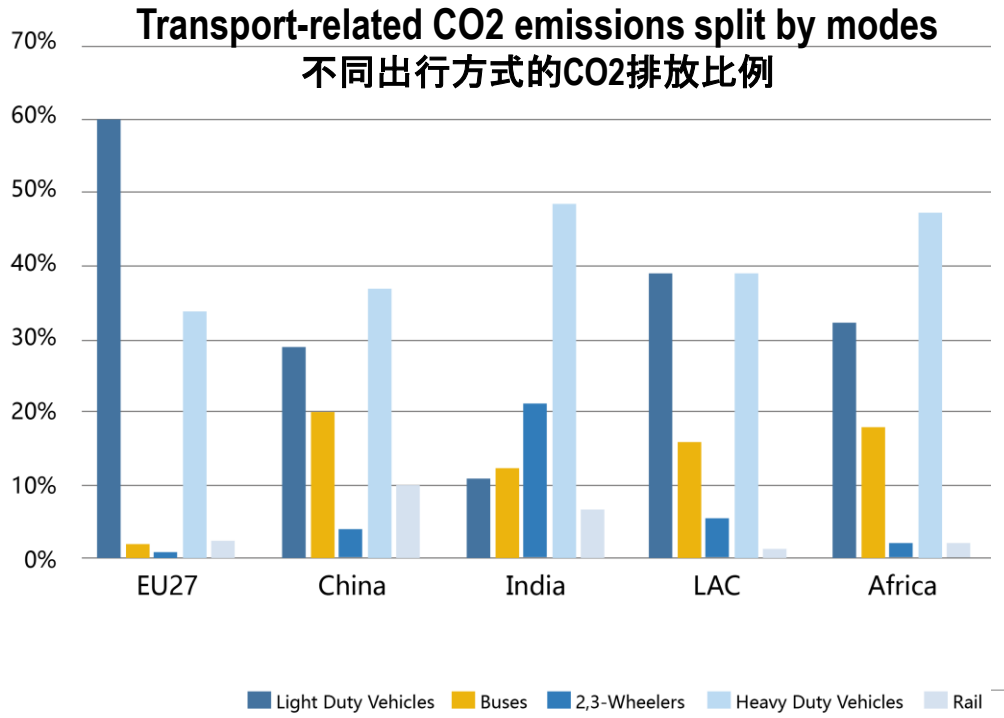
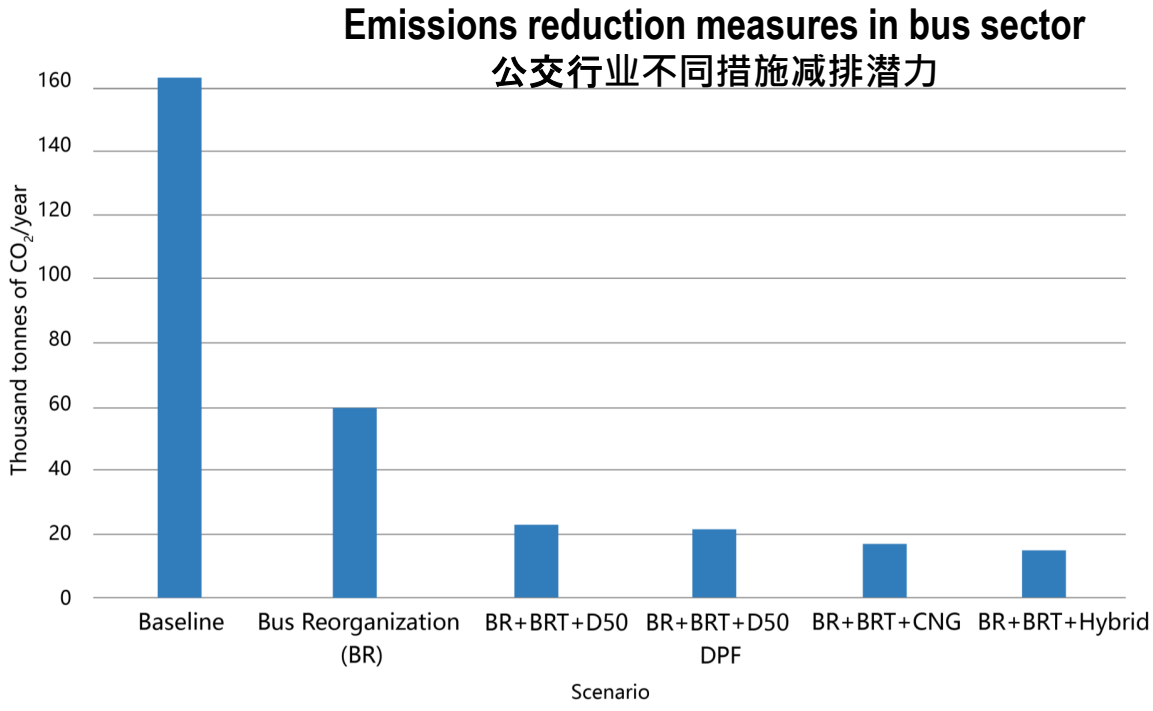
Using Smart Card and GPS for Transit Policy-Making in Ulaanbaatar 乌兰巴托基于公交刷卡和GPS的公交服务分析

Emissions Reduction Potentials in the Bus Sector
传统公交行业的减排潜力

- In developing countries, the bus sector doesn't always deliver the full emissions reduction potential, because of 发展中国家，公交减排潜力往往受制于:
  - Competing services重复竞争服务
  - Inefficient operation运营效率低
  - Low ridership 客流量低
  - Old high-emissions fleets 车辆老旧、排放高





Source: ICCT, Cordeiro et al. 2008

Reforms in the Bus Sector
传统公交行业的变革

Traditional 传统、无序的服务

Source: World Bank, EMBARQ, Reforma, Magic Bus.

Formalized services 正规、有序的服务

Source: Flickr, EMBARQ, El Espectador, EMBARQ, World Bank.

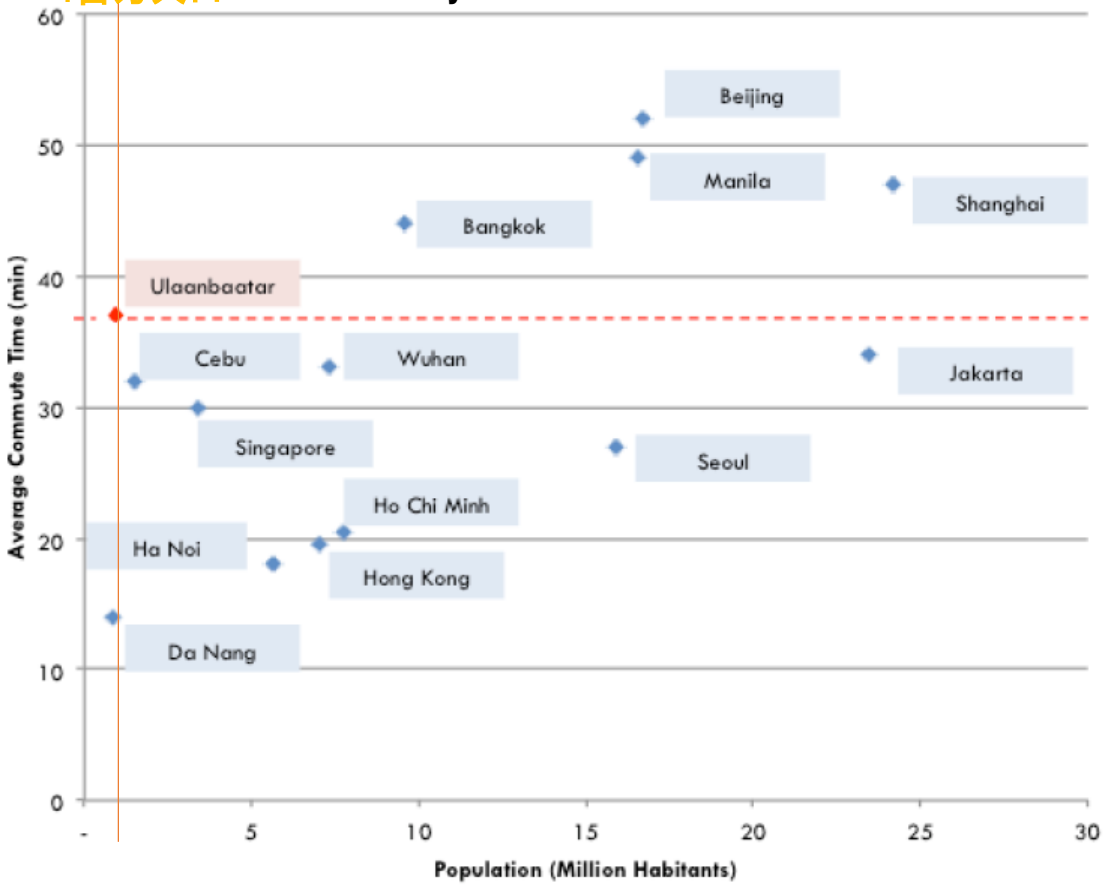
- Formalize informal bus operators/drivers/service branding 规范非正式公交
- Realign inefficient bus route system 公交线网优化
- Establish intelligent bus management system and smart cards 公交信息化
- Improve transfer facilities and bus lanes 专用道、换乘等基础设施改善
- Procure low-emissions vehicle fleets 购置低排放车辆

Public Transit in UB
乌兰巴托公交现状

- Commute time by bus公交通勤时间: 30-40 mins

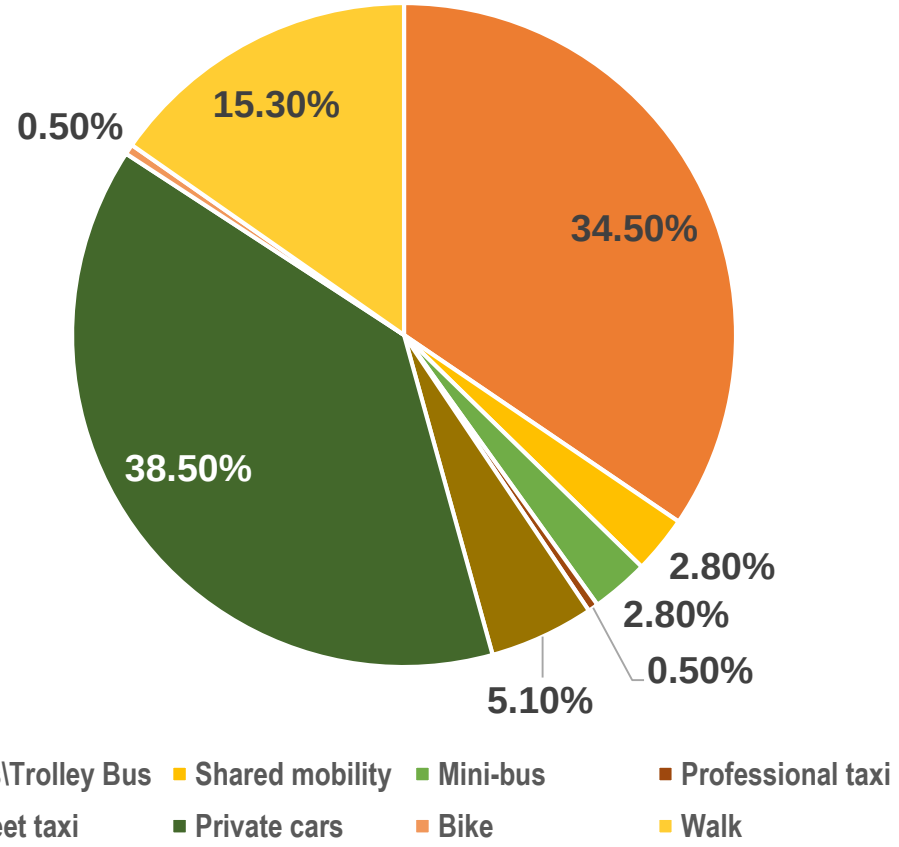
1million population
1百万人口

Daily Commute Time 日通勤耗时



- Weekday card boardings公交日客流: 638,975 trips人次
- Weekday bus passengers公交日乘客: 271,056 persons人
- Mode share of formal transit service全方式公交分担率: 34.5%
  (paratransit service: 10.7% 非正式公交分担率)

