THE HONG KONG POLYTECHNIC UNIVERSITY
香港理工大學

Proactive resilience building through route diversity: A close look at the metro system from the travelers' perspective

通过路线多样性建立主动弹性：从乘客的角度审视地铁系统

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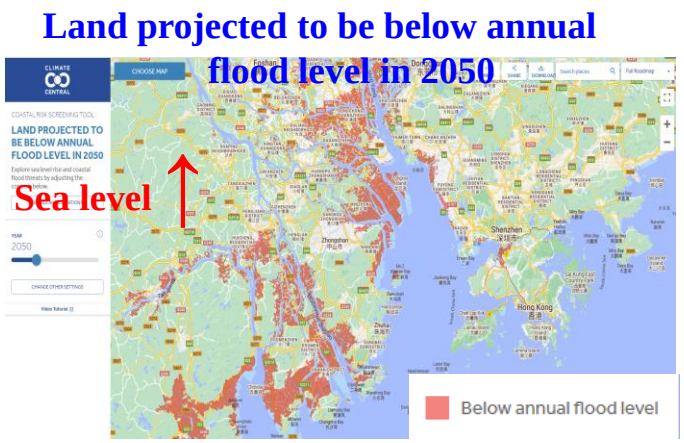
Introduction

- The **resilience of transport systems** is defined as their ability to *resist, absorb, accommodate and recover* from disruptions (Gu et al., 2020).
- **Climate change** (e.g., sea level rise) and **extreme climate** (e.g., typhoon, heavy rain) become a pressing threat to transportation infrastructures (e.g., erosion and subsidence of road bases, flooding of underground tunnels and low-lying infrastructure).



Gu, Y., Fu, X., Liu, Z., Xu, X., Chen, A., 2020. Performance of transportation network under perturbations: Reliability, vulnerability, and resilience. Transportation Research Part E Logistics and Transportation Review. 133, 1–16. https://doi.org/10.1016/j.tre.2019.11.003

Introduction

- Recent social shocks (Covid19) have drawn scholars' attention to transport resilience (Budd and Ison, 2020)
  - led operators and governments to identify individual responsibilities and collective considerations from the user perspective in the form of "responsible transport" policies (from supply-side resilience strategies to demand-side strategies)

Effective measures

Budd, L., Ison, S., 2020. Responsible transport: A post-COVID agenda for transport policy and practice. Transportation Research Interdisciplinary Perspectives. 6, 100151.

Introduction

- *How can travelers **proactively build resilience** by using alternative routes in response to adverse events?*
  - *The resilience of a system can be proactively built by its stakeholders if they anticipate adverse events and "actively wait" for them (Sull, 2005).*
  - *Route diversity is relevant to the proactive resilience of transport system.*
    - *This measure, which is one of two network-based measures for characterizing transport network redundancy, has been used to assess the redundancy and vulnerability of various metro networks (Chan et al., 2021; Yang et al., 2017), road networks (Xu et al., 2018), and freight networks (Jansuwan et al., 2021).*

Sull, D.N., 2005. Strategy as active waiting. Harv. Bus. Rev. 83, 120–129.
Chan, H.-Y., Chen, A., Li, G., Xu, X., Lam, W., 2021. Evaluating the value of new metro lines using route diversity measures: The case of Hong Kong's Mass Transit Railway
Xu, X., Chen, A., Jansuwan, S., Yang, C., Ryu, S., 2018. Transportation network redundancy: Complementary measures and computational methods. Transp. Res. Part B Methodol. 114, 68–85. https://doi.org/10.1016/j.trb.2018.05.014
Yang, X., Chen, A., Ning, B., Tang, T., 2017. Measuring route diversity for urban rail transit networks: A case study of the Beijing Metro Network. IEEE Trans. Intell. Transp. Syst. 18, 259–268. https://doi.org/10.1109/TITS.2016.2566801

Methods

- Shortest-time (ST) versus least-transfer (LT) route
  - Existing route search tools, provided by the map services of Google, Baidu and the Beijing subway operator, recommend routes based on the ST and LT criteria.
  - Although ST and LT routes can be identical, we focus on the OD pairs that provide different routes.
  - We examine how the flow differs when passengers choose different routes from the ST and LT choices.
- Set of reasonable routes
  - Routes other than the ST and LT routes are available to passengers.
  - The sizes of reasonable route sets vary among travelers, and reasonability is based on the extra cost compared with the shortest route.
  - We examine how the increase in the acceptable extra cost enhances route diversity and hence contributes to proactive transport resilience.

