Applying Bi-objective Shortest Path Methods to Model Cycle Route-choice

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Outline

Commuter Cyclists
   - Motivation
   - Choice Set
   - Route Choice Factors

Cyclist Route Choice Model
   - Basics
   - Time and Attractiveness Objectives

Bi-objective Shortest Paths
   - Traditional Approach to Route Choice
   - Route Choice with Two Objectives

Case Study
   - Study Area
   - Results

Conclusion
Why does cycling matter?

Shift to use of active modes in commuting

- Government’s vision: Increase active mode trips (cycling and walking) to 30% of total trips in urban areas by 2040 [Ministry of Transport (2008)].
- Active modes encouraged to reduce vehicle emissions and reduce traffic queues.
- To promote cycling it is important to understand how cyclists choose their routes.

Cyclists and safety

- Cycling can be dangerous.
- Good, safe cycle facilities are required to encourage more cycle trips – where should these facilities be developed?
Route choice models for motorised vehicles

Traditional traffic assignment

- Mainly performed for motorised vehicles, but not for active modes such as cycling and walking (e.g. Auckland).
- Models route choice of travellers given known demand between origins and destinations.
- Travellers choose route to minimise their own travel time (or generalised cost function).
How do we model cyclist route choice?

**Aim: develop commuter cyclist traffic assignment**

- First step: which routes do cyclists consider? Determine the *choice set*, i.e. the potential routes that cover the needs of each cyclist for each OD pair.
- Second step: Which of the routes in the choice set does each individual cyclist choose?
- Third Step: Commuter cyclist assignment algorithm.
How do we model cyclist route choice?

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Areas of application

- Planning / evaluation of infrastructure developments.
Main factors influencing commuter cyclist route choice.

We identify time as main objective and distinguish another objective that contains other important factors.
Main factors influencing commuter cyclist route choice.

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Time or Distance are a major factor in route choice

- [Aultman-Hall et al. (1997)] find that 58% of all commuter cyclists choose the route with minimal distance (survey in Guelph, Ontario, Canada).
- [Stinson and Bhat (2003)] confirm travel time is the most important factor (online survey in the US).
Main factors influencing cyclist route choice.

Other factors – attractiveness
There are many other factors that characterise suitability of a road for cyclists such as

- motor traffic volume,
- topography,
- presence of cycle facilities,
- lane width,
- and many more.

[Land Transport Safety Authority (2004), Stinson and Bhat (2003)]
Main factors influencing cyclist route choice.

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[Land Transport Safety Authority (2004), Stinson and Bhat (2003)]

We summarise these factors in the term *attractiveness*.

We explicitly exclude subjective factors such as physical fitness or value of time.
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Basis of model

Auckland Regional Transport Model

- links are major roads.
- nodes are intersections.
- origin and destination of cyclists at centroids.
Time objective

Time to traverse a road

- Assumption: Cyclists are not affected by traffic congestion.
- Assumption: Time proportional to distance.
- Assumption: Do not take road gradient into account, which is part of attractiveness objective.
Time objective

Time at intersections

- Modify network to model intersection delay depending on turning movements.
Time objective

Time at intersections

- Modify network to model intersection delay depending on turning movements.
- Calculate average cyclist delay: \[ \frac{R^2_t}{2C_t} \] (stop rate) \(\times\) (average delay)
Attractiveness objective

Attractiveness of road

- British method [Palmer et al. (1998)] to derive attractiveness score between 1 (worst) and 6 (best).
- Consider 20 different non-subjective factors such as: traffic volume, traffic speed, lane width, on-street parking, gradient, % heavy vehicles, cycle facilities, pavement condition, etc.

