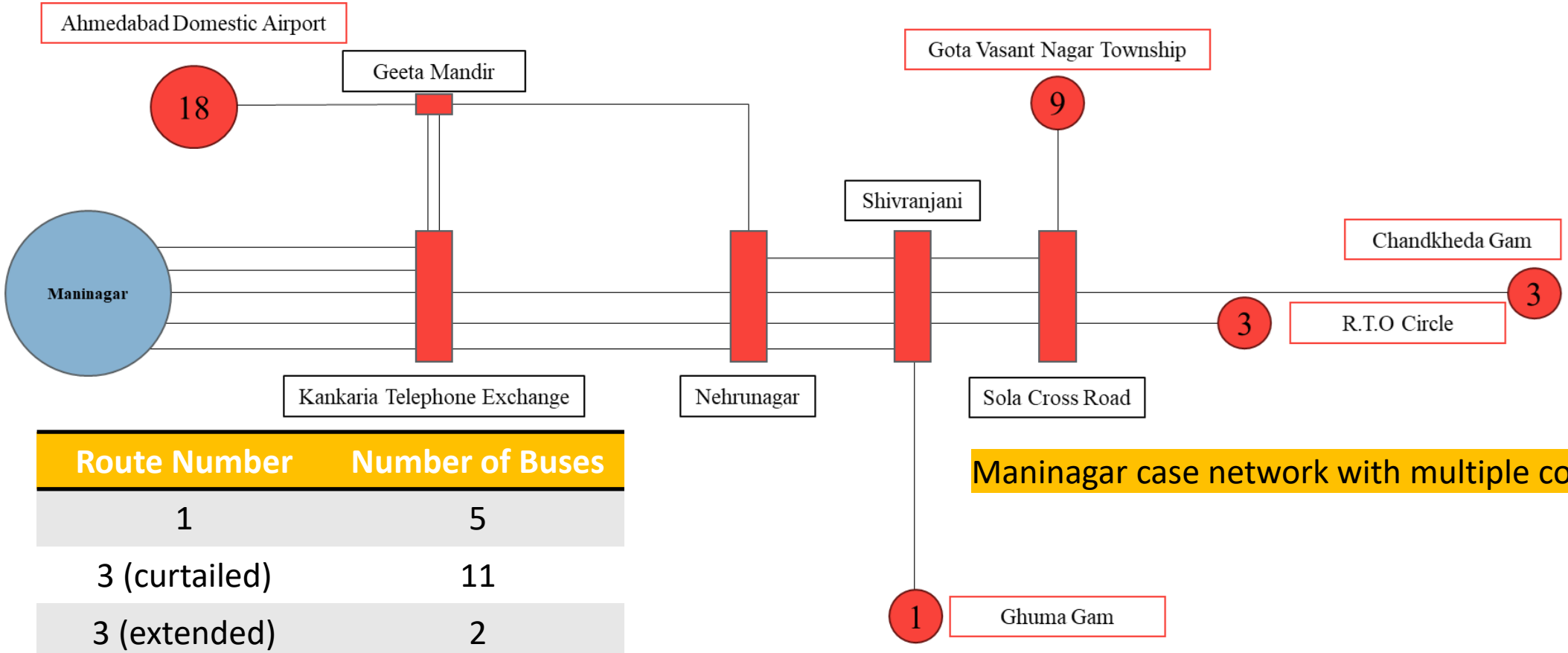
(Scheduling Model) → (Assignment Model)

Epoch/Batch	Iteration	Scheduling Model Inputs				Assignment Model Outputs			
		Route 5 (Buses)	Route 6 (Buses)	Route 7 (Buses)	Total Buses	Total Waiting Time (Mins)	Average Passenger Wait Time (Mins)	Passenger Unserved	
Base	Base	1	2	8	11	99582	11.86	7	(Base Solution)
Epoch 1	Iteration 1	0	2	8	10	99872	11.94	36	
	Iteration 2	1	1	8	10	153240	18.25	8	
	Iteration 3	1	2	7	10	111227	13.25	7	(Updated Solution)
Epoch 2	Iteration 1	0	2	7	9	111715	13.35	36	
	Iteration 2	1	1	7	9	219236	26.21	8	
	Iteration 3	1	2	6	9	130070	15.49	7	(Final Solution)

