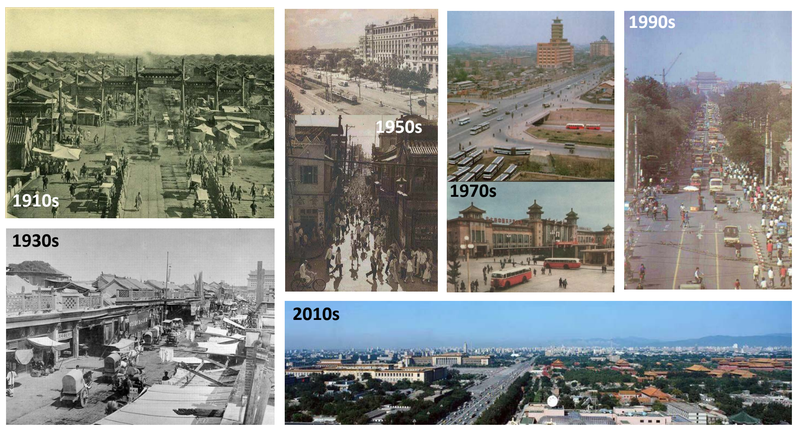
SINGAPORE DATA SCIENCE CONSORTIUM

Anchored at NUS National University of Singapore | Computing

Movement Efficiency – A New Way to Understand the Evolution of A City

Background

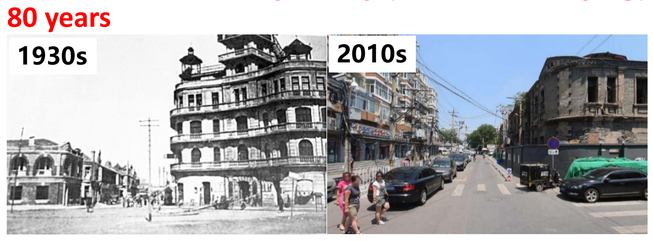


- Understand the evolution of a city
- City map - a network connecting different regions of a city
- Human activities are partially facilitated or confined by the planning of a city
- Floyd–Warshall algorithm-based method
- Movement efficiency - a new way to understand the evolution of a city

Understand the evolution of a city

The Evolution of A City (Streets in Beijing)

80 years



260 meters apart

Historical buildings with new life

Urban Planning in Different Time Periods
The Old Town in Beijing City

Time Periods		Planning Principle
1271-1368	Yuan dynasty (元朝)	A system of King city
1368-1912	Ming-Qing dynasty (明清)	A strict ritual system
1912-1949	Republic of China (民国)	Mergence with western modern planning
1949-2016	People's Republic of China	A conservation-development game
2016-2035	People's Republic of China	Protection of historical and cultural heritage

Space Syntax

- A set of theories and techniques for the analysis of spatial configuration
- The network of a city can be broken into components
- Analysis of the connectivity and integration of a city

Flowchart

Digital historical maps

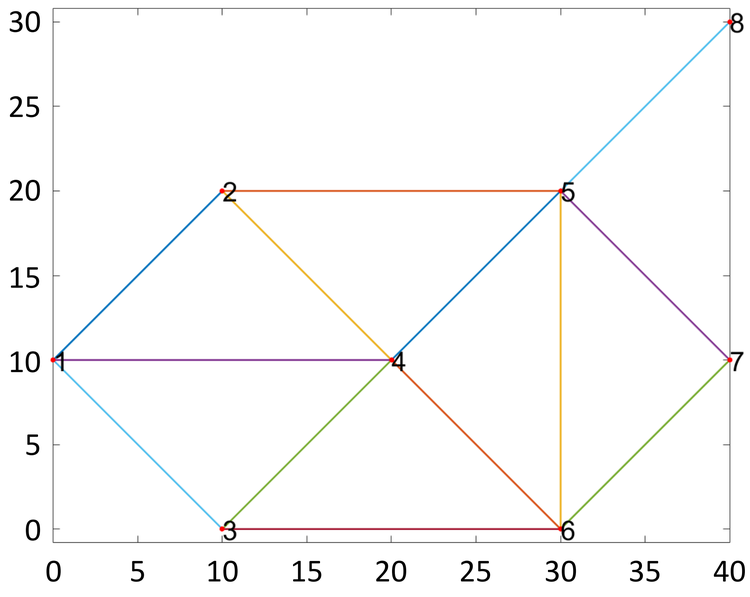
Extraction of **vertices**	Extraction of **turning events**
 vertex	
Construct **vertex** adjacency matrix (with each entry as a distance)	Construct **turning event** adjacency matrix (with each entry as a turning angle)
Use Floyd–Warshall algorithm to determine the **shortest distance between every two vertices**	Use Floyd–Warshall algorithm to determine the **smallest turning angle between every two turning events**
Record the **corresponding routes** during the above calculation	Record the **corresponding routes** during the above calculation
Determine the turning angles of the above routes	Determine **the distances** of the above route

Movement Efficiency is described by

The shortest distance	**The smallest turning angle**
ratio	*ratio*
The distance corresponding to the smallest turning angle	**The turning angle corresponding to the shortest distance**