Methods

Estimation of travel time between adjacent stations and transfer time

All OD pairs
- Recommended route
- Travel time

Recommended routes
- Links
- Transfer stations

API

Riding scheme

Network topology

- **Travel time between adjacent stations**
- **Transfer time**

Search all possible routes

Simplified network: Transfer and terminal nodes

↓ Depth-first search (DFS)

All rail line pairs: Available transfer schemes

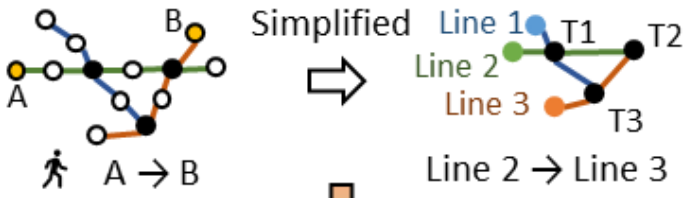
↓ Expansion

All OD pairs: Route set with possible routes

↓ Selection

Shortest time (ST) & Least transfer (LT) routes

Illustration



Choice	Transfer scheme	Travel time (min)	Transfer
1	T2	10	1
2	T1, T3	20	2

Methods

Spatial analysis of route diversity

Research question: How can travelers proactively build resilience by responding to adverse events using alternative routes?

Sub-question 1: Which groups of travelers can be targeted to build proactive resilience?

Assumption 1: Travelers of OD pairs with different routings for ST and LT routes can be targeted to build proactive resilience.

Spatial distribution of the ST and LT routes of these OD pairs

- *Decentralization of flow from city center if travelers shift from ST to LT routes.*
- *22% OD pairs can benefit from building proactive resilience.*

Sub-question 2: How can proactive resilience be built with the least cost?

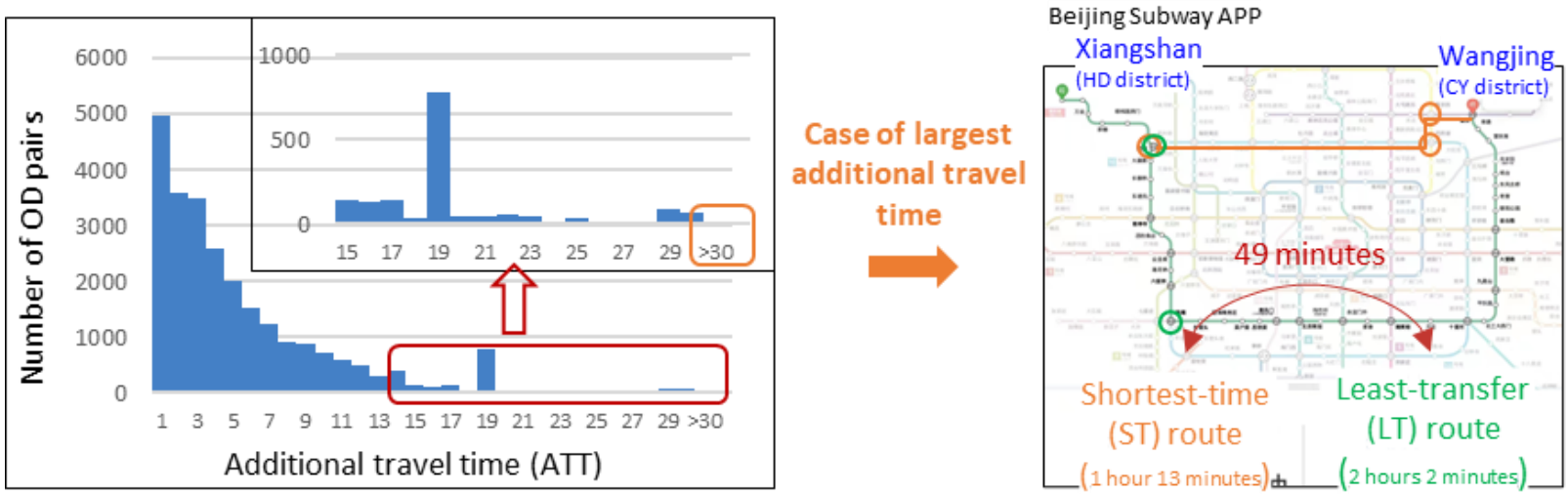
Assumption 2: Proactive resilience can be built with the least cost if travelers are willing to pay extra time cost to adopt alternative routes

