Design and Implementation of a Demand Responsive Mobility as a Service

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PACIFIC TELECOMMUNICATIONS COUNCIL

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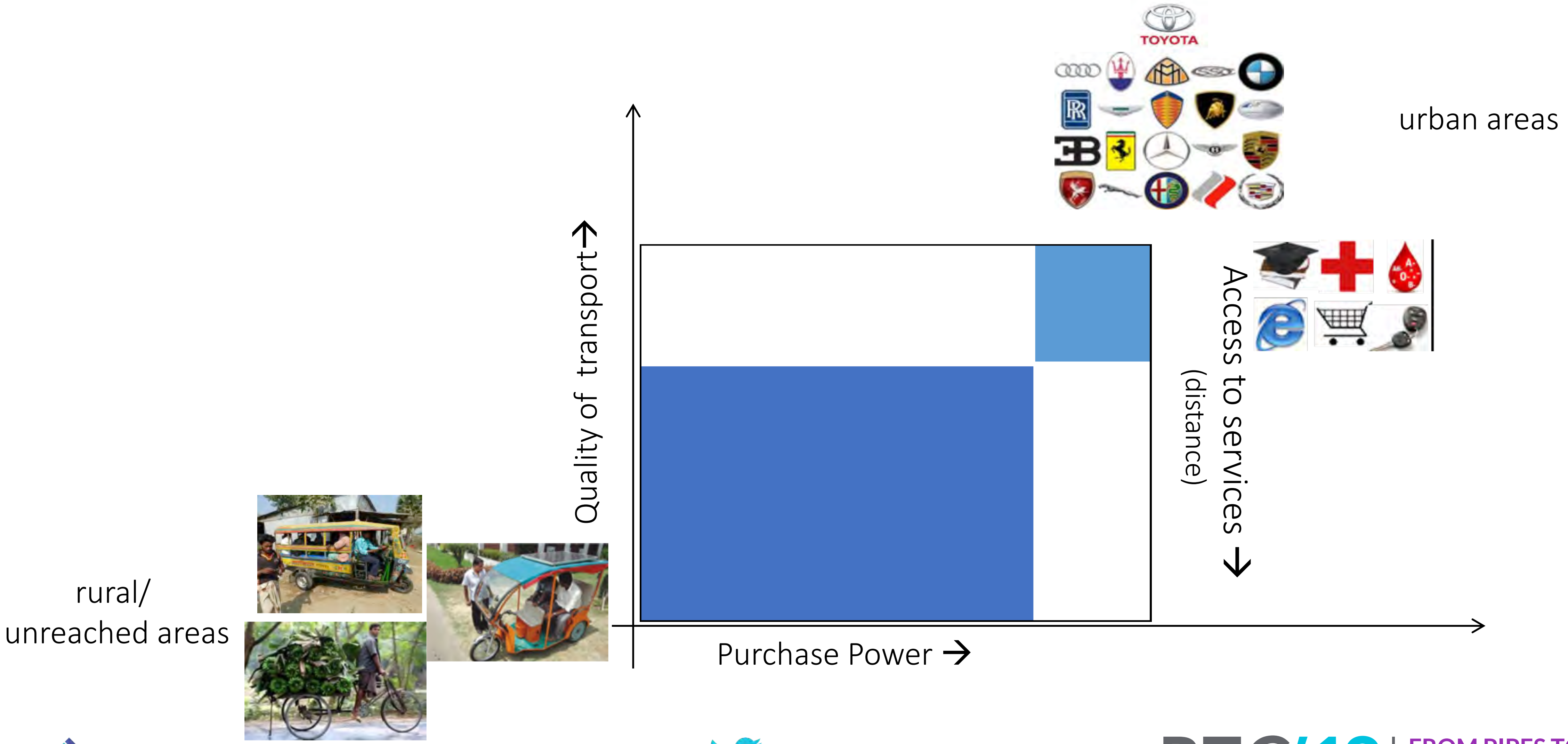
Outline

1. Introduction
2. Demand Responsive Transport
3. Our Approach: Demand Responsive MaaS
4. Scheduling Demand Responsive MaaS
5. Experiment, Results and Evaluation
6. Conclusion