(Feedback)

(Feedback)

Maninagar Network – Competing Routes



Route Number	Number of Buses
1	5
3 (curtailed)	11
3 (extended)	2
9	7
18	17

Maninagar case network with multiple competing sections.

Problem to solve - 3 of the 42 buses are unavailable for operations.

Maninagar Network – Best Solution for reducing 3 buses

Epoch Batch	Iteration	Scheduling Model Inputs						Assignment Model Outputs			
		Route 18 (Buses)	Route 1 (Buses)	Route 3 Curt. (Buses)	Route 3 Ext. (Buses)	Route 9 (Buses)	Total Buses	Total Waiting Time (Mins)	Average Passenger Wait Time (Mins)	Passenger Unserved	
Base	Base	5	11	2	7	17	42	1,53,216	8.62	166	(Base Solution)
Epoch 1	Iteration 1-1	4	11	2	7	17	41	1,56,622	8.81	166	
	Iteration 1-2	5	10	2	7	17	41	1,57,342	8.85	166	
	Iteration 1-3	5	11	1	7	17	41	1,54,601	8.70	168	
	Iteration 1-4	5	11	2	6	17	41	1,54,775	8.70	166	
	Iteration 1-5	5	11	2	7	16	41	1,53,239	8.62	166	(Updated Solution)
Epoch 2	Iteration 2-1	4	11	2	7	16	40	1,60,392	9.02	166	
	Iteration 2-2	5	10	2	7	16	40	1,60,782	9.04	166	
	Iteration 2-3	5	11	1	7	16	40	1,58,108	8.89	168	
	Iteration 2-4	5	11	2	6	16	40	1,58,107	8.89	166	(Updated Solution)
	Iteration 2-5	5	11	2	7	15	40	1,60,868	9.05	166	
Epoch 3	Iteration 3-1	4	11	2	6	16	39	1,61,770	9.10	166	
	Iteration 3-2	5	10	2	6	16	39	1,62,092	9.12	166	
	Iteration 3-3	5	11	1	6	16	39	1,59,387	8.97	168	
	Iteration 3-4	5	11	2	5	16	39	1,61,557	9.09	166	(Final Solution)
	Iteration 3-5	5	11	2	6	15	39	1,62,395	9.14	166	

(Feedback)

(Feedback)

(Feedback)