Additional travel time (ATT) and acceptable elongation ratio (AER)

- *Shorter trips (≤15 min): An absolute threshold of ATT = 10 min*
- *Longer trips (>15 min): A relative threshold of AER = 1.3 * time of ST route*

Findings

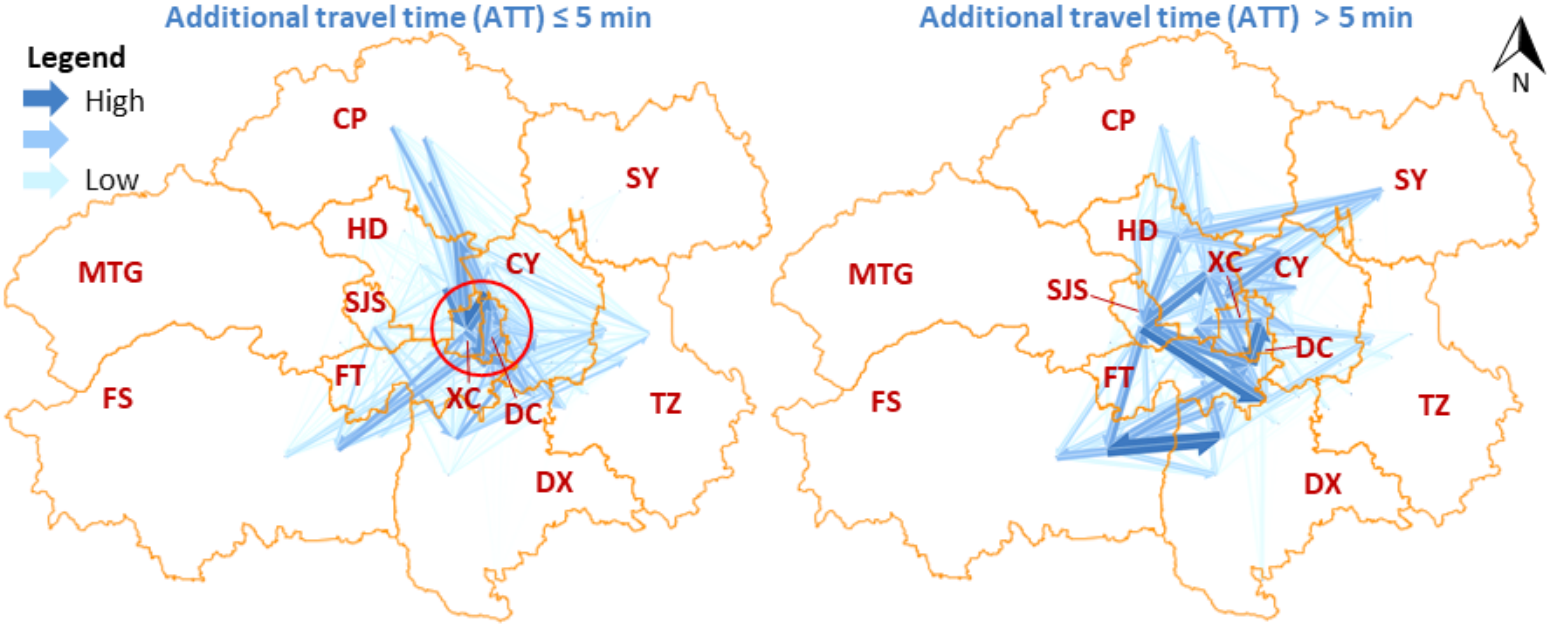
- Which groups of travelers can be targeted to build proactive resilience?
  - 22% of the ST and LT routes of the same OD pairs have different routings.
  - Travelers of 65% of OD pairs can save an average of 5.2 min by opting for an additional transfer.