RESEARCH MOTIVATION

Quality of transport vs. access to social services



Motivation

Social Need

for quality and affordable transport alternative

Technological Improvement

scheduling and routing algorithms

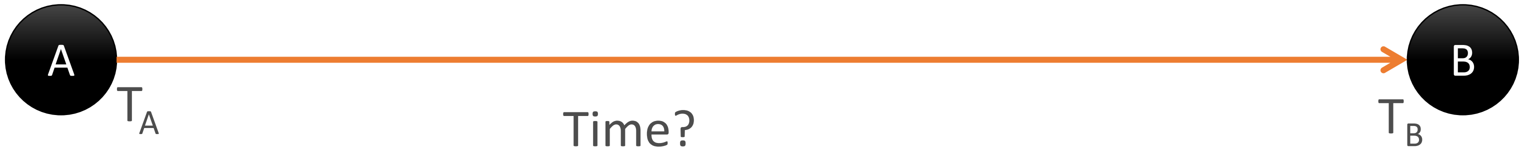
Innovation Opportunity

Demand Responsive Community Mobility Service

DEMAND RESPONSIVE MOBILITY

Objective of Mobility

Moving from one place to another

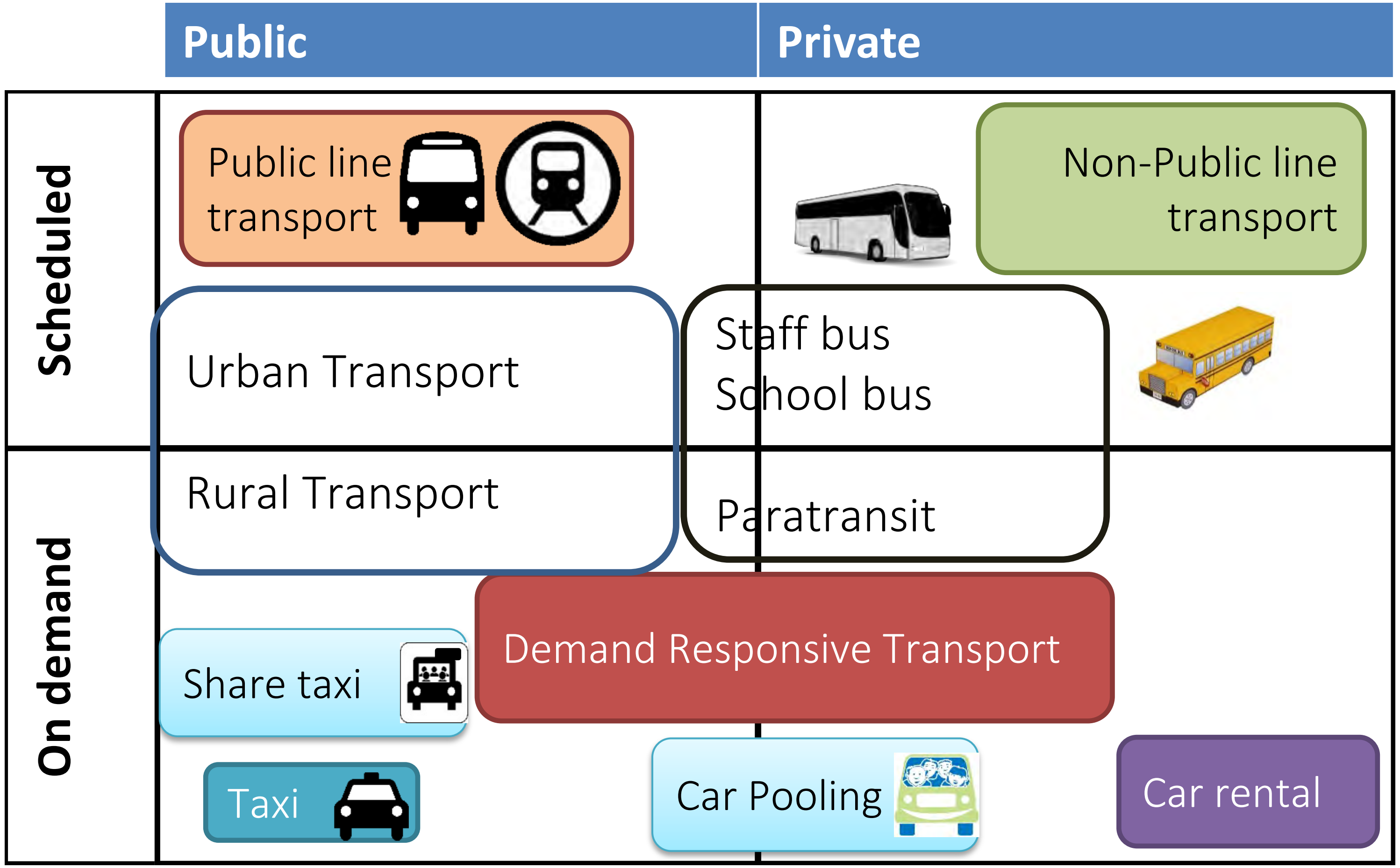


Time?
Cost?
Comfort?

	Time efficient	Cost efficient	Comfortable	Flexibility
Taxi	○	×	○	○
DRT	△	△	△	△
(Shared) **Bus, Train** (Developing countries)	△×	○	△×	×