Mode split (all modes) **全方式出行比例**

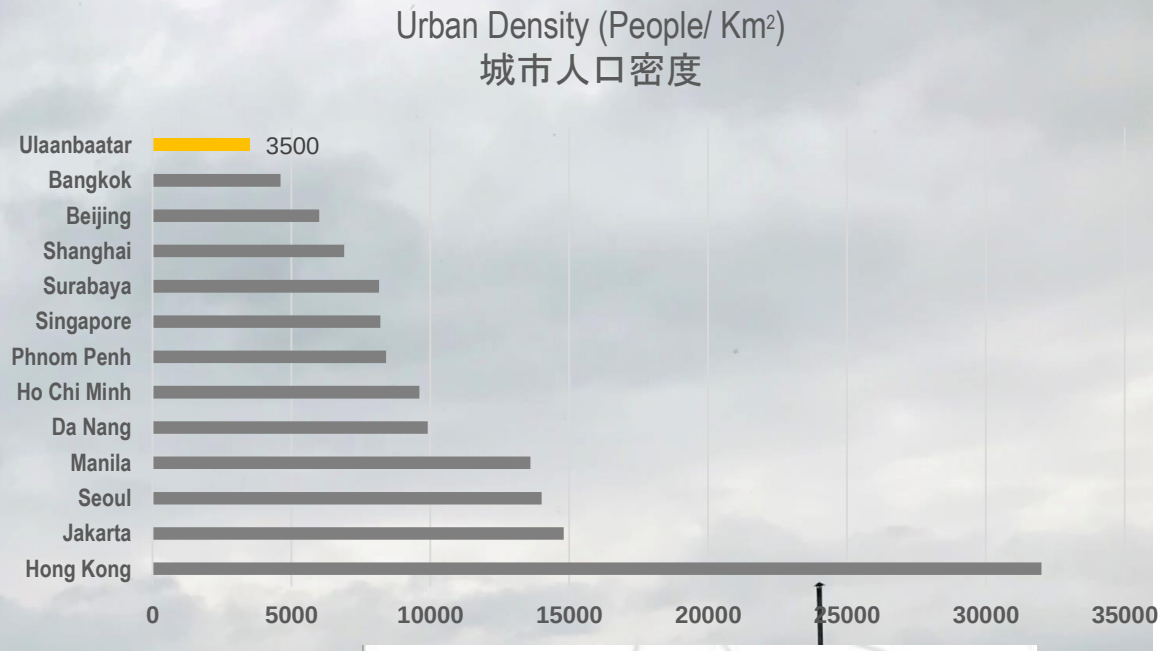


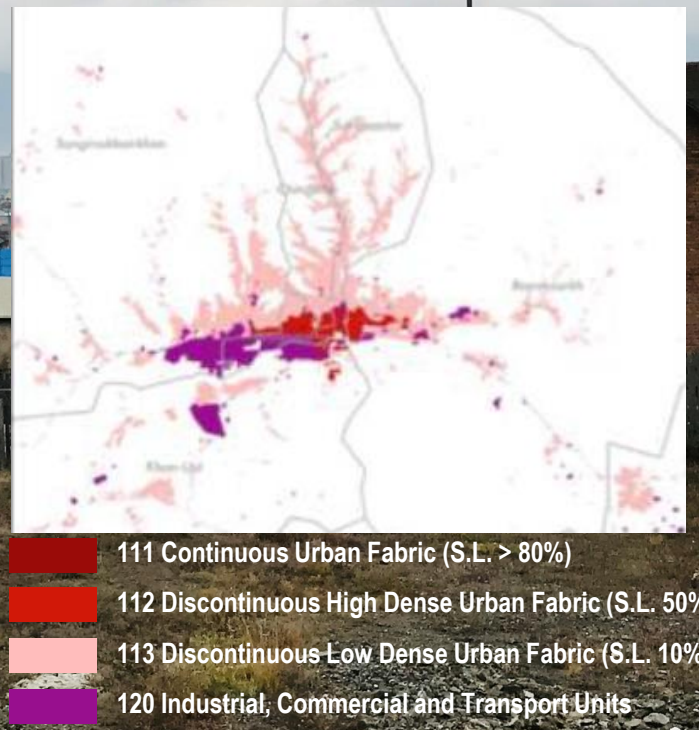
Source: WRI smart card study, UB household survey, World Bank 2015

Public Transit in Ger Area
乌兰巴托公交现状

- Uneven Distribution of Demand: Public Transit Service in Ger Area:
  不均衡发展：郊区蒙古包地区的公交

Fragmented sprawl and unpaved local roads pose challenges to transit service provisions. 低密度城市蔓延和缺乏铺装的路面给公交规划造成难度。





Source: World Bank 2015

Bus management and E-ticketing system in UB
乌兰巴托公交信息化

Automatic Fare Collection System in UB 智能公交刷卡系统

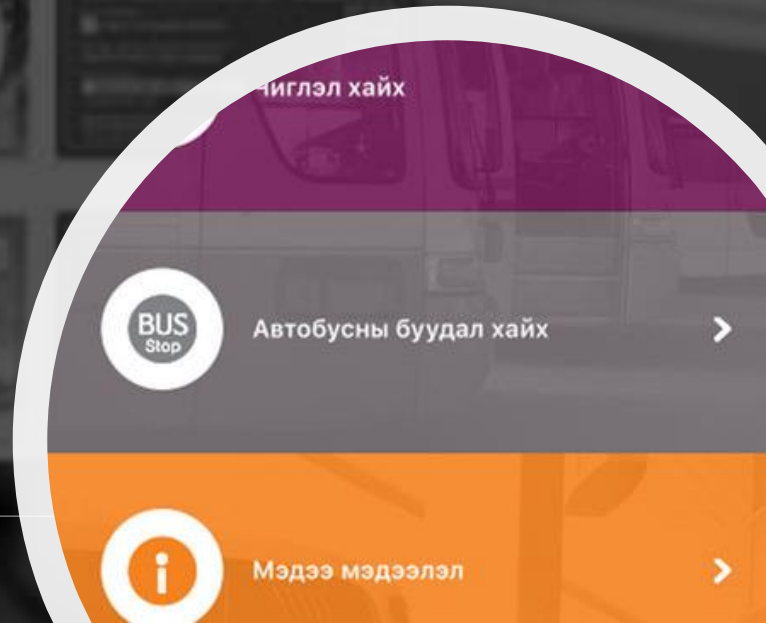
- Cash payment is no longer accepted from April 1st 2017

  (nearly 100% penetration vs. China's average 61%)

  2017年4月起，所有公交支付必须刷卡完成，刷卡渗透率达到几乎100%

Automatic Vehicle Location System in UB 公交智能定位系统

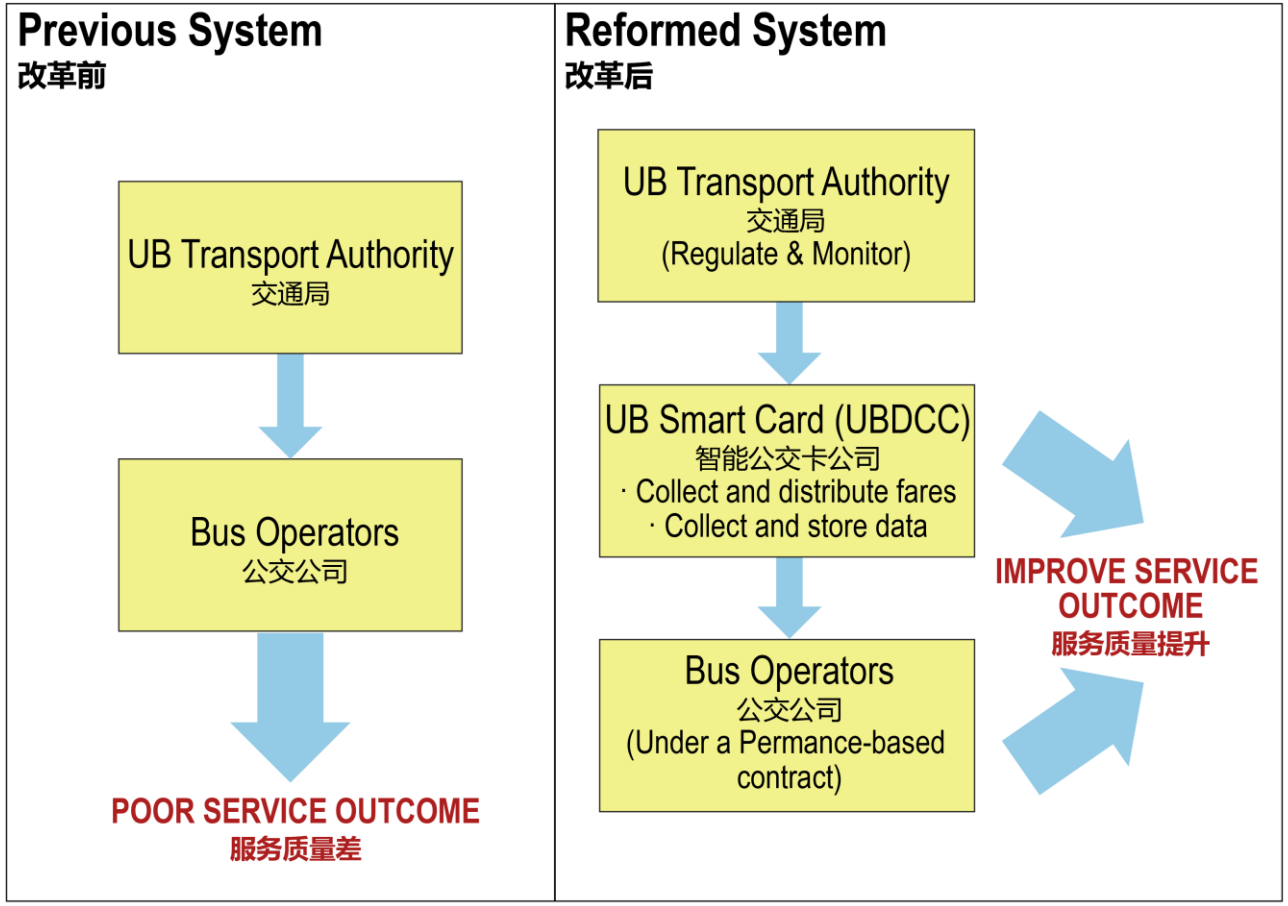
- All the buses are equipped with GPS systemwide to enhance transit operation in real time 所有公交车均配备GPS智能定位系统
- Mobile-based user information system put into operation 手机客户端到站查询系统