Attractiveness objective

Attractiveness at intersections

- Through movements [Landis et al. (2003)]. Factors are: lane width, crossing distance, traffic volume, no. of through lanes.
- Turning movements: There is no previous study, developed own approach using similar criteria: crossing distance, no. of through lanes, gradient of approach to intersection
Objective values of each route

Minimise travel time
sum of travel times on all links:

\[ T(\text{route}) = \sum_{i: \text{link in route}} t_i \]
Objective values of each route

Minimise travel time
sum of travel times on all links:

\[ T(\text{route}) = \sum_{i: \text{link in route}} t_i \]

Maximise attractiveness
attractiveness rating times link length over total route length:

\[ A(\text{route}) = \sum_{i: \text{link in route}} \frac{a_i t_i}{T(\text{route})} \]
Objective values of each route

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attractiveness rating times link length over total route length:

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Example

\[
\begin{array}{c}
(300,5) \xrightarrow{(50,2)} (470,4)
\end{array}
\]

\[ T = 820 \quad A = 4.244 \]
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Traditional route choice

Shortest path

- Assumption: A route that is minimal with respect to a single objective is chosen (e.g. distance) or generalised cost function.
- Relatively easy to find the best route by solving shortest path problem.
Traditional route choice

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- There exists a single shortest route.
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In our case, we do not combine time and attractiveness:

\[ T(\text{route}) + \alpha \cdot A(\text{route}) \]
Traditional route choice

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Because \( \alpha \) is different for every cyclist!
Route choice with two distinct objectives

Consider the true bi-objective problem

- Plot distance-attractiveness pairs for each possible path connecting origin and destination:
Route choice with two distinct objectives

Consider the true bi-objective problem

- Plot distance-attractiveness pairs for each possible path connecting origin and destination:

![Graph showing distance-attractiveness pairs and efficient routes.]

- Find all routes that are **efficient**, they cannot be improved.
Route choice with two distinct objectives

Consider the true bi-objective problem

- Plot distance-attractiveness pairs for each possible path connecting origin and destination:

- Find all routes that are efficient, they cannot be improved.
The efficient routes represent the optimal trade-offs between the two objectives.
Efficient paths represent commuter cyclist choice set

- The efficient routes represent the optimal trade-offs between the two objectives.
- We believe that is is a reasonable assumption that a cyclist chooses one of the efficient routes.
Finding the commuter cyclist choice set

Algorithms to solve the bi-objective shortest path problem exist. But the attractiveness objective prohibits use of a standard bi-objective algorithm.

**Algorithm**

We made enhancements to a bi-objective shortest path algorithm to be able to solve the commuter cyclist problem:

- **Modify**: modify original problem with objectives $T, A$ to problem with objectives $T, A'$ and $A'(route) = \sum_{i: \text{link in route}} a_it_i$.
- **Solve modified problem**: find all efficient paths for modified problem.
- **Efficient paths of original problem**: selected from efficient paths for modified problem.
Main differences in motorised vehicles and commuter cyclist traffic assignment

<table>
<thead>
<tr>
<th>Differences in traffic assignment</th>
<th>Traffic assignment for motorised vehicles</th>
<th>Traffic assignment for commuter cyclists</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of objectives</td>
<td>single objective</td>
<td>two objectives</td>
</tr>
<tr>
<td>type of objective</td>
<td>generalised cost</td>
<td>time, attractiveness</td>
</tr>
<tr>
<td>objective is</td>
<td>flow-dependent</td>
<td>fixed</td>
</tr>
<tr>
<td>solutions</td>
<td>one:</td>
<td>many:</td>
</tr>
</tbody>
</table>

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Case study Auckland

Source of data: Auckland Regional Council
Case Study Auckland

We select a single origin-destination pair, from Pt Chevalier to Auckland CBD.

Source of data: Auckland Regional Council
Results

Efficient paths

Distance and attractiveness of efficient paths
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- Need to validate that this actually represents cyclists’ choice set.
- Cycle maps.
- Commuter cyclist traffic assignment; economic valuation of proposed cycle infrastructure improvements.
- The idea is also applicable to traffic assignment for motorised vehicles, as alternative to generalised cost functions and value of time.
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