DRT – Demand Responsive Transport

Shared Mobility Accessibility



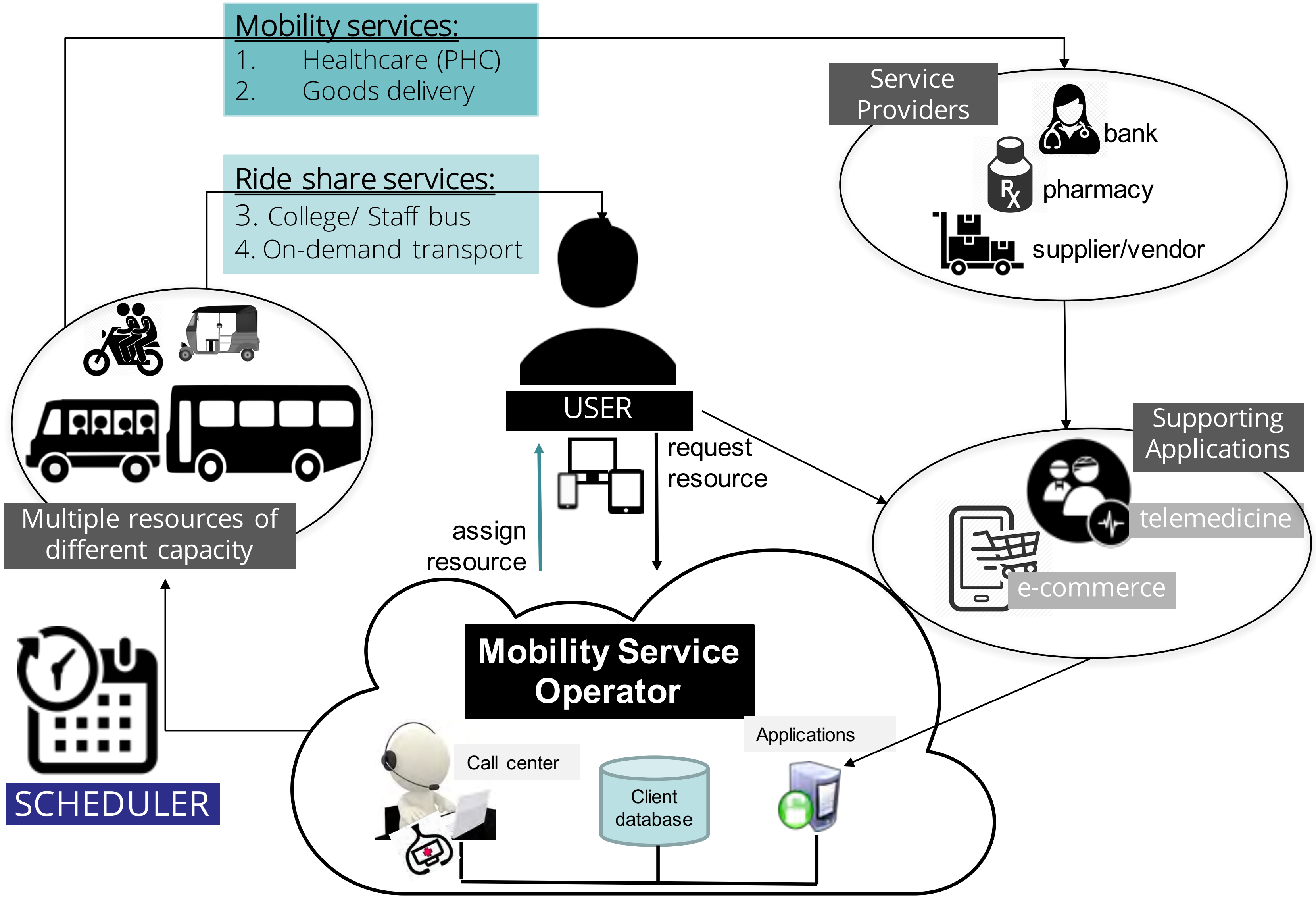
Public: Ride is accessible to everyone
Private: Ride only accessible to registered persons

From Ownership to Sharing

If owning a car is prohibitive for the last mile community, can the community share a car?