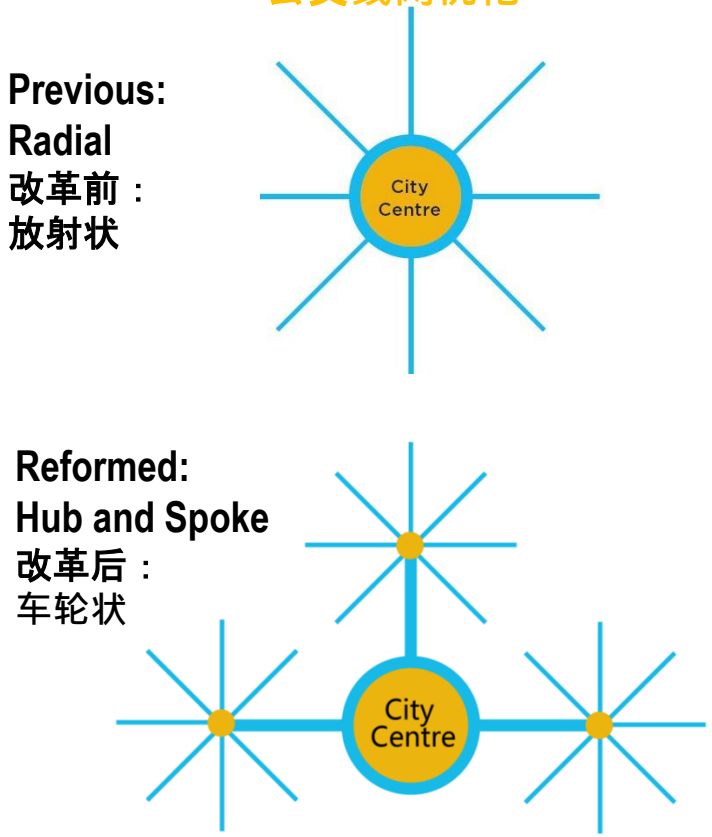
Bus Reform in UB 乌兰巴托公交改革

- E-ticketing (AFC) shouldn't be seen as a process of simple replacement for traditional ticketing. It is also an opportunity to reform the bus sector. 引入公交智能化系统也是公交改革的契机。

1. Informal service to regulated service 公交管理体制改革

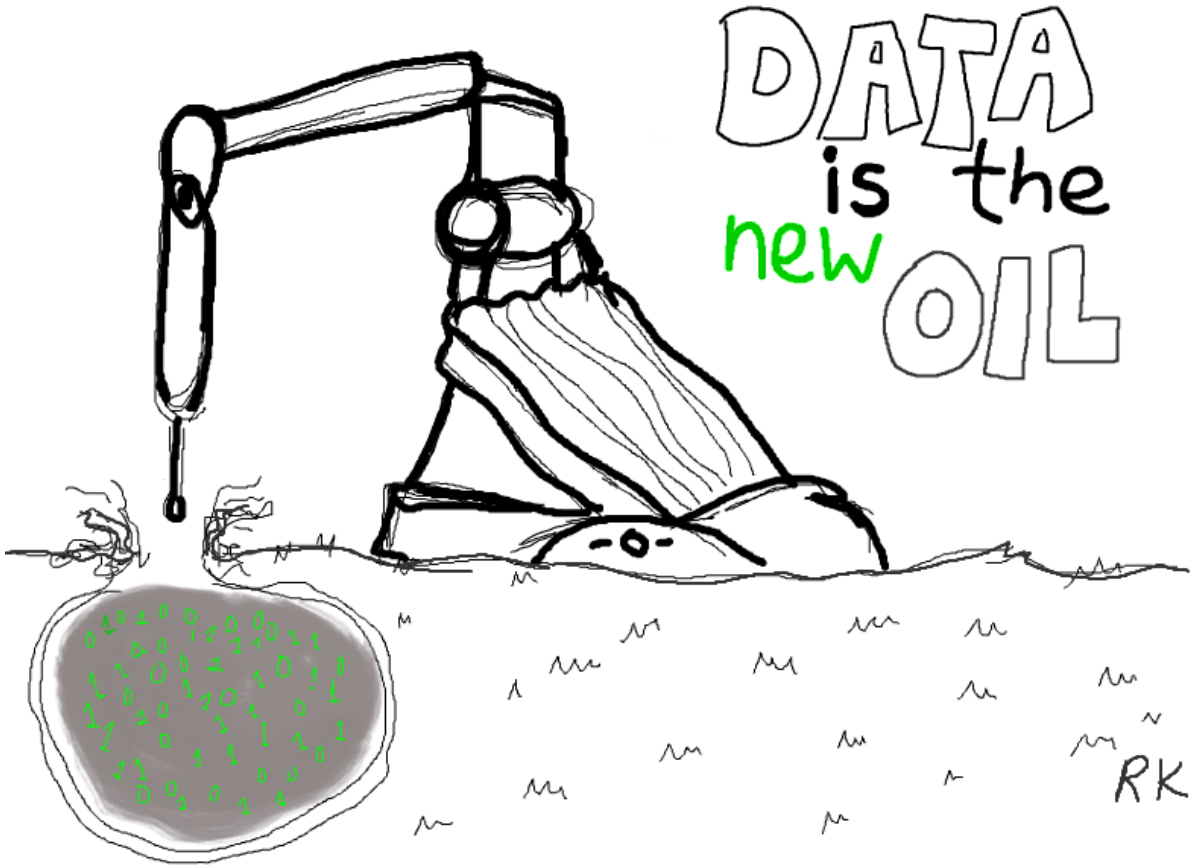


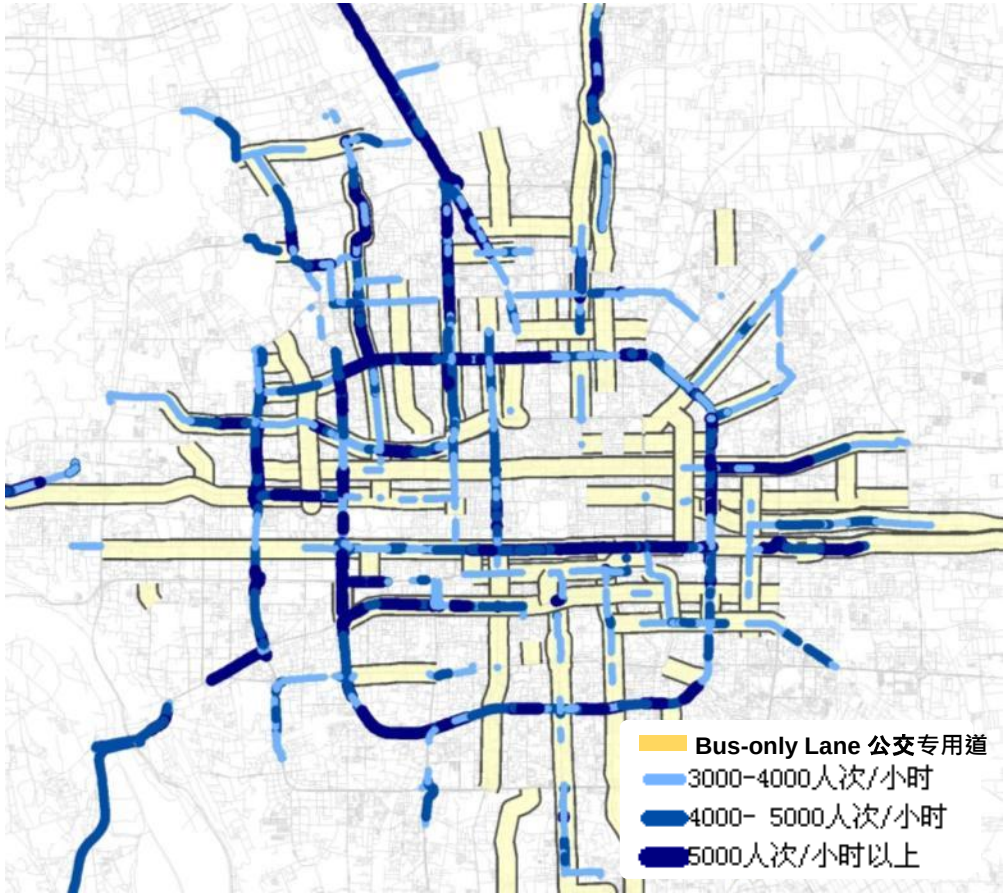
2. Route structure optimization 公交线网优化



Source: Adapted from ADB 2009

3. Proposed: Using Smart Card and GPS data for policy making and planning
建议：基于公交刷卡和GPS数据改进公交服务



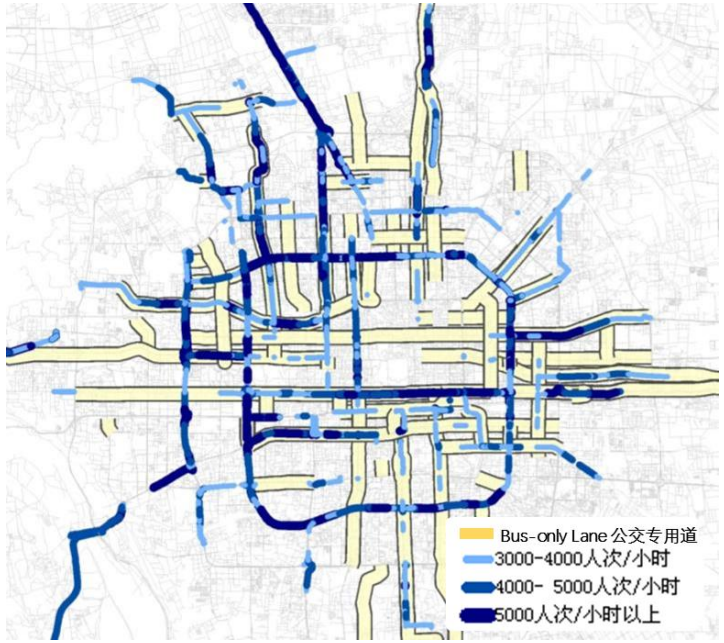


Source: Beijing Transport Institute 2017

3. Proposed: Using Smart Card and GPS data for policy making and planning
建议：基于公交刷卡和GPS数据改进公交服务

1.Transit Planning 公交规划: Prioritize transit investment to match with travel demand 优化公交投资，加强与需求匹配