(a) Distribution of the additional travel time (ATT)

Findings

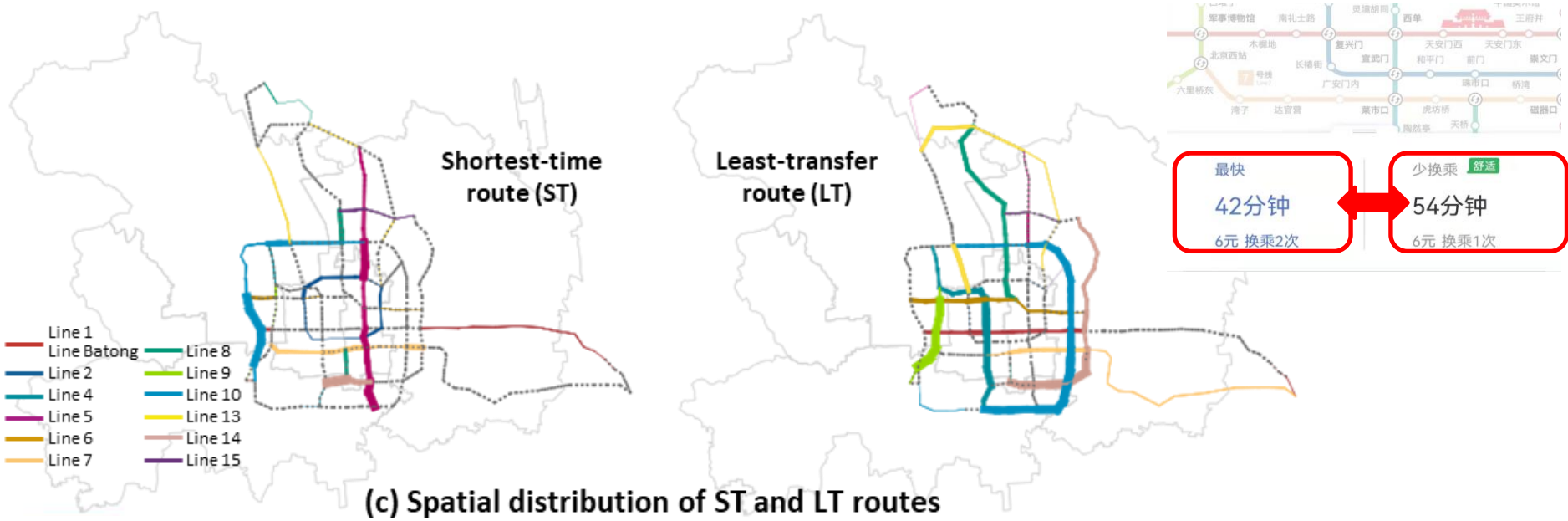
- Which groups of travelers can be targeted to build proactive resilience?
  - Most of the OD pairs with ATT ≤ 5 min connect to the central area (Xicheng (XC) and Dongcheng (DC) districts).
  - The OD pairs with ATT > 5 min are concentrated in Shijingshan (SJS) district, which connects the western and eastern parts of Beijing.



(b) Spatial distribution of the OD pairs with different routings for ST and LT routes