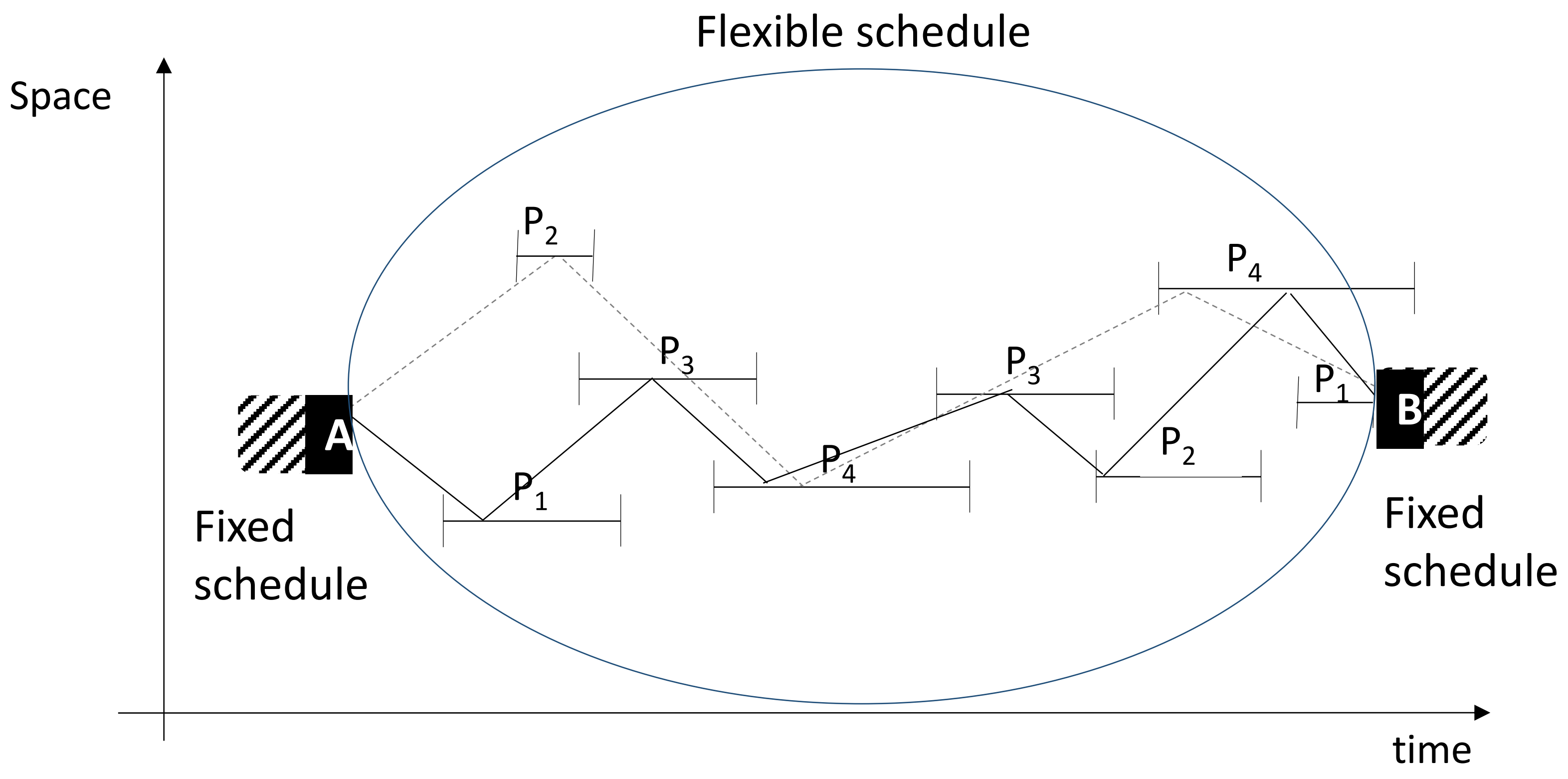
COMMUNITY SHARED MOBILITY SERVICE

Community Shared Mobility Model



Scheduling Shared Mobility Service

The scheduling problem



P_1 (S_1, T_1, TW_1)
P_2 (S_2, T_2, TW_1)

P_3 (S_3, T_3, TW_1)
.
.
.
P_n (S_n, T_n, TW_n)

A (S_A, T_A)
B (S_B, T_B)

$$S_1 \geq S_A \text{ and } T_1 \geq T_A$$
$$S_n \leq S_B \text{ and } T_n \leq T_B$$
$$\text{Min} \sum_1^n RideTime(S_{n-1}, S_n)$$

pickup and drop off time window for passengers

fixed vehicle schedule stop points

OBJECTIVE:
minimizing travel time and user waiting time, while maximizing number of users served