Program Runtime

Schedule Generation Model Run Time

$$schedule\ run\ time(secs) = 0.028x,$$

where:
x is number of fleet size

Passenger Assignment Model Run Time

$$y = 0.24x$$

$$assignment\ run\ time\ (secs) = 0.24x,$$

where:
x is total number of bus trips

Fleet Size

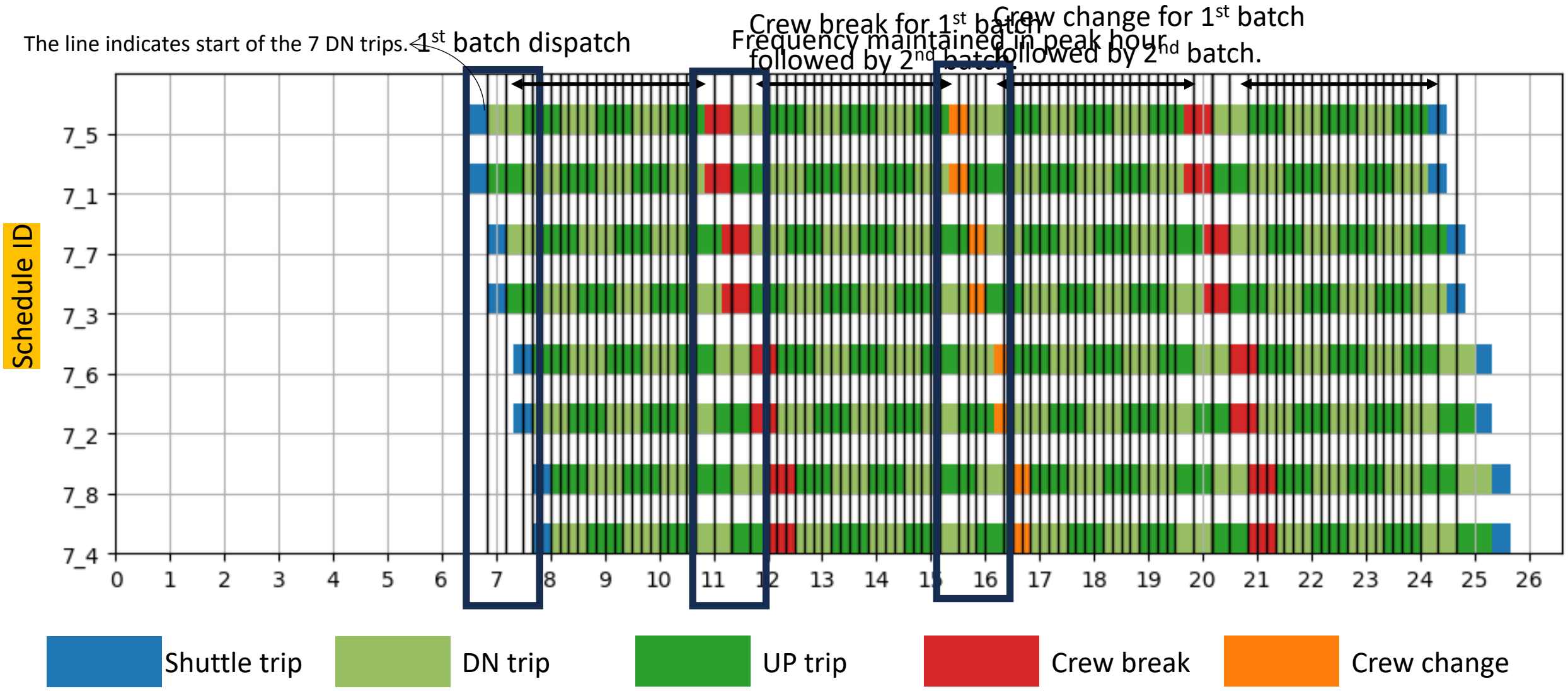
Number of Buses Unavailable	10	20	30	40	50	60	70	80	90	100
1	1	3	6	11	17	25	34	45	57	70
2	1	6	13	22	35	50	68	89	113	140
3	2	8	19	34	52	75	103	134	170	209
4	3	11	25	45	70	101	137	179	226	279
5	3	14	31	56	87	126	171	223	283	349
6	4	17	38	67	105	151	205	268	339	419
7	5	20	44	78	122	176	239	313	396	489
8	6	22	50	89	140	201	274	357	452	558
9	6	25	57	101	157	226	308	402	509	628
10	7	28	63	112	175	251	342	447	565	698

Practical Application

- A real-world application of the model, in a mid sized city will help in improvisation of public transport system and efficiency of the model.
- Initially, the model shall be used for base allocation of buses within a network to optimize system-level wait time.
- For contingency plans (for all possibilities) should be formulated as preliminary solutions, while the base schedules are prepared.
- We shall explore on possibilities where; the solutions shall be prescribed to depot managers based on the pre-generated contingency plans. The standard operating procedure will shall include the contingency plans (schedules) to be followed in case of uncertainties.

THANK YOU

Understanding the Scheduling model



Passengers Accumulation at Stops – Visualization