Metro Passenger Flow Management in a Megacity: 

*Challenges and Experiences in Beijing*

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Outline

➢ Challenge
  • Fast development of urban rail network
  • Passenger volume increases rapidly
  • Isolated operation→ Network operation
  • Single operator→ Multi-operator

➢ Experience
  • Passenger flow forecast
  • Calculation and evaluation of station capacity
  • Metro operation simulation
  • Passenger flow control
Metro map of Beijing in 2015
(18 lines, 660km)
Metro planning of Beijing in 2020
(30 lines, 1177km)
In 2020, the network of Beijing subway will consist of 30 lines, and the operation mileage will be 1177km.

The operation mileage of Beijing subway from 2003 to 2015

<table>
<thead>
<tr>
<th>Year</th>
<th>Operation Mileage (km)</th>
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<tbody>
<tr>
<td>2003</td>
<td>114</td>
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<td>2013</td>
<td>527</td>
</tr>
<tr>
<td>2014</td>
<td>660</td>
</tr>
<tr>
<td>2015</td>
<td>700</td>
</tr>
</tbody>
</table>

Operator
- Beijing subway
- Beijing subway, Beijing MTR
Metro map of Shanghai in 2015

(14 lines, 548 km)
Metro planning of Shanghai in 2020
(18 lines, 800km)
Metro map of Guangzhou in 2015
(9 lines, 260km)
Metro planning of Guangzhou in 2020
(17 lines, 677km)
Outline

**Challenge**

- Fast development of urban rail network
- **Passenger volume increases rapidly**
- Isolated operation $\rightarrow$ Network operation
- Single operator $\rightarrow$ Multi-operator

**Experience**

- Passenger flow forecast
- Calculation and evaluation of station capacity
- Metro operation simulation
- Passenger flow control
The daily passenger volume of Beijing subway from 2008 to 2015

- **Daily passenger volume (million)**
  - 2008: 3.33
  - 2009: 3.90
  - 2010: 5.22
  - 2011: 6.01
  - 2012: 6.72
  - 2013: 8.65
  - 2014: 9.56
  - 2015: 10.46
Passenger Status of Beijing Subway during morning peak hours
(8:15-8:30, Wednesday, May 20, 2015)
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Isolated Lines $\rightarrow$ Network
**Outline**

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**Experience**
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- Passenger flow control
2 Operators since 2009

Beijing Subway

Beijing MTR Corporation

16 lines

2 lines

Line 4, Daxing Line, Line 14
Outline

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Experience

- Passenger flow forecast
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Experience in Beijing

• Project
  • “Transport organization key technologies and system development on urban rail transit network”

• Participant Organization
  • State Key Laboratory of Rail Traffic Control and Safety (RCS) of Beijing Jiaotong University
  • Beijing Metro Network Control Center (TCC)
Objective of the Project

• *Analysis of passenger demand*
• Deployment of transportation capacity
• Coordination among stations, lines and network
• Corresponding evaluation method and standard for operators
Experience in Beijing

• During 2011-2014, we established the “Networked-operation Decision Center” (NDC)
Experience in Beijing

• NDC has been deployed in the information system of Beijing Metro Network Control Center.
• It can analyze the impact of new lines to existing lines, and evaluate the coordination of capacity and demand.
• It also can be used as a reference to the design of stations and lines in urban rail transit.
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Passenger flow forecast of new lines

The passenger volume impact of new lines to transfer stations.

The passenger volume forecast of new lines to an existing line.
Multi-resolution modeling and simulation: Station Simulation

A multi-agent-based microscopic pedestrian simulation model in the station is proposed.
Multi-resolution modeling and simulation: Facility capacity calculation

Based on the concept of the stress test, the facility capacity can be calculated by the station simulation system.
Identification and Relief of Bottlenecks

According to the bottleneck transmission characteristics, we proposed a bottleneck identification method and the sensitivity analysis-based bottleneck relief strategy.
Evaluation of Station Capacity

Indexes of station efficiency

Capacity utilization rate of facilities
Multi-resolution modeling and simulation: Network Simulation

- Network topology model building
- Simulation experimental project management
- Simulation experiment process control
- Passenger distribution
- Simulation data acquisition and processing
- Visual display of simulation process
- Calculation and display of evaluation indexes
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Metro Passenger flow control: Boarding-limiting method

✓ 65 constant boarding-limiting stations in Beijing
✓ 58 stations at morning peak hours
✓ 19 stations at evening peak hours
Inbound passenger flow control

Control the number of inbound passengers per unit time, to reduce the load of facilities in the station.