Where;
P: passenger
S: stop
T: time
TW: time window

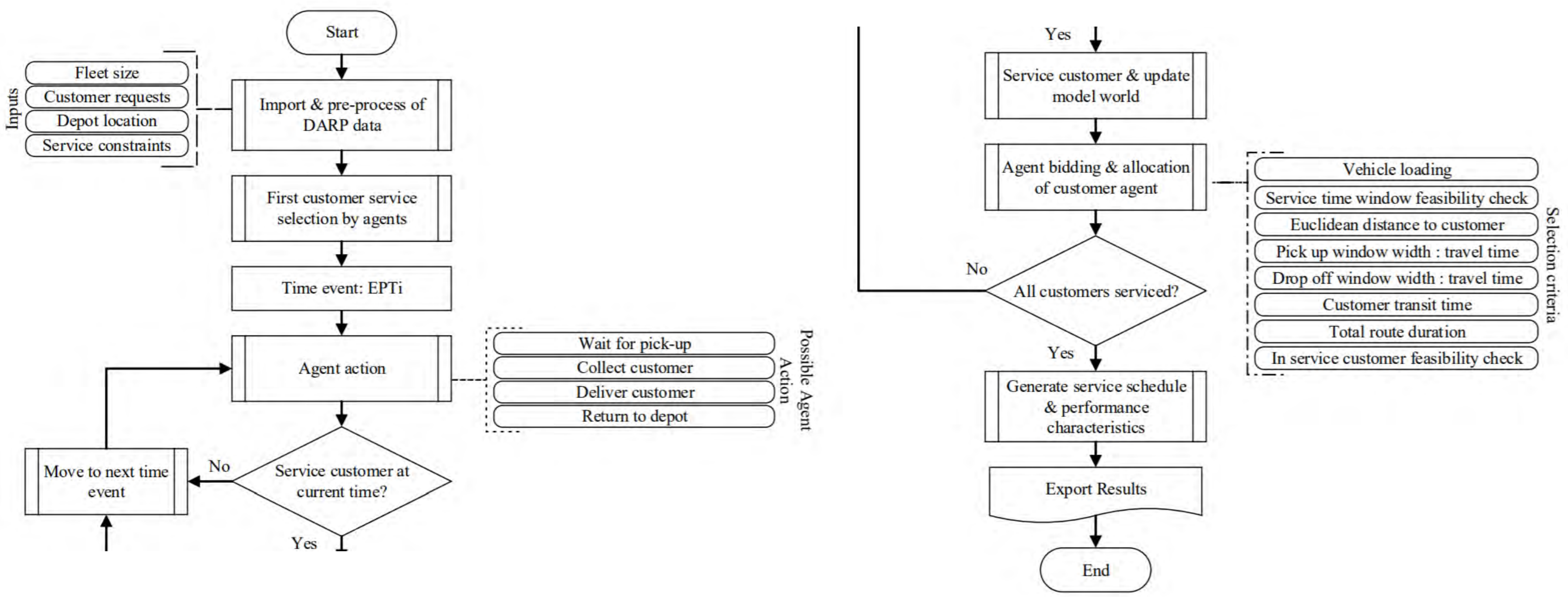
Related Research Review

*Selected Literature

DRT Scheduling Research	Goal	Constraints	Approach	Result
ADARTW [1]	ensure ride time is not exceeded and time window is respected	fixed stops vehicle capacity	Heuristic insertion Upper bounds on ride time and time window	average waiting time 15 minutes.
IATRS [2]	assure passenger arrival time	fixed stops vehicle capacity	Time windows	average waiting time 9 minutes
POCS [3]	provide estimated time instantaneously	real time requests flexible stops	upper bounds on ride time	average waiting time 5 minutes
Community Shared Mobility (Our Approach)	reduce waiting time maximize passenger turnover	-both fixed and flexible stops -vehicle capacity -quorum	Heuristic insertion Time windows	

[1] Jang-Jei Jaw, Amedeo Odoni, Harilaos Psataftis and Nigel Wilson, "A Heuristic algorithm for the multi-ride advance request dial-a-ride problem with time windows, Transport Research Part B, vol. 208, no. 3 pp. 243-257 (1986)
[2] Kota Tsubouchi,et. al., "The Development of A New Public Transportation System: On-Demand Bus", Proceedings of AEARU Joint Workshop - International Collaboration for Asian Sustainable Society(ICASS07), pp. 363-366, Wuxi, China (2007)
[3] Masabumi Furuhata, Liron Cohen and Sven Koenig, "Online Cost-Sharing Mechanism Design for Demand-Responsive Transport Systems", METRANS Transportation Center (2003)

Solution Model



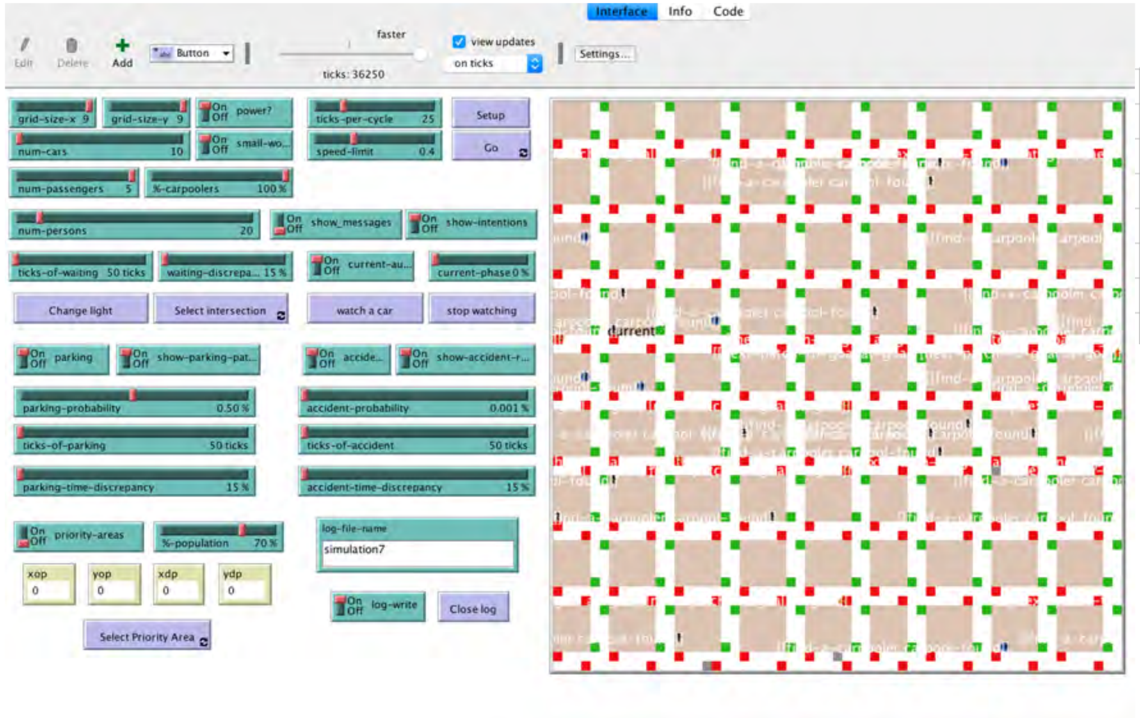
Validating Our approach

Simulation & Experiment

Simulation Configuration

	Configuration 1	Configuration 2
Number of requests	100	100
Time Window	15	5,10,15,20
Stop points	10	10
Stop time	20 seconds	5-20 seconds
Max ride time	1:30 hrs	1:30 hrs
Fleet size	1 vehicle	1 vehicle
Vehicle speed	30 kmph average	30 kmph average
Vehicle capacity	10 seats	10 seats
Vehicle operating hours	12	12

Simulation Design



INPUT

Passenger	Source	Destination	RPT	RDT	TW
Request					
1	S1	S8		08:00	00:10
2	S1	S8		08:10	00:20
3	S6	S10		08:30	00:15
4	S4	S6	07:30		00:10
5	S1	S10		08:40	00:20
6	S2	S5	06:50		00:10

