Applying Spatial Aggregation Methods to Identify Opportunities for New Bus Services in London

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As demand patterns change, public transport systems must adapt.

- Land use and population changes impact travel demand.
- Planners make incremental changes to public transport networks.
Origin-destination (OD) data can support planning decisions
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## Network Planning

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<table>
<thead>
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<tbody>
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<td>Network design</td>
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<td>Frequency setting</td>
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<td>Timetable development</td>
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<td>Vehicle scheduling</td>
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<td>Crew scheduling</td>
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Existing approaches to bus network planning

TNDP partial optimization methods

- Full network
- Design from scratch
- Demonstrated for real networks but rarely applied

(Guihaire and Hao, 2008; Yan, 2013; Bagloee and Ceder, 2011)

Ad hoc analysis

- Localized
- Existing networks

(Trial and error

(White, 1995; Cascetta and Carteni, 2014; Deakin et al., 2004)

abstract

proactive

realistic

reactive
Existing approaches to bus network planning

**TNDP partial optimization methods**
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**abstract**

**proactive**

**realistic**

**reactive**
Objectives

Develop a framework and specific methodologies to identify opportunities for new bus routes that can be added to an existing network.

The methodology must:

- Systematically evaluate the entire network, including complex, multi-modal networks
- Be flexible
New bus routes can...

- Reduce circuity/stages
- Expand coverage
New bus routes can...

Reduce circuitry/stages

Expand coverage
Framework
Define OD pairs

OD-Level Analysis: Filter OD pairs and estimate potential benefits

(Spatially) aggregate OD-level information to generate planning recommendations
Spatial abstraction

abstraction

Nodes and lines

Road/walking networks, geographic barriers, constraints (termini)

reality
Step 1: Define OD pairs
Zones account for multiple paths
Roads as boundaries in existing zonal schemes
Objectives for zonal scheme

- Zone size reflecting access and egress distance
- Produce zones of uniform size and shape
- Cluster data points (bus stops and rail stations) near centroids

Options:
- Use euclidean or road (walking) network distance for similarity
- Weight stops/stations by mode
- Weight stops/station by demand
Step 2: OD Analysis
Well-served and improvable

**Well-served:**
OD pair is served by single-stage rail or direct and single-stage bus service

- **single-stage rail:** no in-station or out-of-station transfer required
- **direct:** distance within target distance standard

**Improvable:**
OD pair is not well-served, and expected travel time with new bus service is better than the current travel time
Target distance standard

Based on:
- Shortest path distance through the road network, avoiding highways (accounts for barriers)
- Scaling factors to account for required deviations from shortest path

Target travel time

Based on:
- Shortest path travel time through the road network, avoiding highways (accounts for barriers)
- Expected stopping time
- Scaling factors to account for required deviations from shortest path
Estimating OD-level benefits

Benefits to current passengers
- Estimate current passengers who are expected to shift to new service
- Benefits measured in terms of potential travel time savings

New passenger benefits
- Estimate new passengers expected to be attracted to the new service
  (Four-step model, direct demand model, elasticity)

Weighting: can weight each benefit according to planner priorities

Uncertainty: Estimates are uncertain - can estimate a range for each component
Step 3: Spatial Aggregation
Need to identify corridors
Trajectory clustering

● Extension of density-based scan to lines/trajectories instead of points
● Some cluster full trajectories, other cluster partial trajectories
● Bahbouh et al., 2015 built on work by Lee et al., 2007 to cluster desire lines for pedestrian planning.
**Corridor identification algorithm**

<table>
<thead>
<tr>
<th>Part 1</th>
<th>Define candidate corridors of appropriate shape, size, and demand for new bus services.</th>
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<tr>
<td>Part 2</td>
<td>Define final corridors, prioritized by potential benefits, with OD pairs assigned to at most 1 corridor.</td>
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</table>
Application
1,000 Zones Defined
Fewer stops and stations on boundaries
Of 45,154 OD pairs...

19,752 OD pairs

OD served by single-stage rail?

yes

well-served

OD served by single-stage bus?

yes

Current bus distance > target bus distance?

yes

not well-served

Current travel time > (\(\beta\) expected travel time)?

yes

improvable

no

not improvable

Add journey stages, if OD pair is in single-stage improvable set

17,942 OD pairs

no

well-served

Current travel time > (\(\beta\) expected travel time)?

yes

improvable

no

not improvable

Assign journey stages to zonal OD pairs

5,856 OD pairs

1,737 OD pairs

1,621 OD pairs

37,694 OD pairs
Journeys: all vs. improvable OD pairs

OD pairs analyzed

45,154 OD pairs
248,829 journeys per AM peak hour

Improvable OD pairs

7,477 OD pairs (17%)
17,418 journeys/AM peak hour (7%)
## Opportunities for new bus routes

<table>
<thead>
<tr>
<th>Distance (time) multiplier ($m$)</th>
<th>1.1</th>
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<tbody>
<tr>
<td>Distance additive term ($a$)</td>
<td>0.9 miles</td>
</tr>
<tr>
<td>Elasticities</td>
<td>-0.4 to -0.6</td>
</tr>
<tr>
<td>Maximum distance</td>
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<td>Corridor length</td>
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<td>Maximum angle</td>
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<tr>
<td>Minimum flow</td>
<td>50 passengers per hour</td>
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Sensitivity to parameters

Increasing performance standards

Base
## Base scenario

<table>
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<th>Value</th>
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Corridor 1

potential time savings (minutes)
- 2 - 6
- 6 - 10
- 10 - 14
- 14 - 18
- 18 - 22

EDR
Corridor 1
Corridor 6

potential time savings (minutes)
- 2 - 6
- 6 - 10
- 10 - 14
- 14 - 18
- 18 - 22

0 1 2 miles
Corridor 6

Potential time savings (minutes):
- 2 - 6
- 6 - 10
- 10 - 14
- 14 - 18
- 18 - 22

EDR
Discussion

- Depending on parameters, identified 4 to 16 corridors for improvement
Discussion

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● Corridors appear promising based on post-analysis, particularly because flow is likely significantly underestimated.
  ○ Possible improvement: incorporate a more sophisticated demand model
Discussion

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● Corridors appear promising based on post-analysis, particularly because flow is likely significantly underestimated.
  ○ Possible improvement: incorporate a more sophisticated demand model

● Opportunities for improvement in spatial representation
  ○ Can help ensure corridors can be served by a single route
  ○ Can better account for barriers
  ○ Can identify opportunities for non-linear corridors
Discussion

- Only 3 to 11% of improvable journeys assigned to corridors
  - Suggests need/opportunities for other modes (non fixed route)
Extension

- Adapt for planning of other modes or specific services
- Allow a transfer as part of improved service
- Recommend existing routes for removal
Contributions

- Bus network sketch planning framework
- New system for defining zones that reflect the transportation network.
- New metrics to evaluate quality of service and potential for improvement
- A spatial aggregation methodology that groups OD pairs into corridors
Thank you!