Findings

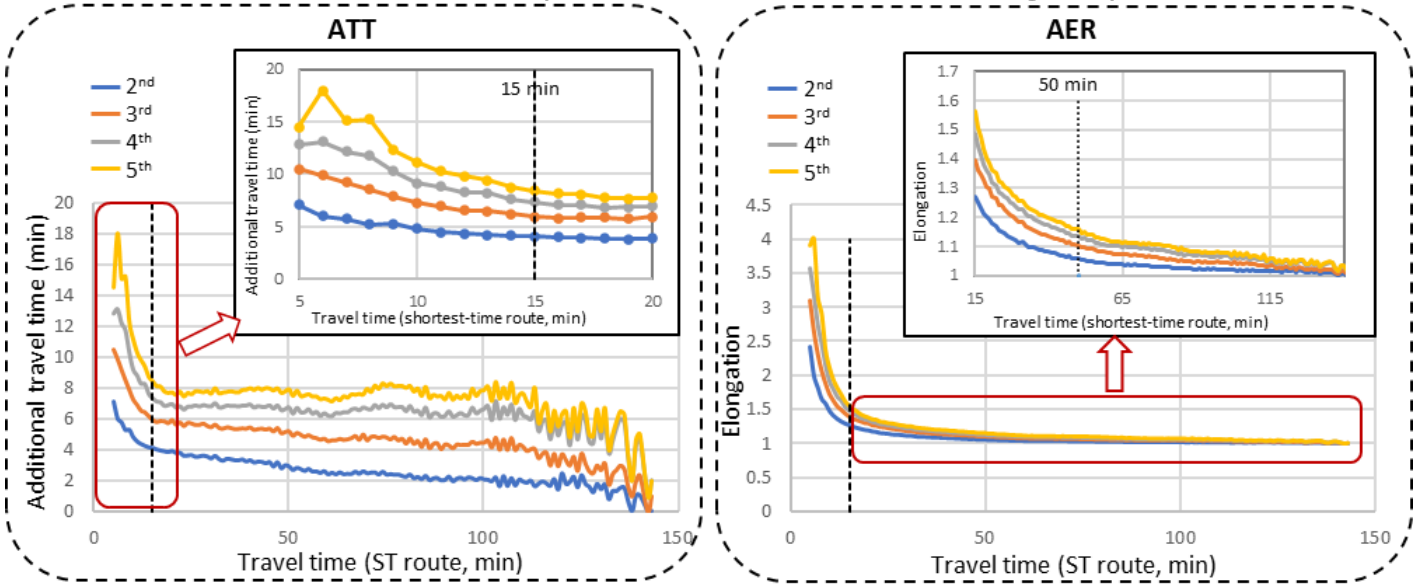
- Which groups of travelers can be targeted to build proactive resilience?
  - If passengers choose the ST routes, the flow could potentially be directed to Line 5 and to west of Line 10;
  - however, if they choose the LT routes, the eastern section of Line 10 and the links of Lines 4 and 9, which are geographically closely to the central area, are required to cope with the influx of passengers.



(c) Spatial distribution of ST and LT routes

Findings

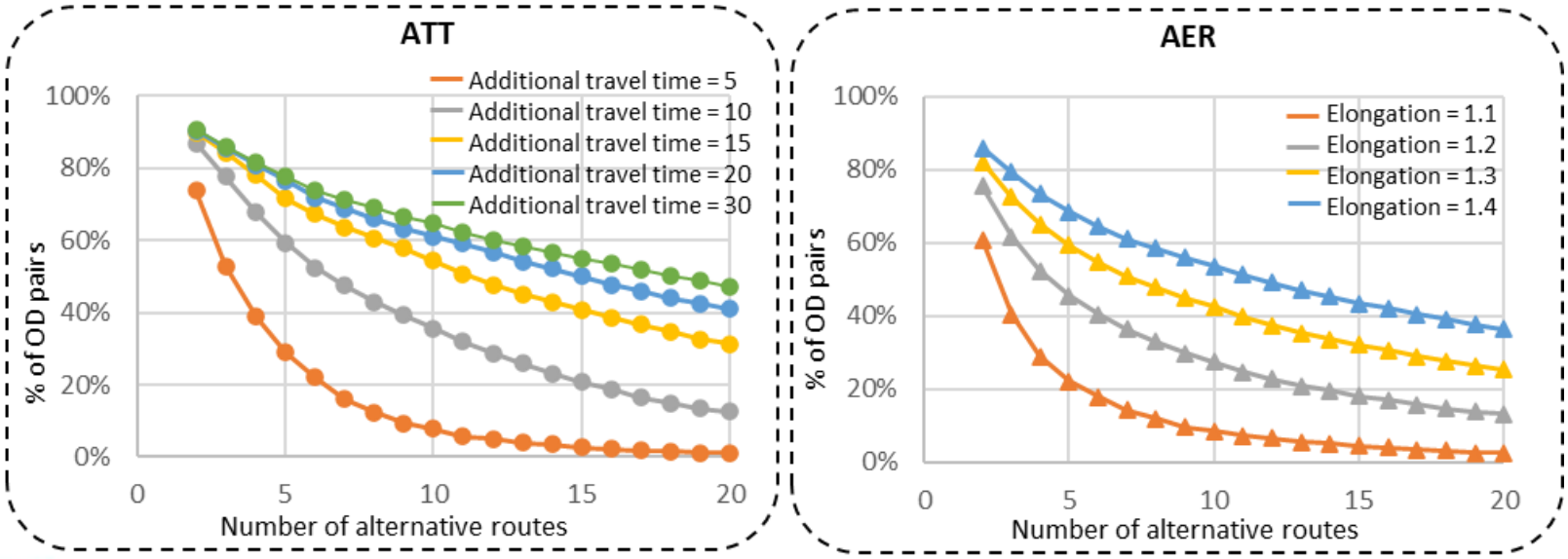
- How can proactive resilience be built with the least cost?
  - For short trips (≤15 min), the ATT declines rapidly as the travel time increases. For long trips (>15 min), the AER of the alternative routes decreases slowly as the travel time increases. Another critical threshold is AER = 50 min, as it remains almost constant for trips > 50 min.
  - A combination of the ATT and the AER as the threshold of the extra cost: the ATT for short trips and the AER for long trips.



