# Understanding passenger path choice in congested metro networks – the case of reverse routing

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## Introduction

Ridership in transit networks and especially in metro networks in many cities is constrained by the capacity of the system. Overcrowding in peak hours on these systems can lead to special situations, where passengers can gain an advantage by choosing routes, which under normal conditions would be dominated alternatives. This study investigates these unusual route choices and specifically develops methods to quantify what in this research is defined as *reverse routing*.

The principle of *reverse routing* is illustrated in Figure 1 below. There are two base cases of reverse routing:

**Case 1**: Passengers travelling from station 1 to station 4 must transfer between lines X and Y to complete their journeys. The transfer would logically occur at station 2, which would be expected to minimize the in-vehicle times on both lines X and Y. But, if the travel time between stations 2 and 3 is low and the denied boarding probability is much higher at station 2 than at station 3, some passengers may continue to station 3 and transfer there, if the probability of being denied boarding is very low and the chance of getting a seat is higher there.

**Case** 2: A similar strategy might be followed by passengers starting their journeys at station 2, although in this case the perceived benefits would have to be higher than in the first case, because of the extra waiting time which would be incurred at station 2 to board line X as well as the extra transfer time at station 3 compared to directly boarding line Y at station 2.

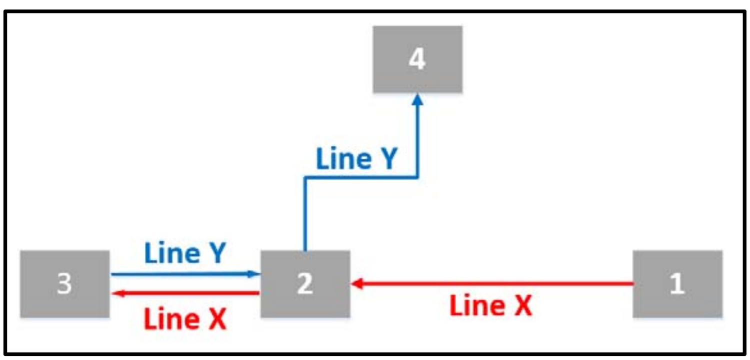


*Figure 1 - Concept of reverse routing*

The estimation of the number of passengers adopting *reverse routing* can help metro operators identify critical bottlenecks in the network and indicate if appropriate measures should be implemented to avoid the additional passenger kilometers travelled in the network. The study will also improve the estimates of denied boardings to more accurately reflect the level of service experienced by passengers (Koutsopoulos et al, 2018). Furthermore, the study identifies the conditions under which passengers adopt the *reverse routing* strategy, including the crowding levels, the destination and the length of the trip.

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## Methodology and data

The study utilizes data and observations from the metro network in Hong Kong (MTR) a small part of which is shown in Figure 2. A survey in 2012 showed that 7% of the transfers between the Island (dark blue) line and the Tsuen Wan (red) line in the PM peak period transferred at Central station instead of the more obvious transfer at Admiralty station (Li, 2014). The behavior was only evident in the peak periods and is therefore likely caused by congestion in the network. Since 2012 the number of passengers in the network has increased by 17% and a new line has been opened connecting at Admiralty station, which further increases the number of passengers transferring to the Tsuen Wan line at this station.

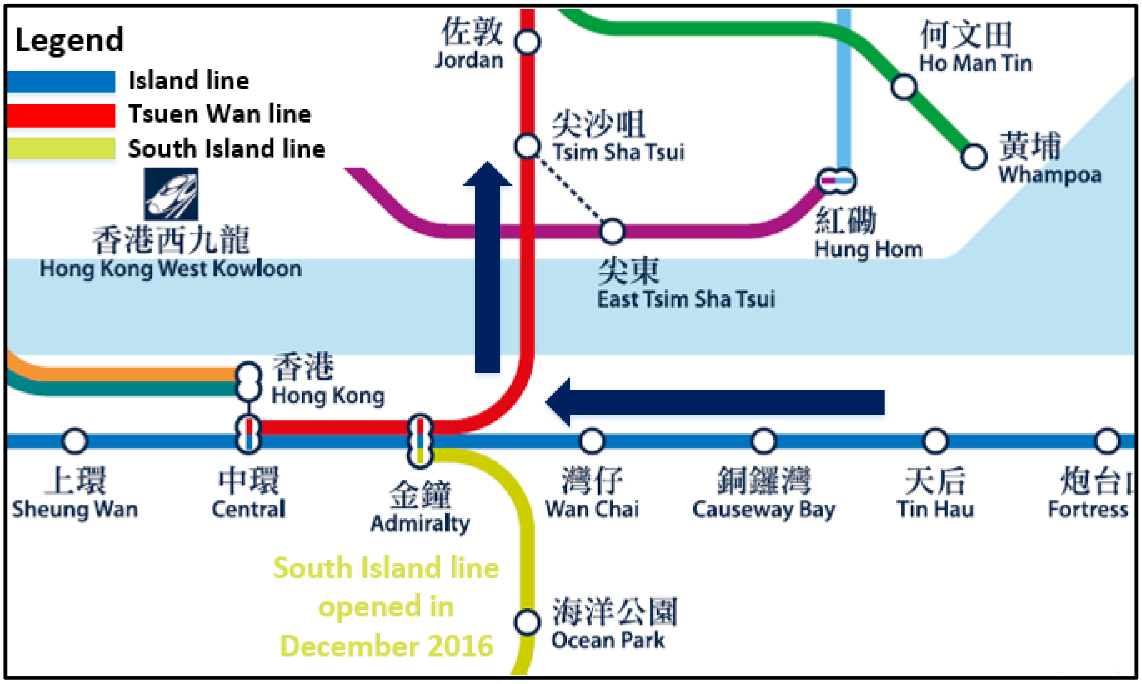


*Figure 2 - Part of the MTR network. Example of case 1 reverse routing from Island line (blue) to Tsuen Wan line (red) where passengers can transfer at either Admiralty or Central station*