Wuhan\Chongqing\Kunming: Reorganization of bus route
一二线中国城市：公交线网优化

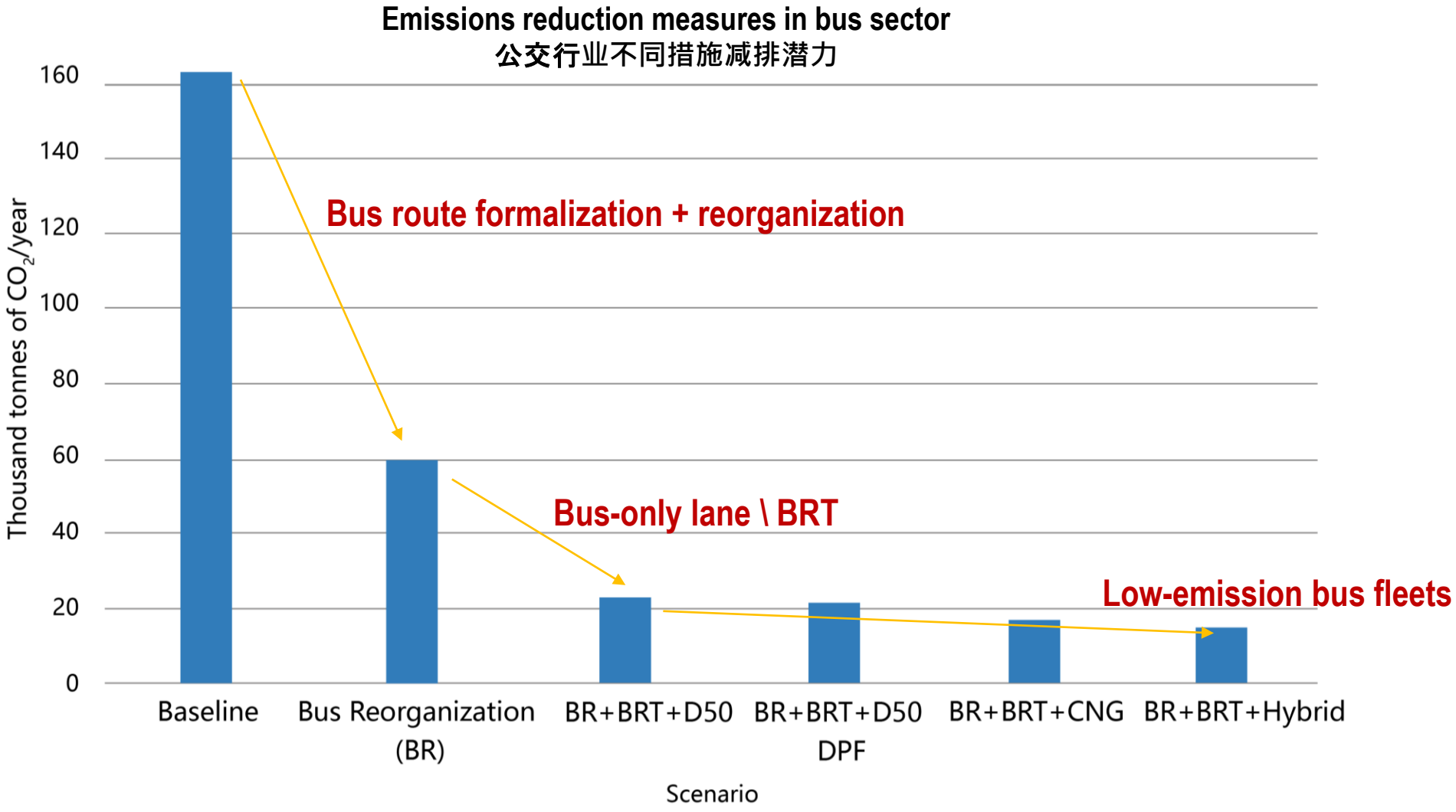


Beijing: Bus-only Lane Plan
北京：公交专用道网络规划

2. Daily Operation 公交运营监管: Monitor and plan bus operation in real-time 公交运营的实时监督和动态调整

Zhengzhou Bus Corporation: Smart scheduling and dynamic dispatching
郑州公交：智能运营计划编制

Source: Beijing Transport Institute 2017



Source: Cordeiro et al. 2008

3. Proposed: Using Smart Card and GPS data for policy and planning
建议：基于公交刷卡和GPS数据改进公交服务

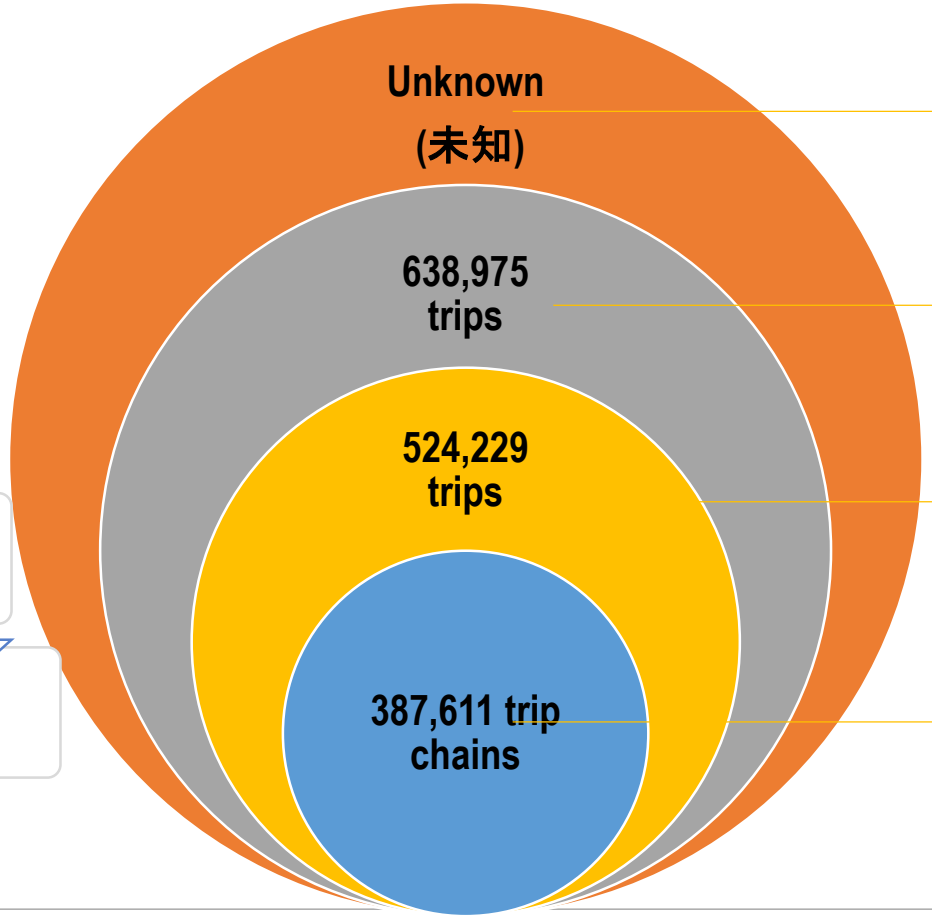
- Model inputs: smart card and GPS records on Sept 4, 2018(Tuesday)
  模型输入：2018年9月4日一天刷卡和GPS数据
- Model results:
  模型结果

Infer transit destinations
下车站点推导

Cascade trips by transfers
识别换乘出行

Construct OD matrix
创建公交出行OD矩阵

Validation
验证结果



Total trips
公交日客流量

Fare invasions, equipment malfunction
逃票，系统故障

Trips w/ valid smart card taps
公交日刷卡客流量

Trips impossible to derive destinations
部分出行无法推导出下车站点

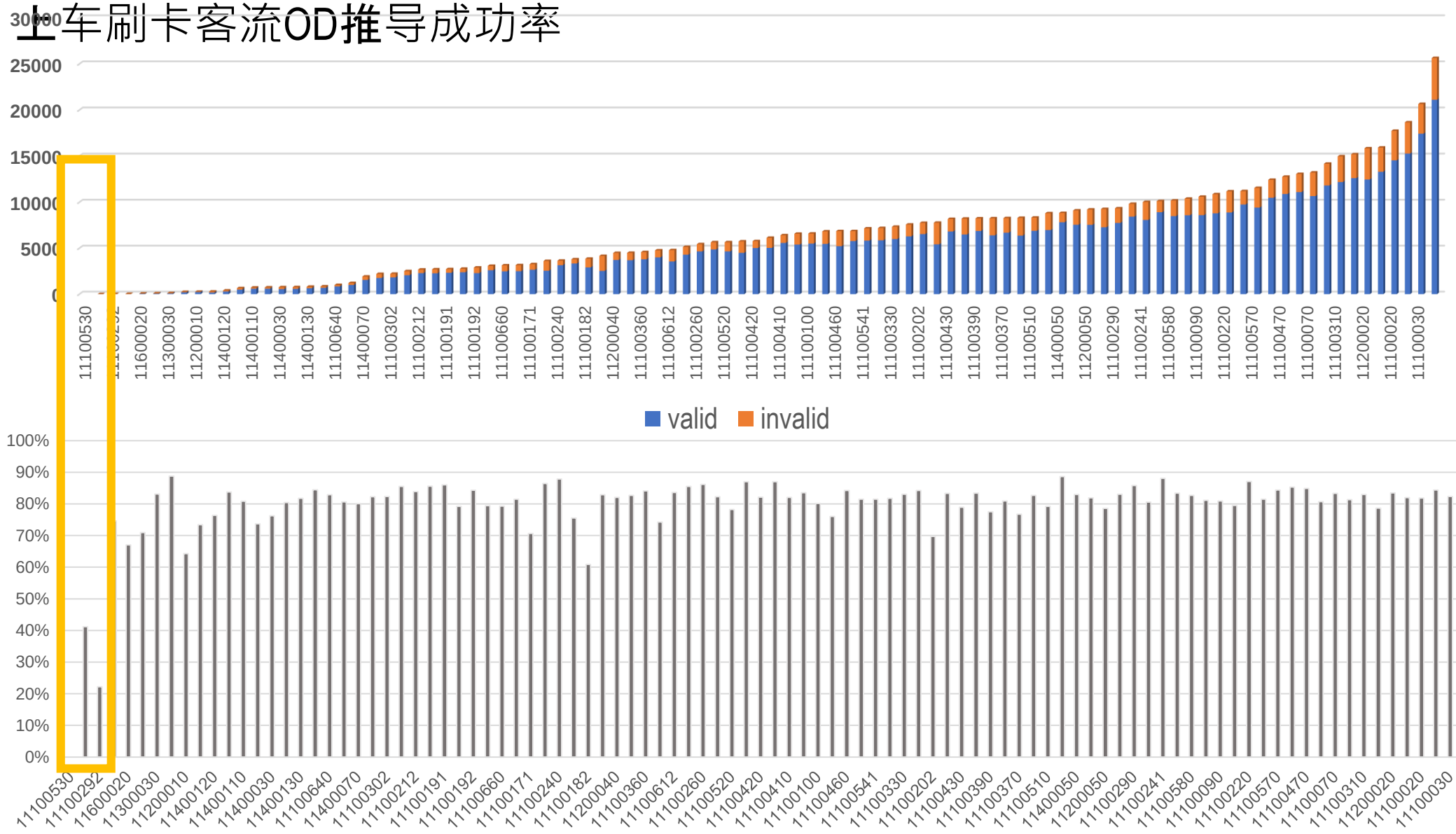
Trips w/ valid Origin-Destination inference
可推导出下车站点的日客流量