STORED DATA

travel time matrix

	S1	S2	S3	S4	S5	S6	S7
S1		0:10	0:20	0:30	0:40	0:50	1:00
S2	0:10		0:10	0:20	0:30	0:40	0:50
S3	0:20	0:10		0:10	0:20	0:30	0:40
S4	0:30	0:20	0:10		0:10	0:20	0:30
S5	0:40	0:30	0:20	0:10		0:10	0:20

OUTPUT

vehicle schedule									
Trip 1	Stops	EST	LST	waiting time	travel time	Passenger in	Passengers off	booked seats	empty seats
	S1	7:00	7:02	0:02		8	0	8	2
	S2	7:10	7:10	0:00	0:10	2	0	10	0
	S3	7:20	7:20	0:00	0:10	0	0	10	0
	S4	7:30	7:31	0:01	0:10	1	1	10	0
	S5	7:40	7:42	0:02	0:10	2	5	7	3
	S6	7:50	7:56	0:06	0:10	4	1	10	0

*Scheduled trips are manifested

Where;
P: passenger
S: stop
T: time
TW: time window

6 demand trips
84.7% accepted requests

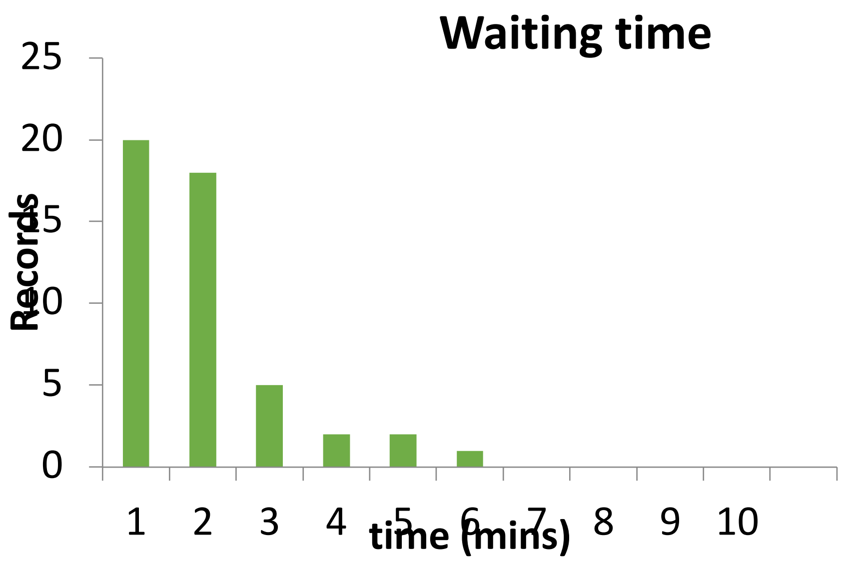
•Wilensky, U. (1999). NetLogo. http://ccl.northwestern.edu/netlogo/. Center for Connected Learning and Computer-Based Modeling, Northwestern University, Evanston, IL.

Results: Time performance (Fixed Time Window and Stop time)

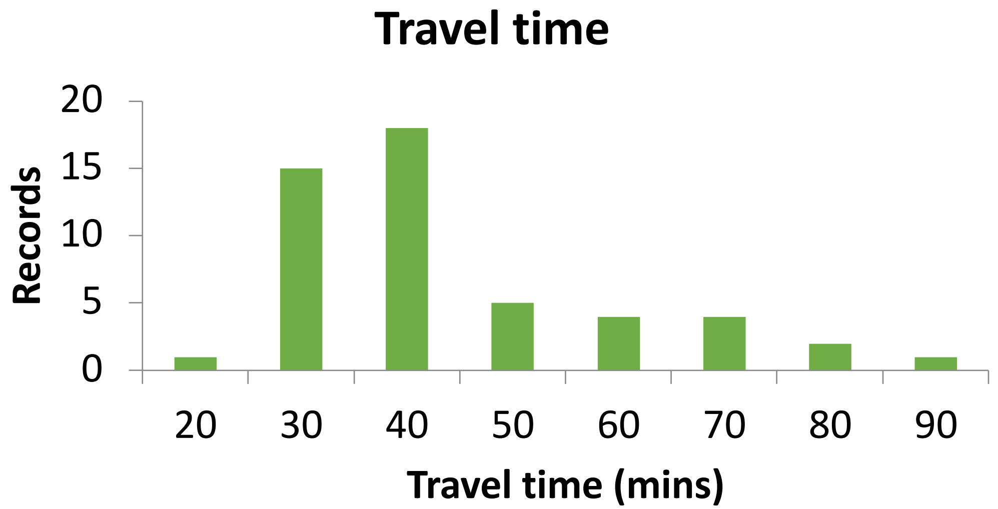
Average passenger turnover: 74%
Average waiting time: 5 mins
(reduced by 44.4%
compared to DRT research review)

Kota Tsubouchi,et. al., "The Development of A New Public Transportation System: On-Demand Bus", Proceedings of AEARU Joint Workshop - International Collaboration for Asian Sustainable Society(ICASS07), pp. 363-366, Wuxi, China (2007)

Results: Time performance (variable Time window and Stop time)

