Design and Implementation of a Demand Responsive Mobility as a Service

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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
Quality of transport vs. access to social services

Quality of transport vs. access to social services in rural/unreached areas versus urban areas.

- Quality of transport
- Access to services (distance)
- Purchase Power

Urban areas vs. rural/unreached areas.
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


<table>
<thead>
<tr>
<th></th>
<th>Time efficient</th>
<th>Cost efficient</th>
<th>Comfortable</th>
<th>Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taxi</td>
<td>○</td>
<td>×</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td>DRT</td>
<td>△</td>
<td>△</td>
<td>△</td>
<td>△</td>
</tr>
<tr>
<td>Bus, Train</td>
<td>△</td>
<td>○</td>
<td>△</td>
<td>×</td>
</tr>
</tbody>
</table>

DRT – Demand Responsive Transport

(Shared) (Developing countries)
### Shared Mobility Accessibility

<table>
<thead>
<tr>
<th>Public Line Transport</th>
<th>Non-Public Line Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scheduled</strong></td>
<td></td>
</tr>
<tr>
<td>Urban Transport</td>
<td>Staff bus</td>
</tr>
<tr>
<td></td>
<td>School bus</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>On demand</strong></td>
<td></td>
</tr>
<tr>
<td>Rural Transport</td>
<td>Paratransit</td>
</tr>
<tr>
<td>Share taxi</td>
<td>Demand Responsive Transport</td>
</tr>
<tr>
<td>Taxi</td>
<td></td>
</tr>
<tr>
<td>Car Pooling</td>
<td></td>
</tr>
<tr>
<td>Car rental</td>
<td></td>
</tr>
</tbody>
</table>

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

Mobility services:
1. Healthcare (PHC)
2. Goods delivery

Ride share services:
3. College/Staff bus
4. On-demand transport

Multiple resources of different capacity

Service Providers
- bank
- pharmacy
- supplier/vendor

Supporting Applications
- telemedicine
- e-commerce

Mobility Service Operator
- Call center
- Client database

SCHEDULER

USER
- request resource
- assign resource
Scheduling Shared Mobility Service
The scheduling problem

**Flexible schedule**

- P1 (S1, T1, TW1)
- P2 (S2, T2, TW1)
- P3 (S3, T3, TW1)
- \( P_n (S_n, T_n, TW_n) \)

**Fixed schedule**

- A (SA, TA)
- B (SB, TB)

**Objective:**
- Minimizing travel time and user waiting time, while maximizing number of users served

Time conditions:
- \( S_1 \geq S_A \) and \( T_1 \geq T_A \)
- \( S_n \leq S_B \) and \( T_n \leq T_B \)

\[
\text{Min} \sum_{1}^{n} \text{RideTime}(S_{n-1}, S_n)
\]

Where:
- \( P \): passenger
- \( S \): stop
- \( T \): time
- \( TW \): time window

**Fixed vehicle schedule stop points**

- pickup and drop off time window for passengers
**Related Research Review**

*Selected Literature*

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

Solution Model
Validating Our approach
Simulation & Experiment
## Simulation Configuration

<table>
<thead>
<tr>
<th></th>
<th>Configuration 1</th>
<th>Configuration 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of requests</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Time Window</td>
<td>15</td>
<td>5, 10, 15, 20</td>
</tr>
<tr>
<td>Stop points</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Stop time</td>
<td>20 seconds</td>
<td>5-20 seconds</td>
</tr>
<tr>
<td>Max ride time</td>
<td>1:30 hrs</td>
<td>1:30 hrs</td>
</tr>
<tr>
<td>Fleet size</td>
<td>1 vehicle</td>
<td>1 vehicle</td>
</tr>
<tr>
<td>Vehicle speed</td>
<td>30 kmph average</td>
<td>30 kmph average</td>
</tr>
<tr>
<td>Vehicle capacity</td>
<td>10 seats</td>
<td>10 seats</td>
</tr>
<tr>
<td>Vehicle operating hours</td>
<td>12</td>
<td>12</td>
</tr>
</tbody>
</table>
Simulation Design

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

6 demand trips
84.7% accepted requests

INPUT

<table>
<thead>
<tr>
<th>Passenger</th>
<th>Source</th>
<th>Destination</th>
<th>RPT</th>
<th>RDT</th>
<th>TW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S1</td>
<td>S8</td>
<td>08:00</td>
<td>00:10</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>S1</td>
<td>S8</td>
<td>08:10</td>
<td>00:20</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>S6</td>
<td>S10</td>
<td>08:30</td>
<td>00:15</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>S4</td>
<td>S6</td>
<td>07:30</td>
<td>00:10</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>S1</td>
<td>S10</td>
<td>08:40</td>
<td>00:20</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>S2</td>
<td>S5</td>
<td>06:50</td>
<td>00:10</td>
<td></td>
</tr>
</tbody>
</table>

OUTPUT

TRAVEL TIME MATRIX

<table>
<thead>
<tr>
<th></th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>0.10</td>
<td>0.20</td>
<td>0.30</td>
<td>0.40</td>
<td>0.50</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td>0.10</td>
<td>0.20</td>
<td>0.30</td>
<td>0.40</td>
<td>0.50</td>
<td>0.60</td>
<td></td>
</tr>
<tr>
<td>S3</td>
<td>0.20</td>
<td>0.30</td>
<td>0.40</td>
<td>0.50</td>
<td>0.60</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>S4</td>
<td>0.30</td>
<td>0.40</td>
<td>0.50</td>
<td>0.60</td>
<td>0.70</td>
<td>0.80</td>
<td></td>
</tr>
<tr>
<td>S5</td>
<td>0.40</td>
<td>0.50</td>
<td>0.60</td>
<td>0.70</td>
<td>0.80</td>
<td>0.90</td>
<td></td>
</tr>
</tbody>
</table>

STORED DATA

S1 0:10 0:20 0:30 0:40 0:50 1:00
S2 0:10 0:20 0:30 0:40 0:50 0:60
S3 0:20 0:30 0:40 0:50 0:60 0:70
S4 0:30 0:40 0:50 0:60 0:70 0:80
S5 0:40 0:50 0:60 0:70 0:80 0:90
S6 0:50 0:60 0:70 0:80 0:90 1:00
S7 1:00 1:10 1:20 1:30 1:40 1:50

PACIFIC TELECOMMUNICATIONS COUNCIL

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)

Records
0 5 10 15
1 2 3 4 5 6 7 8 9 10
Time (mins)
Waiting time

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

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

Waiting time

Travel time
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

Total no. of trips 185

Rides given 897

PTC’19 FROM PIPES TO PLATFORMS 20–23 January 2019 | Honolulu, Hawaii
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.
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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