Trips be merged into a trip chain
根据出行规律，分析换乘

Trip chains (with transfers)
计入换乘后的日公交出行次数(换乘算1次出行)

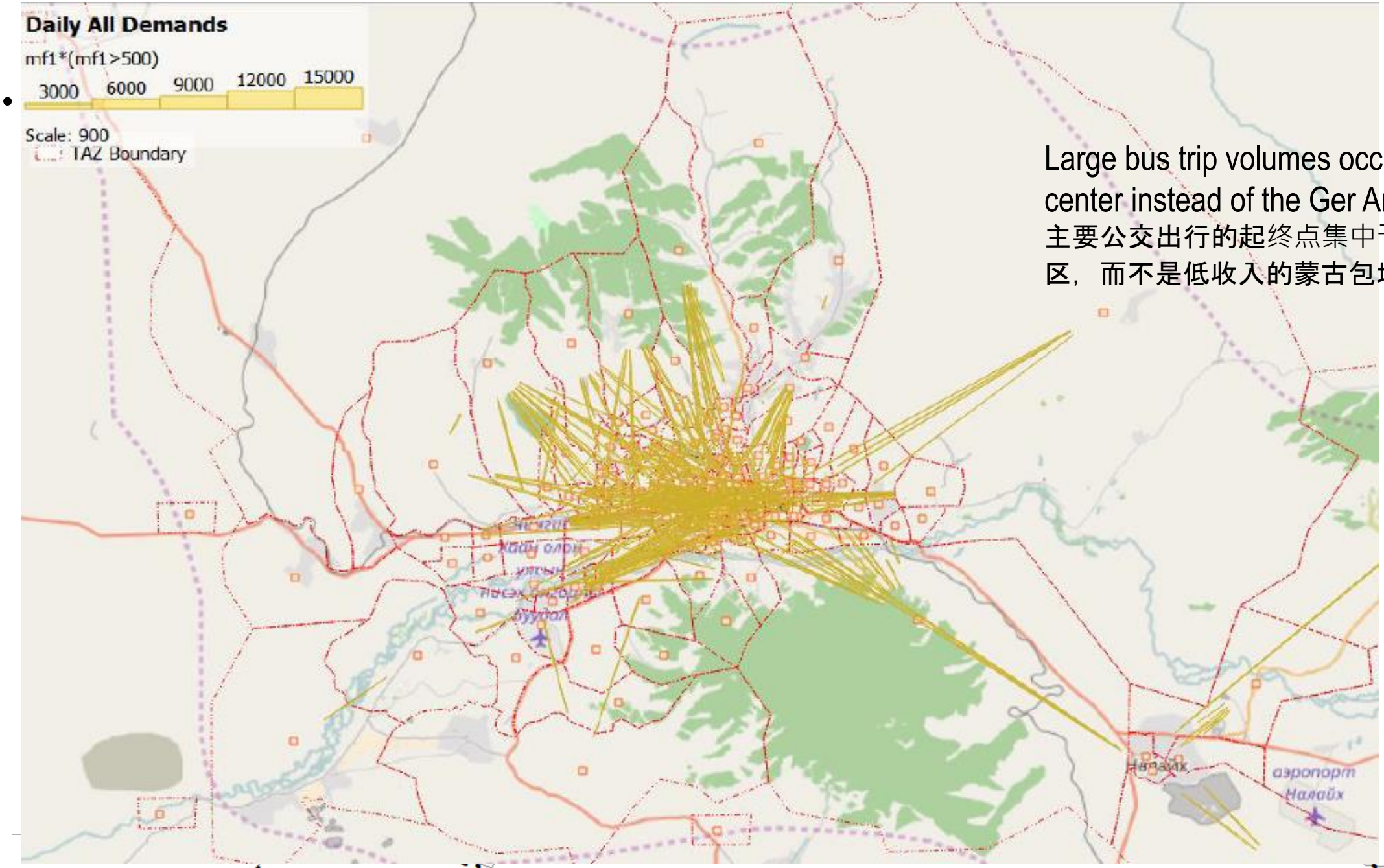
- Bus Passenger Origin-Destination Estimation: OD Inference Rate by Route

上车刷卡客流OD推导成功率



Card boardings
公交日刷卡量

% of trips with destinations inferred 刷卡下车站点推导成功率
(most is >80%)
(多数线路>80%)

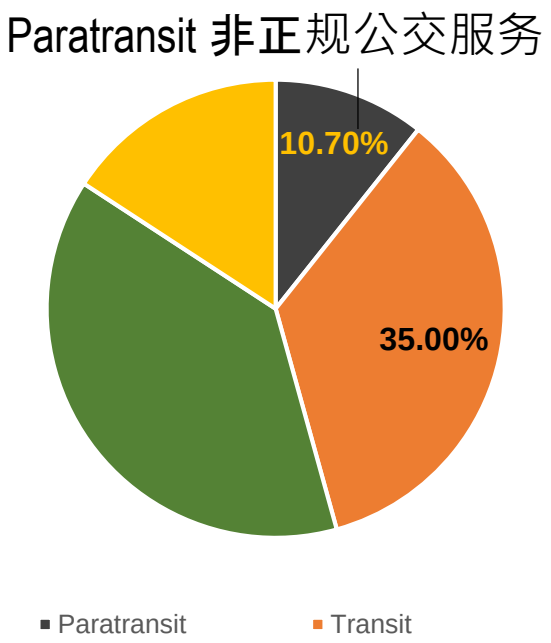


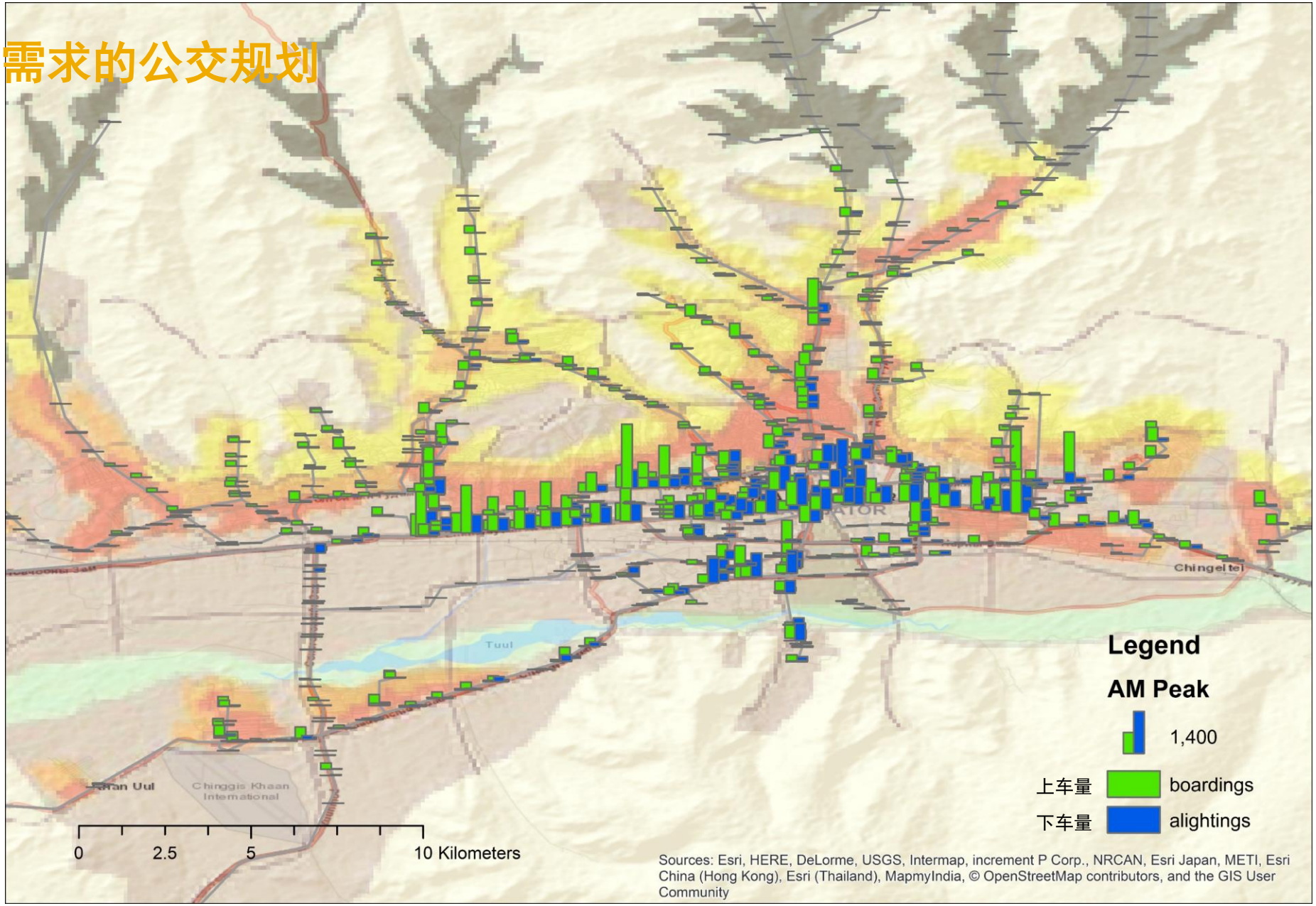
Large bus trip volumes occur in the city center instead of the Ger Area.