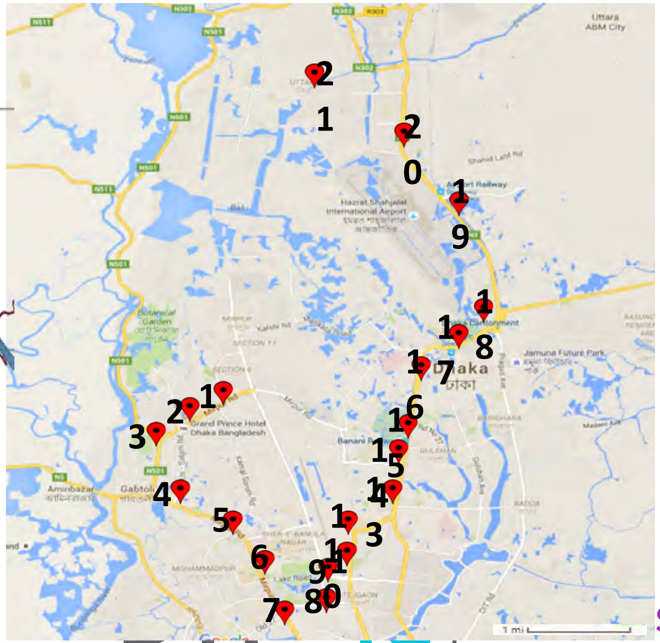


Average passenger turnover: 84.7%
Average waiting time: 2 mins
(reduction by 60%)

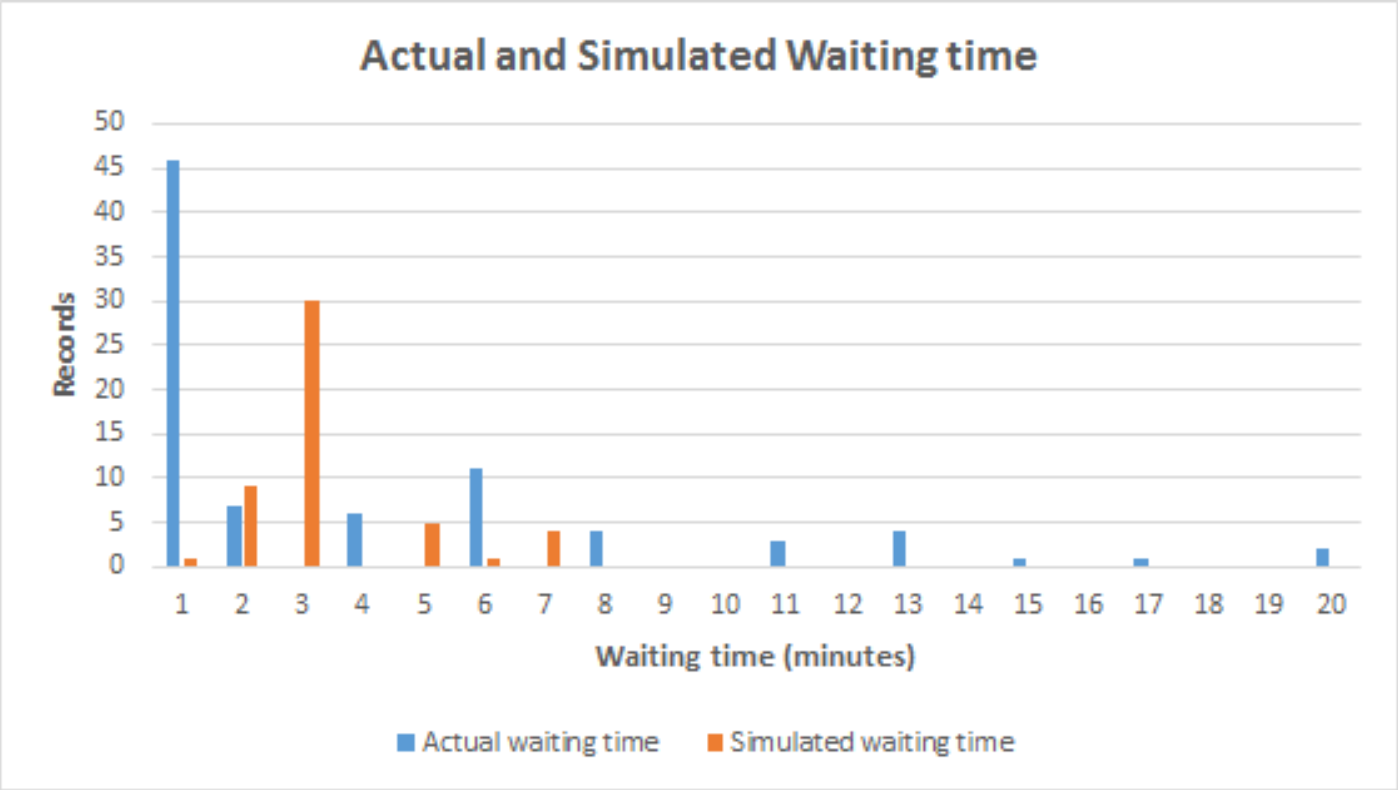


Experiment Profile

- Dhaka, Bangladesh
- Route: 32km
- 2 Toyota Hiace
- 4 Notebook PCs
- 2 Driver consoles
- Call center
- Operation hours: 12
- Web and Android Application