✓ Fencing in the entrances
✓ Adjust the number and the location of the ticket gates
✓ Change the speed of ticket sale
Transfer passenger flow control

Control the transfer passenger volume per unit time from one line to another, to influence the number of boarding passengers of another line and passenger route choice.

✓ Adjust the width of transfer walkway
✓ Change the transfer streamline
Multi-station Collaborative Boarding-Limiting (MCB)

- During rush hours, intensive passenger flow usually appears not only at a single station but also at several adjacent stations on the urban rail transit network.
- The organization scheme of an upstream station will influence the passenger boarding at several downstream stations.

Section load factor of line 6 during morning peak hours

Inbound passenger volume of line 6 during morning peak hours
The influence of the MCB method on the station congestion

The same line

Before MCB

After MCB

The adjacent line

Before MCB

After MCB
The influence of the MCB method on the route choice

Before MCB

After MCB
MCB Model

Control the number of passengers boarding at each station to allocate the train capacity reasonably.

Assumption

(1) The OD demand of the network is fixed.
(2) The inbound passengers enter the station at a constant speed.
(3) The headway of each line, running time in the each section and dwelling time at each station are fixed.

Decision variable

Number of inbound passengers taking line r at station n per unit time
Number of transfer passengers taking line r at station n per unit time
MCB Model: Object function

(1) Maximize the number of boarding passengers
- It can be calculated by inbound and transfer passenger volume per unit time.

(2) Reduce the congestion in the key stations.
- The key stations means the stations that suffer huge passenger volume. More passengers should be allowed to board the trains than other stations.
- This objective can be expressed by the variable coefficient of the ratio of boarding passenger volume to passenger demand.
MCB Model: Constraints

(1) Passenger demand constraints
   The boarding passenger volume should be less than passenger demand per unit time.

(2) Dwell time constraints
   The passengers on the platform should be able to board during dwell time.

(3) Train capacity constraints
   The number of passengers on the platform should be less than the residual train capacity.

(4) Transfer walkway capacity constraint
   The number of boarding-limiting transfer passengers should be less than the transfer walkway capacity.
MSA Algorithm

Object function
(1) Maximum boarding passengers
(2) Reduce the congestion in the key stations

The MCB Model: Algorithm framework

Decision Variable
(1) Inbound passenger volume per unit time
(2) Transfer passenger volume per unit time

MSA Algorithm

Update route choice

Object function
(1) Maximum boarding passengers
(2) Reduce the congestion in the key stations

Multi-objective Optimization

Passenger assignment with multi-path and varying impedance

GA algorithm

The MCB Scheme
Case Study

Adjacent boarding-limiting station

- Nanshao
- Shahe University Park
- Shahe
- Gonghuacheng
- Zhuxinzhuang
- Life Science Park
- Yuzhilu
- Pingxifu
- Huilongguandongdajie
- Longze
- Huilongguan
- Huoying
- Yuxin
- Xixiaokou
- Yongtaizhuang
- Lincuiqiao
- Beishatan
- South Gate of Forest Park
- Olympic Green
- Olympic Sports Center
- Liudaokou
- Olympic Line
- Mudanyuan
- Jiandemen
- Beiducheng
- Line 08
- Line 10
- Line 13
- Line 15
- Changping Line
The numbers of boarding passengers before and after MCB (Line 13 and Changping Line)
• The section load factors of Line 8 and Line 10 rise slightly. This passenger flow is transferred from heavily jammed Line 13 to less crowded Line 8 and Line 10.

• Taking line 13 and Changping Line into consideration, the total number of boarding passengers increases by 600 passengers per hour after MCB.

(a) Line 13

(b) Line 10

The loading factor before and after MCB (Line 13 and Changping Line)
Thank you for your attention!

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