主要公交出行的起终点集中于城市中心区，而不是低收入的蒙古包地区。

Transit Planning 基于出行需求的公交规划

Bus Boarding and Alighting at AM Peak早高峰站点上下车量

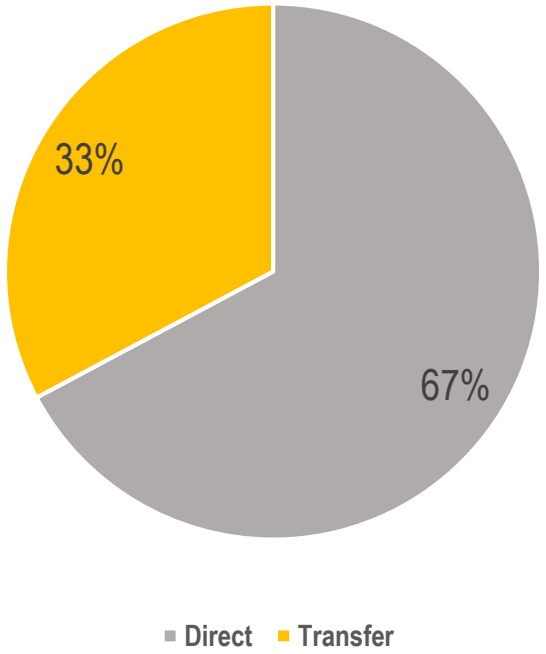




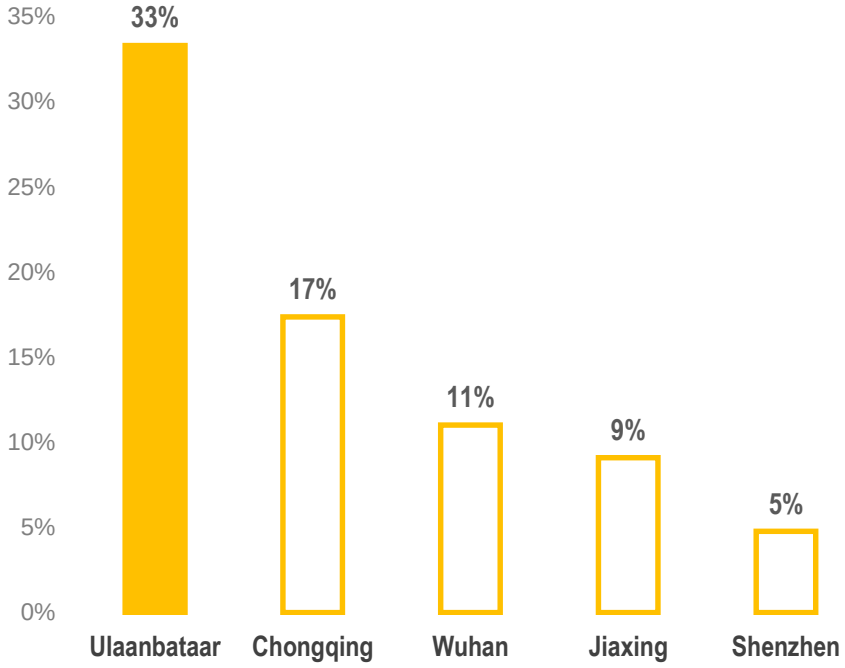
Transit Planning 基于出行需求的公交规划

- **Bus-to-Bus Transfers 公交换乘**

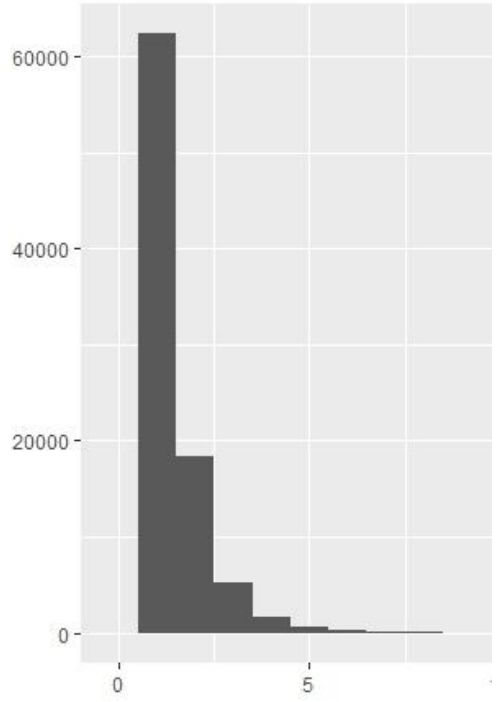
Weekday bus ridership工作日乘客数量: 271,056 persons/day 人每天
Weekday riders with transfers工作日换乘乘客量: 88,896 persons/day人每天



UB-Percentage of bus riders who transfer
乌兰巴托公交换乘乘客比例



Comparisons with typical Chinese cities
换乘比例与中国典型城市的对比

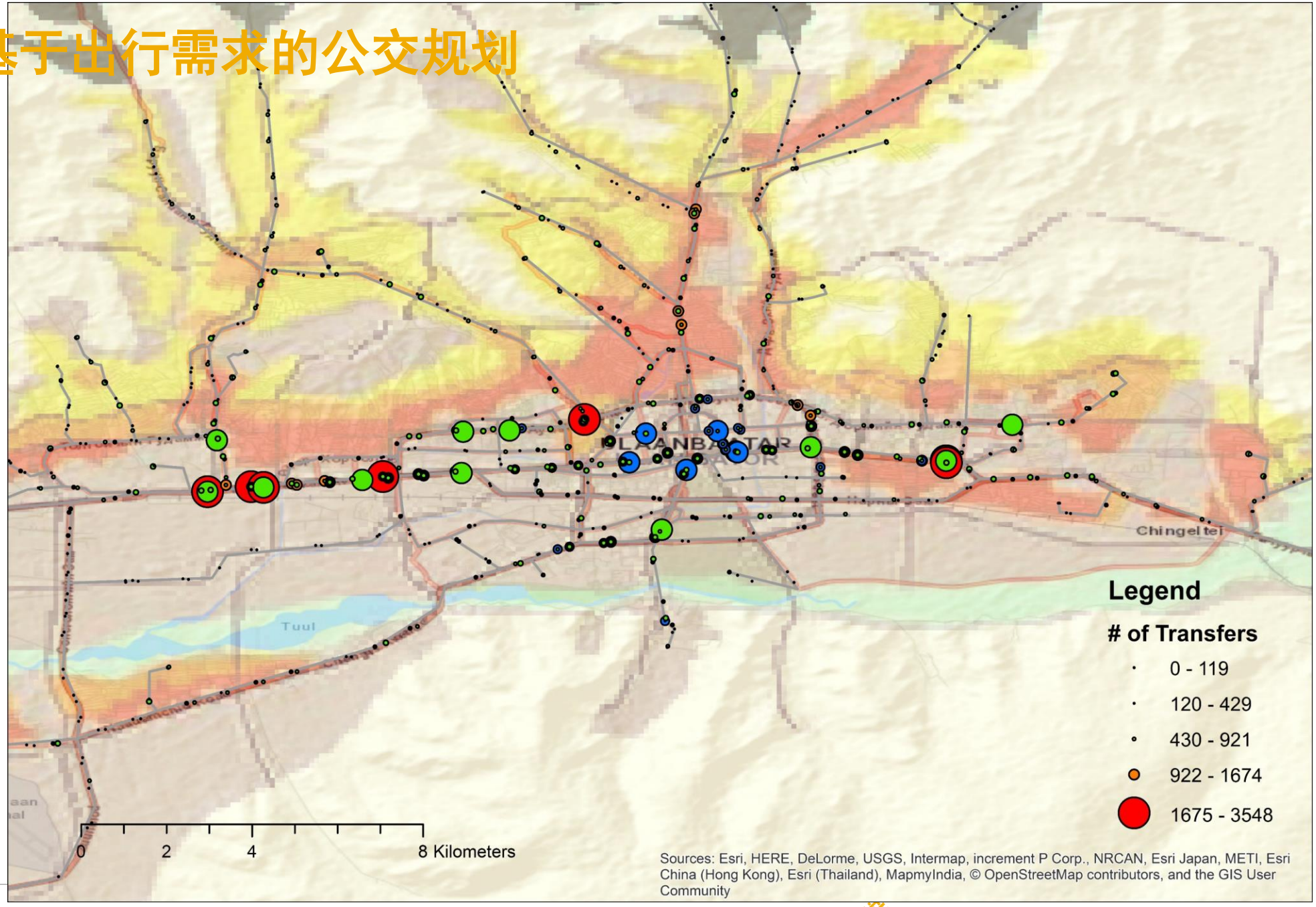


UB-Number of transfers per journey
乌兰巴托公交出行单次换乘频率

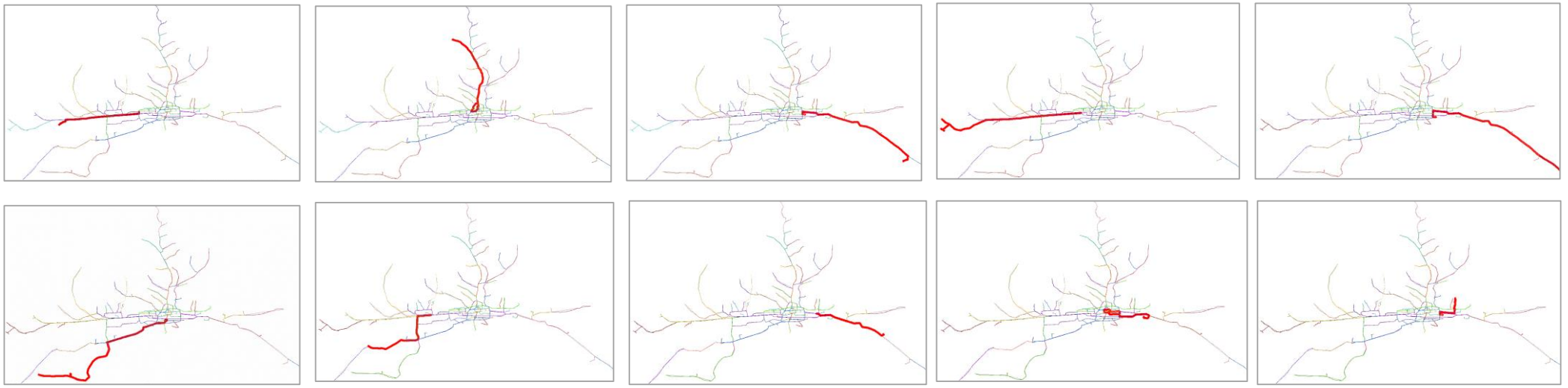
Source: WRI Chinese Cities Transit Big Data Analysis

Transit Planning 基于出行需求的公交规划

Transfers mostly take place at the entry points from the Ger Area to the city center, where jobs are located.
公交换乘往往发生在从蒙古包地区到城市中心的路上。



Transit Planning: Accessibility 公交可达性



Bottom 10 bus routes with the lowest frequencies

- In the Hub-Spoke structure, feeder services serving the Ger area is at low frequencies. 蒙古包地区支线服务，不仅非直达市中心，且频率低。