(a) Additional travel time (ATT) and acceptable elongation ratio (AER) for the alternative (2nd to 5th ST) routes

Findings

- How can proactive resilience be built with the least cost?
  - When the ATT is constrained to 5 min, 74% of OD pairs have one or more alternative routes, with only about 20% having five alternative routes.
  - In conclusion, to build proactive resilience with the least cost, we suggest an absolute threshold of ATT = 10 min for short trips and a relative threshold of AER = 1.3 for long trips.



(b) Percentage of origin-destination (OD) pairs with alternative (2nd to 20th ST) routes

Future work

- Route diversity for trips involving the use of more than one transport mode (intra-city)
  - Better understanding passengers' demands
    - E.g., "door-to-door" service was much valued in choosing among different public transport modes (TSC, 2011).
  - Connection of different transport modes
    - Temporal: timetable optimization for last train, transfer coordination
    - Spatial: fast exit suggestion; walking environment around the stations

Table 3.9 Proportion of Interchanges between Transport Modes

From Mode	To Mode					
	MTR	PLB	Franchised Bus	SPB	Others	Total
MTR	0%	12%	10%	5%	7%	**34%**
PLB	11%	2%	3%	1%	1%	**18%**
Franchised Bus	10%	3%	10%	1%	3%	**27%**
SPB	6%	1%	1%	0%	1%	**9%**
Others	6%	1%	3%	1%	1%	**12%**
Total	**33%**	**19%**	**27%**	**8%**	**13%**	**100%**

Looking for the exit to get out in advance?

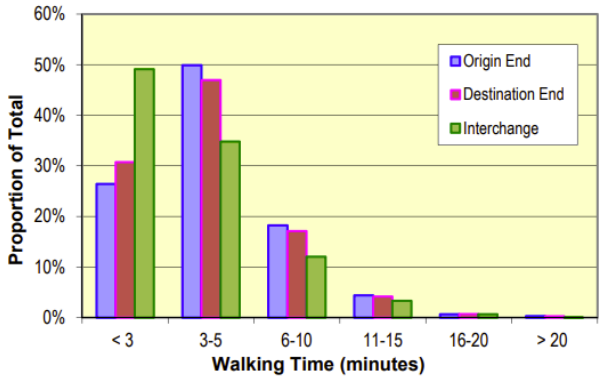
"Fast Exit" function in the "Trip Planner" shows you which specific train car and door number to board so you can reach your destination more quickly.