Experiment Result: Time performance



Average waiting time: 3 mins

(reduced to 25% compared to current shared public transport in Dhaka)

On Demand Bus
operation data at a glance

Overview

6 Stops, 2 trips per day in Urban
6 Stops, 3(2) trips per day in Rural

Tk.44,190
Revenue collected

Days **Operated** **56/61** Working days

Days **Recorded** **53/61** Working days

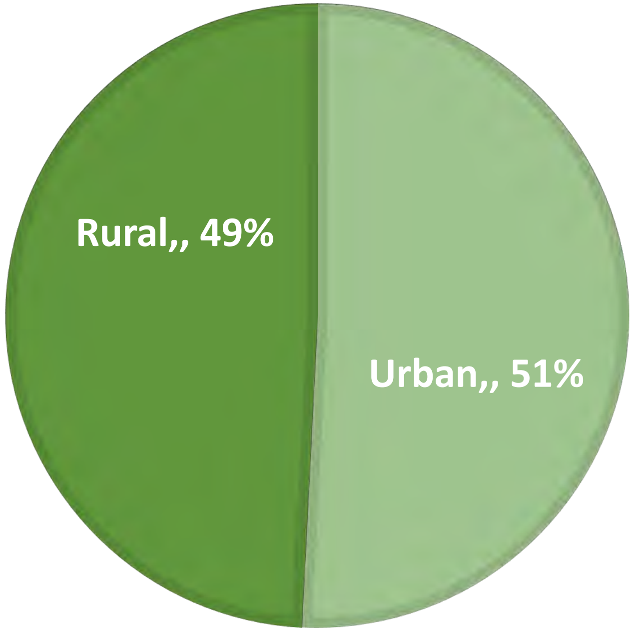
185
Total no. of trips

897
Rides given

Trip Turn over

185/244

Total no. of trips planned

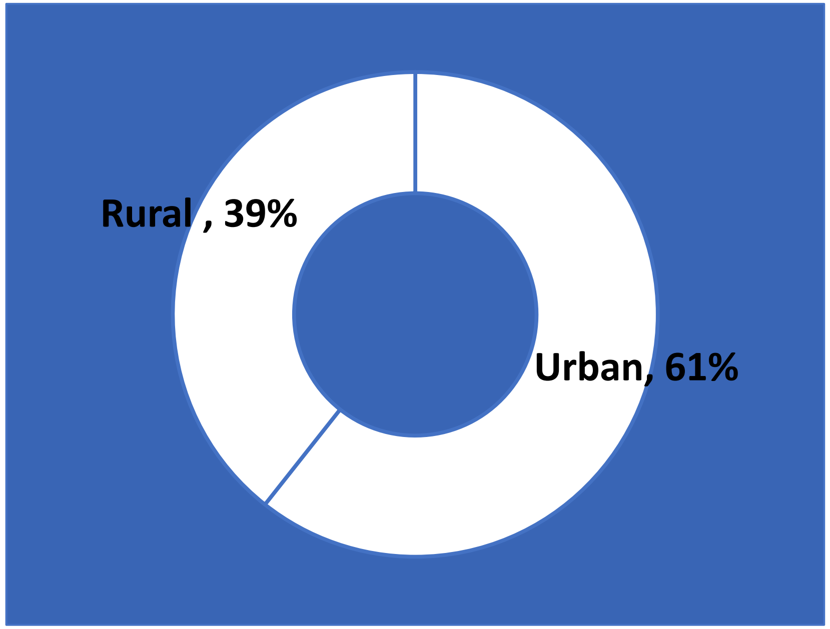


- 75.82% trip turn over
  - 77.05% in Dhaka
  - 65% in Bheramara

- Dhaka has more fulfilled trips than in Bheramara.
  - Due to consistency of staff bus service.

Passengers

897 Cumulative number of passengers



- More passengers in Dhaka

Challenges and suggestions

- Booking process to set up schedule is complicated for users.
  - Suggestion: Simpler interface is suggested; voice recorded input is suggested for less computer literate users without smartphones/ internet access.
- Route changes quite often. It takes time to create new system data files as the system error messages are difficult to understand and take time to troubleshoot. (average 2 days)
  - Suggestion: Automated interface for updating system logs
  - Suggestion: Automatically design system defined route based on user requirements.
- Actual travel time only provided by bus navigation start and end time. Takes lot of time to analyze every day file one by one.
  - Suggestion: Use machine learning to automatically sort out the data for analysis.
- Other vehicle usage data not included in this report.
  - Suggestion: Automatically analyze bus navigation (GPS) data other vehicle usage times and purpose to establish actual vehicle usage vs idle time.

CONCLUSION

Research Contribution and Impact

Society

Quality and affordable transport alternative

Technology

Time and quorum constrained trip scheduling algorithm with reduced waiting time

Business

Community shared mobility model with entrepreneurship opportunity

Summary

- Addressed provision of quality affordable transport alternative.
- Reviewed research in Demand Responsive Transportation offers transport service only on demand and does not consider fixed schedule and quorum.
- Proposed a DRT based mobility as a service model that incorporates multiple services on a vehicle to maximize usage of the vehicle.
- Formulated a trip scheduling algorithm that takes into account the vehicle on-going schedule, quorum and fair cost sharing constraints.
- Our solution resulted in reduced waiting time and increased passenger turn over.

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