Transit Planning: Accessibility 公交可达性

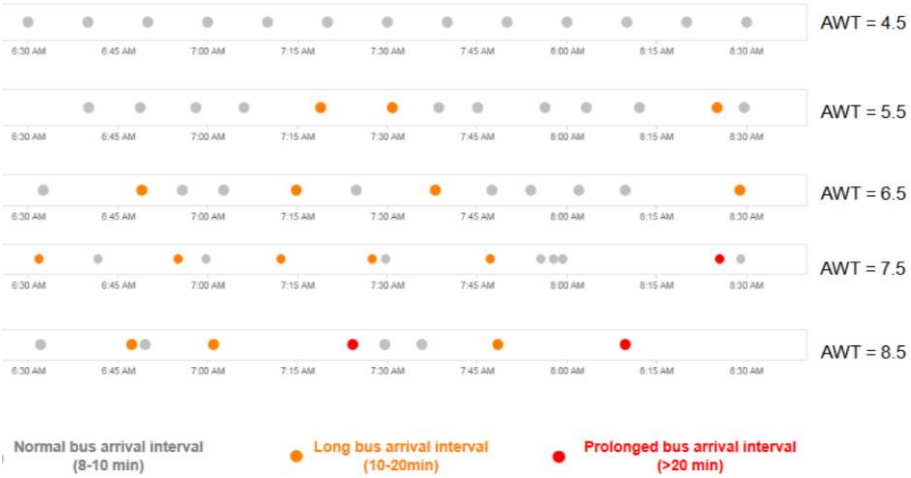
- **Schedule adherence公交准点率**

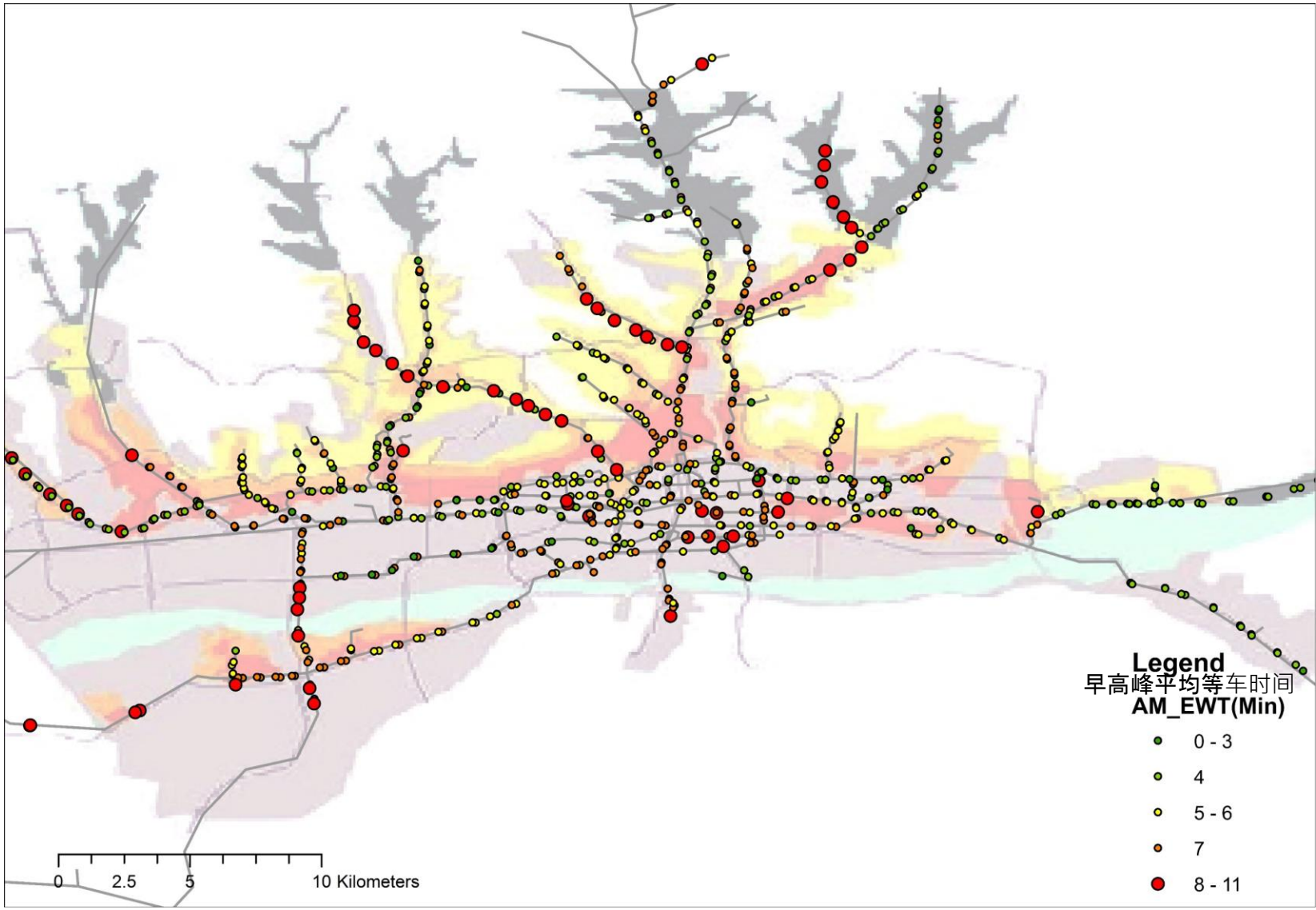
Average Wait Time at peak hours
早高峰平均等车时间

$$AWT = \frac{\sum_{n} \text{actual headway}_n^2}{2 \times \sum_{n} \text{actual headway}_n}$$

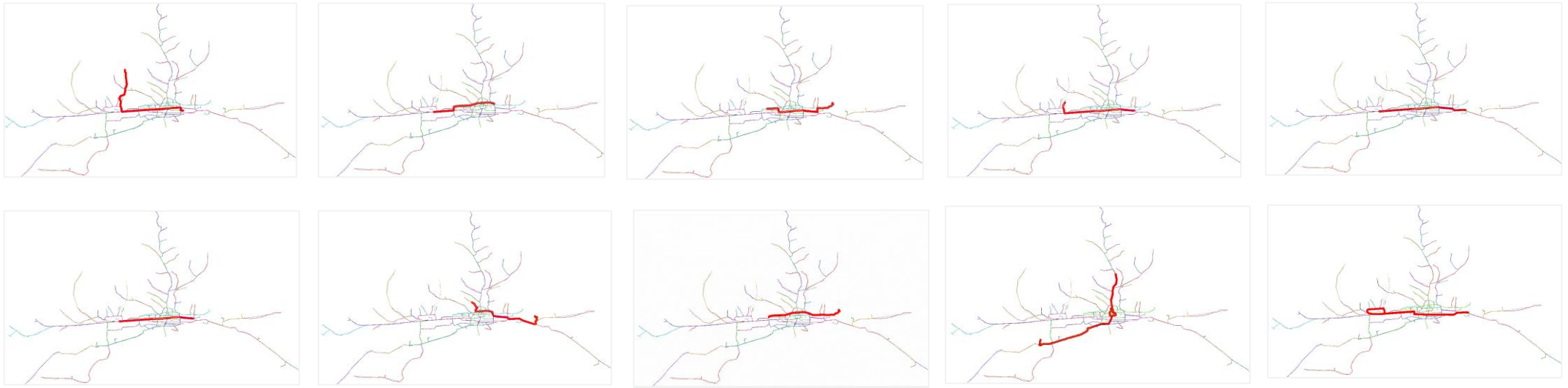
$\sum_{n} \text{actual headway}_n^2$ 实际车头时间间隔

$\sum_{n} \text{actual headway}_n$ 实际车头时间间隔

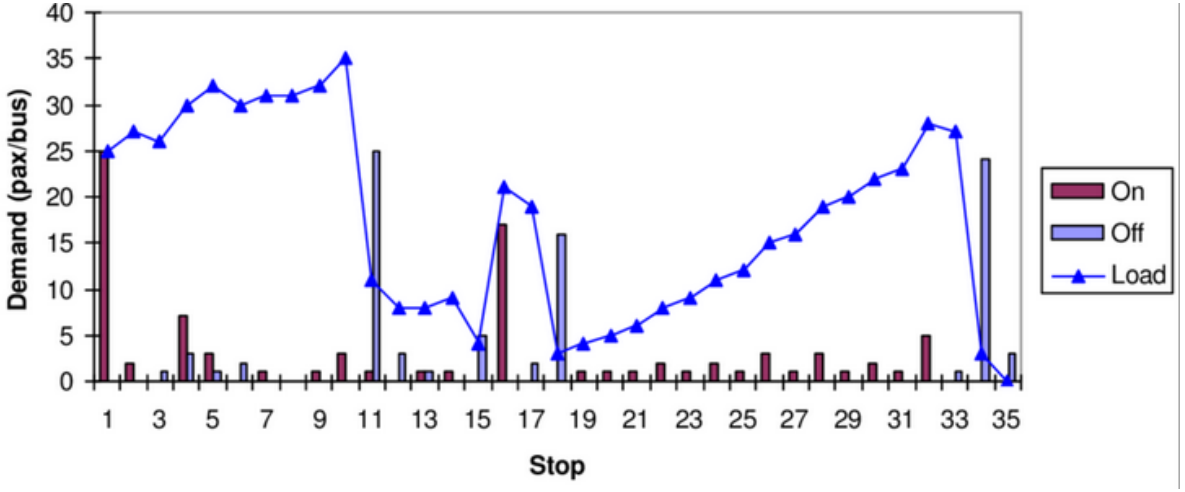




Transit Planning: Accessibility 公交可达性



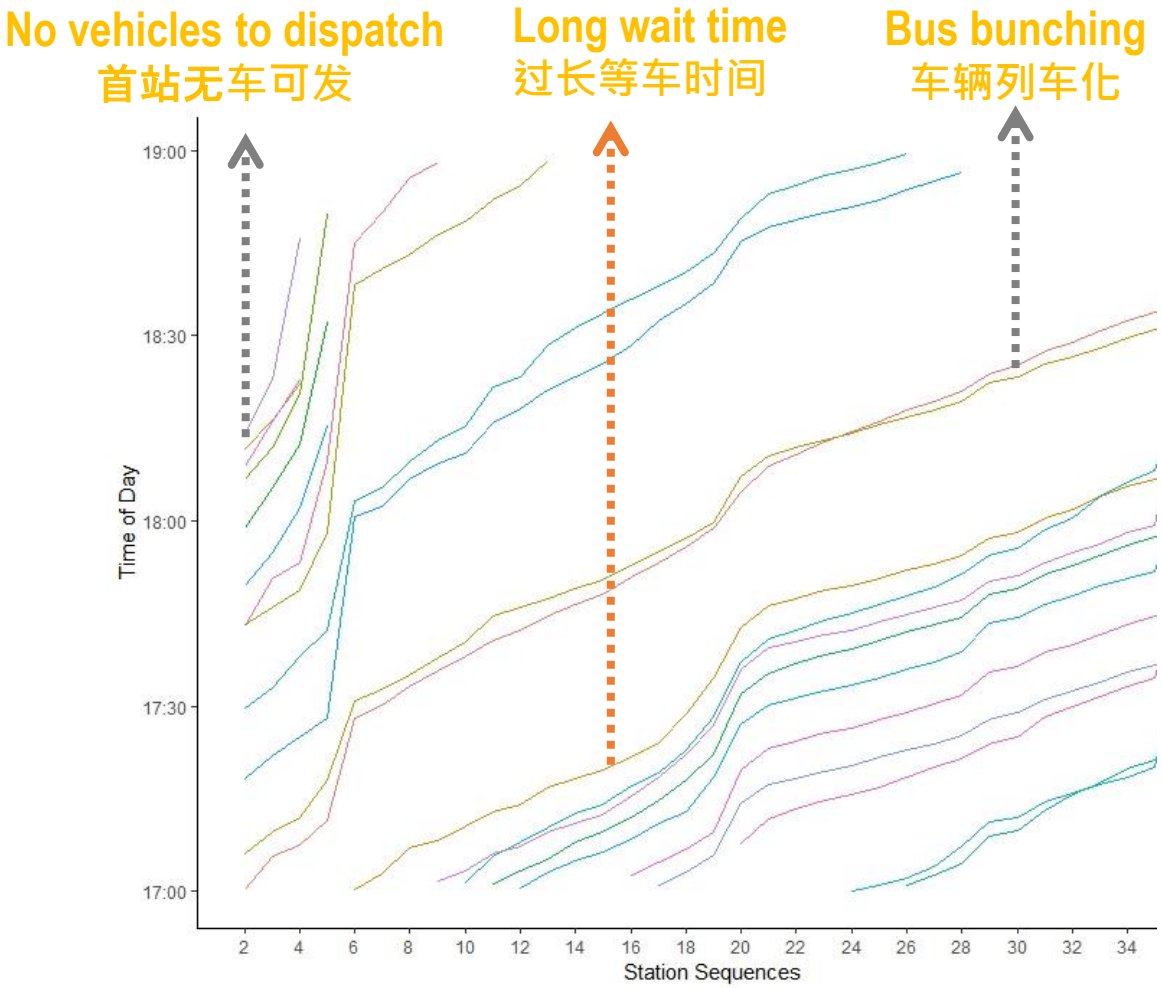
Bottom 10 bus routes with the highest frequencies