1 Set your origin and destination in "Trip Planner" and click "Suggested Route"

2 Select "Fast Exit" on the "Suggested Route" page

3 Pick or search for an exit or landmark as your destination

4 The function shows you the specific train car number and door number for boarding, allowing you to reach your destination more quickly when you get off the train



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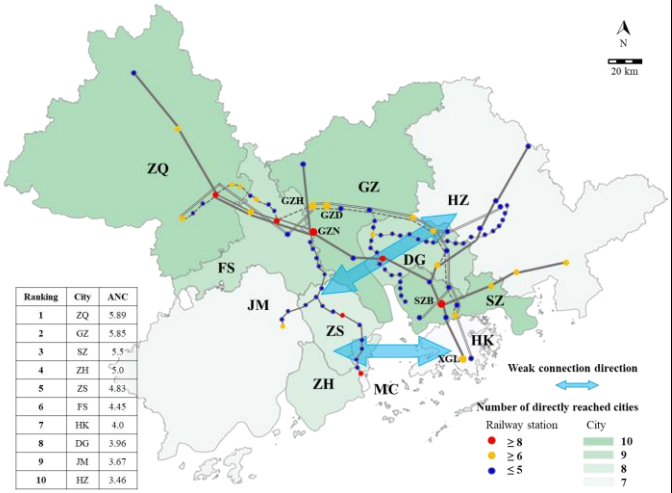
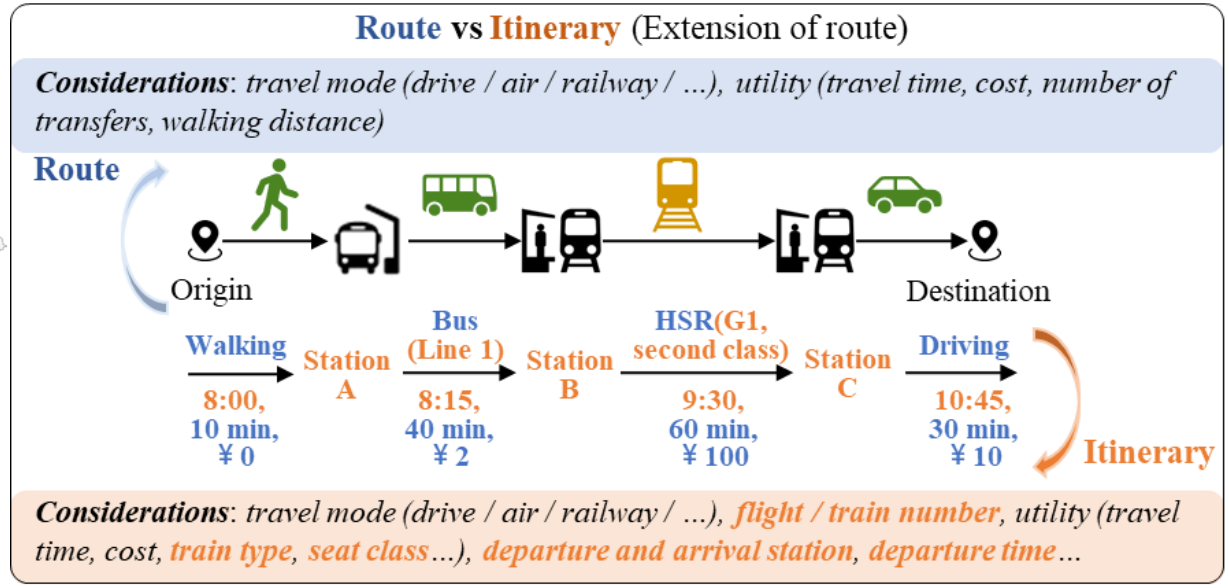
Future work

- Route diversity for trips involving the use of more than one transport mode (inter-city)
  - Guangdong-Hong Kong-Macao Greater Bay Area (GBA): aims to combine the strengths of the cities to a world-class city cluster with deepened cooperation and robust community for living, working and travelling.
  - Itinerary diversity: a detailed plan of journey



Ranking	City	ANC
1	ZQ	5.89
2	GZ	5.85
3	SZ	5.5
4	ZH	5.0
5	ZS	4.83
6	FS	4.45
7	HK	4.0
8	DG	3.96
9	JM	3.67
10	HZ	3.46



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CEE

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