A study by Chigusa (2018) looked at the excess journey times in the MTR network specifically for trips originating at Admiralty to destinations on Tsuen Wan line (red line in Figure 2). The study found, that the excess journey time was higher for longer trips, indicating that some passengers may have adopted a reverse routing strategy.

The strategy of reverse routing is assumed to be mostly adopted by experienced passengers, as they have a better idea of when it can be an advantage to transfer at a less crowded station, given that it has to compensate for the longer in-vehicle time. This assumption has initially been tested by analyzing the journey times from tap-in to tap-out in AFC data. Figure 3 shows the journey times from Causeway Bay on the Island line to Tsim Sha Tsui on the Tsuen Wan line (see Figure 2) based on the tap-in and tap-out times from AFC data. The histograms are based on trips on Monday-Thursdays in March 2017 with departures between 18.00-18.15 divided into two groups of passengers: those with ten or fewer trips, and those with more than ten trips from Island line to Tsuen Wan line in March 2017. There is a clear, statistically significant difference in the distributions which indicates that some experienced passenger choose to transfer at Central station which has a very low denied boarding probability, since it is the origin station on Tsuen Wan line, instead of the heavily crowded Admiralty, where denied boardings are likely during peak hours.

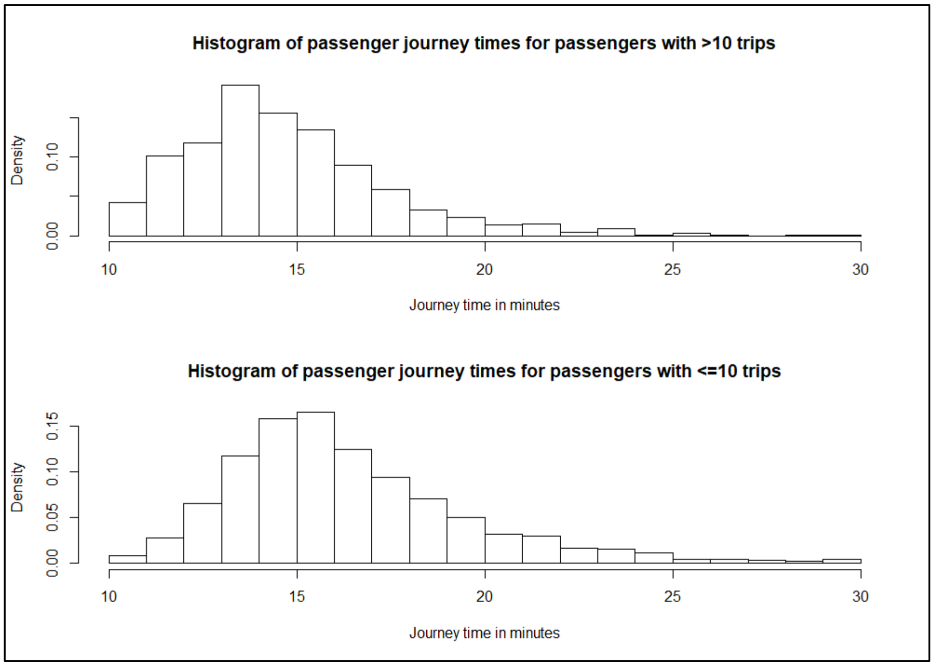


*Figure 3 - Journey time histograms from Causeway Bay to Tsim Sha Tsui on Monday-Thursday departing 18.00-18.15 in March 2017 for two groups - passengers with more than ten 10 trips from Island line to Tsuen Wan line in all of March 2017 and passengers with fewer trips*

This study aims at developing data-driven methods to quantify the extent of reverse routing using Automatic Fare Collection data (AFC) with tap-in and tap-out records for individual passengers, and Automatic Vehicle Location data (AVL) with train arrival and departure times at station platforms. The final estimations will use the more detailed knowledge about each passengers' itinerary by assigning passengers to specific trains (Zhu et al, 2017). Preliminary assignments of passengers to trains has proven successful and can give a more precise estimation of the number of passengers adopting reverse routing behavior when combined with data available from manual counts of denied boarding also available to the study. The denied boarding survey will also help identifying the situations, where a reverse routing strategy is likely to be an advantage and be included in the likelihood functions to be estimated of the probability that the individual passenger adopted a reverse routing strategy.

## Conclusion and future analysis

The conclusions this far are only preliminary and further analyses are required to have a full model that can describe the magnitude of reverse routing in the system. Previous studies have indicated that reverse routing is observed on this part of the MTR network.

The aim of this research is to first identify the magnitude of reverse routing for specific OD pairs in the MTR network, and further to identify passenger and journey characteristics which increase the likelihood of following the reverse routing strategy. Finally, the work aims at understanding the value of passengers' knowledge of the system by using clustering methods to group passengers.

## References

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