- In the Hub-Spoke structure, truck services serving the city centers is highly overlapping and can be truncated at the major destinations. 城市中心区线网重复度高，且存在改善空间。

Transit Planning: Accessibility 公交可达性

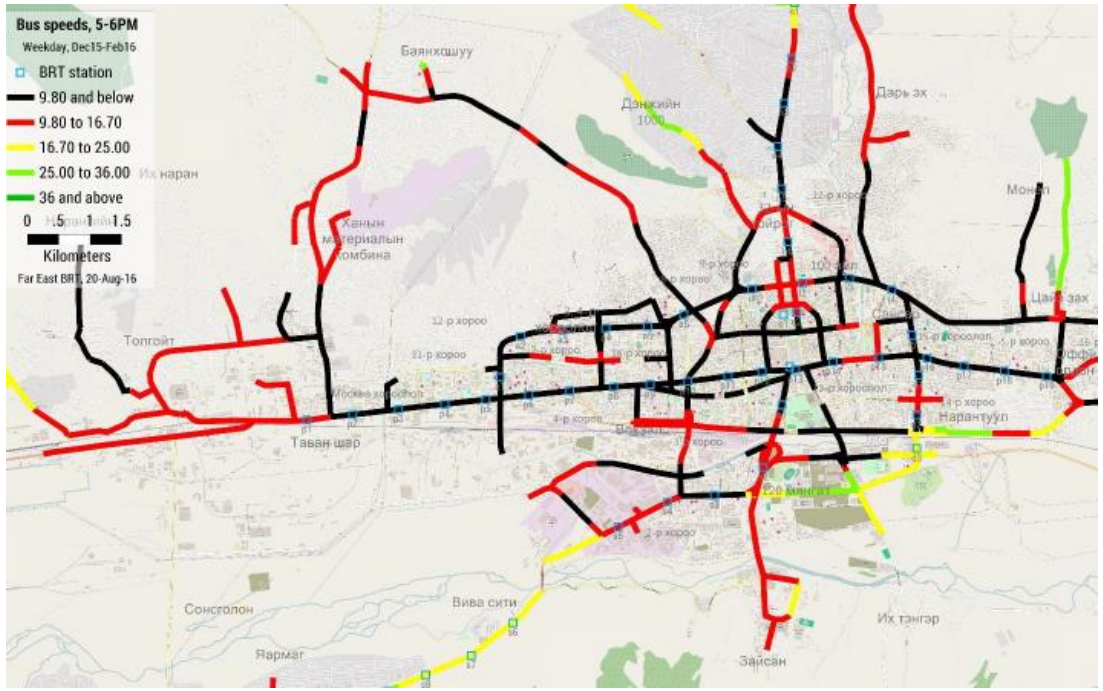
- **Schedule adherence 公交准点率**



Space-time diagram of Route No.3 at PM Peak, Sept 4
公交3号线晚高峰时空分布图
(Route length: 20.8 kilometre per direction 线路长度20公里)

Throughout the day, speed of buses operated in city center is around 10km/h (**cycling speed**)

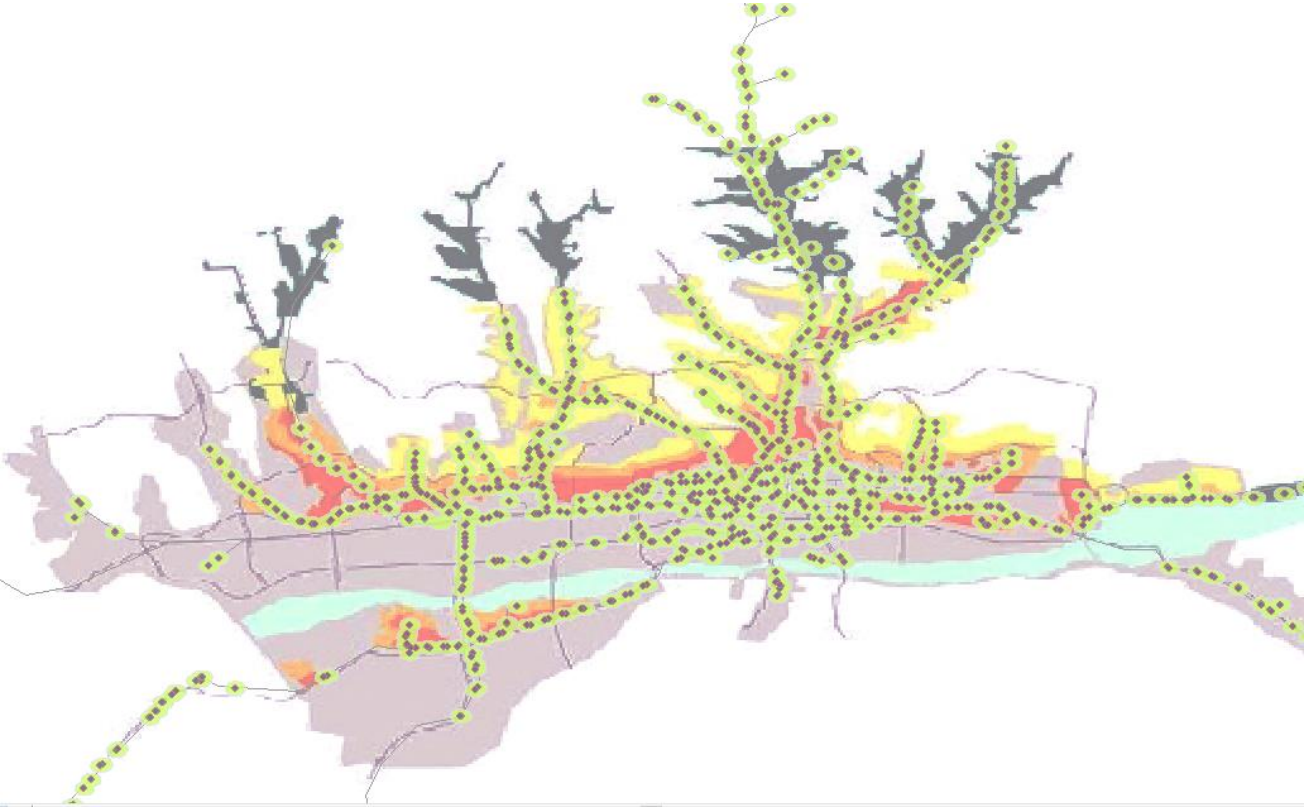
公交运行速度: 市中心全天平均速度为10公里/小时，与自行车速度相当



Source: speed data from ITDP

Transit Planning: Accessibility 公交可达性

Outside the 271,056 bus passengers, there are still many areas(Ger Areas mostly) cannot access to bus services by walk.
除了现有271, 056公交乘客以外，由于公交覆盖度低，在蒙古包地区还有很多现有公交没有服务到的地区。



Built-up area within 300m straight-line distance to bus stations:
建成区公交站点300米覆盖率

44%

Streets\roads served by bus service:
公交线路(道路)覆盖率

25%

Conclusions 结论

- **City Center & High-density Ger Area:城市中心和高密度的蒙古包地区**
  - Optimize the overall route structure: several routes can ends at the major destinations at the city center进一步优化公交骨架结构
  - Improve operational plan: increase the frequencies for feeder services提升蒙古包地区支线公交的频次
  - Plan bus-only lanes to increase bus speed at the city center 规划公交专用道提升城市中心公交车速度
  - Enforce schedule adherence through performance-based contract 加强对准点率的监管
  - Ensure transfer is convenient and reduce transfer costs 方便换乘、减少换乘费用

- **Low-density Ger Area**(mid or fringe): **低人口密度的蒙古包地区** :
  - Provide low frequency, on-demand shared-ride services, enabled by smartphones 增加定制公交或共享出行服务

- **Entire city: 全市层面**
  - Optimize urban form and increase affordable housing provisions 优化城市空间布局、提升公租房供给

Conclusions 结论

Smart Card | GPS | Vehicle OBD System | Surveillance Cameras

Cellphone data | Online surveys | Traffic information

- Making the data-driven decision-making a daily routine 让数据支撑的决策成为常态化:

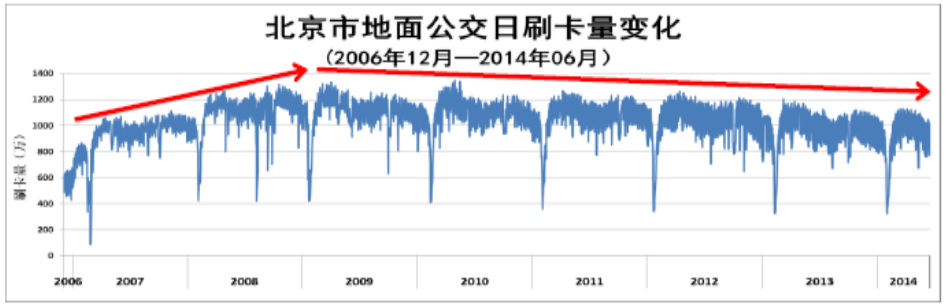
Adapted management/ decision-making process
公交行业管理流程/决策机制改革

涉及指标（大于或小于阈值）	指标意义	优化及调整措施				
		新增或撤消线路	调整线路走向	线路延长或截短	增加或删除站点	调整发车频次
线路长度	反映运营线路规模，应在出行、运营、操作三者可接收范围内			★★★★★		
线路非直线系数	反映了公交线路的曲折程度，满足需求情况下以小为佳		★★★★★	★★★★		
与其它线路重复度	反映了公交线路的重复程度，满足需求情况下以小为佳		★★★★★	★★★★		
高峰满载率	高峰期间被评价公交线路的公交车额定载客量与单车单次实际载客量之比	★★★★				★★★★★
平均站距	被评价线路统计期内公交停靠站点之间的平均距离				★★★★★	

注：“五★”表示优先级最高，指标与调整措施相关性最强，应优先考虑；“四★”表示优先级较高，指标与调整措施相关性较强，应当参考；“三★”表示优先级一般，指标与调整措施相关性一般，可以参考。）

表格来源：上海市公共汽（电）车客运线路优化导则

Institutionalized statistical reporting mechanisms
城市年报统计机制的完善与细化



Data quality assurance
Open data protocols
Cross-departmental data sharing
数据质量管理、跨部门数据共享