Floyd–Warshall algorithm

- A method for finding the shortest paths in a network
- Modification of the algorithm to record detailed routes
- A new application of Floyd–Warshall algorithm to determine the smallest turning angles



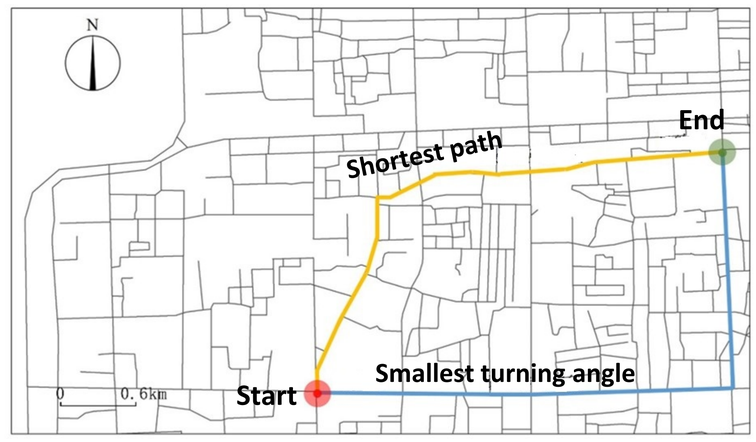
Turning Event Adjacency Matrix

	1->2	2->5	2->4	1->4	3->4	1->3	3->6	4->5	4->6	5->6	5->7	6->7	5->8	2->1	5->2	4->2	4->1	4->3	3->1	6->3	5->4	6->4	6->5	7->5	7->6	8->5
1->2	360	45	90	405	360	360	315	180	90	135	90	180	90	360	315	270	225	180	270	225	180	270	225	270	180	Inf
2->5	315	360	405	360	315	315	270	315	225	90	45	225	45	315	360	225	180	135	225	180	135	225	270	315	135	Inf
2->4	270	315	360	315	270	270	225	90	0	225	180	90	90	270	225	360	135	90	180	135	270	360	135	180	270	Inf
1->4	315	270	315	360	315	315	270	45	45	180	135	135	45	225	180	135	360	135	225	180	315	315	180	225	225	Inf
3->4	270	225	270	315	360	270	315	0	90	135	90	180	0	180	135	90	135	360	270	225	360	270	225	270	180	Inf
1->3	360	315	360	405	90	360	45	90	180	225	180	90	90	270	225	180	225	270	360	315	270	180	135	180	270	Inf
3->6	315	270	315	360	405	315	360	225	315	270	225	45	135	225	180	135	180	225	315	360	225	135	90	135	315	Inf
4->5	360	405	270	315	360	270	315	360	270	135	90	270	0	180	135	270	315	360	270	225	450	270	315	360	180	Inf
4->6	270	315	360	315	270	360	405	270	360	315	270	90	180	270	225	360	315	270	180	135	270	450	135	180	360	Inf
5->6	225	270	315	270	225	315	360	225	315	360	315	135	225	225	270	135	180	225	135	90	315	135	450	225	405	Inf
5->7	270	315	360	315	270	360	405	270	360	405	360	450	270	270	315	180	225	270	180	135	360	180	225	540	90	Inf
6->7	360	405	270	315	360	270	315	360	270	225	450	360	180	180	135	270	225	180	270	315	180	360	405	90	540	Inf
5->8	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf	Inf
2->1	450	405	450	135	180	90	135	180	180	315	270	180	180	360	315	270	315	270	360	315	360	270	225	270	360	Inf
5->2	405	450	135	180	225	135	180	225	135	360	315	225	225	45	360	315	270	225	315	270	405	315	270	315	405	Inf
4->2	450	135	540	225	270	180	225	270	270	225	180	270	180	90	405	360	315	270	360	315	270	360	315	360	270	Inf
4->1	135	180	225	540	225	135	180	225	225	270	225	225	225	405	360	315	360	315	405	360	315	315	270	315	315	Inf
4->3	180	225	270	225	540	450	135	270	270	315	270	180	270	360	315	270	315	360	90	405	360	270	225	270	360	Inf
3->1	90	135	180	135	450	450	405	180	180	225	180	270	180	360	315	270	315	270	360	315	270	360	315	360	270	Inf
6->3	135	180	225	180	135	405	450	135	225	270	225	315	135	315	270	225	270	315	45	360	315	405	360	405	315	Inf
5->4	180	225	270	225	270	180	135	270	90	315	270	180	270	180	315	90	45	0	90	225	360	270	225	270	360	Inf
6->4	180	135	270	225	270	180	225	90	270	225	180	270	90	90	225	0	45	90	180	315	270	360	315	360	270	Inf
6->5	315	360	225	270	315	225	270	315	225	450	135	315	45	135	90	225	180	135	225	270	135	315	360	405	225	Inf
7->5	270	315	180	225	270	180	225	270	180	135	360	270	90	90	45	180	135	90	180	225	90	270	315	360	450	Inf
7->6	180	225	270	225	180	270	315	180	270	315	270	360	180	180	225	90	135	180	90	45	270	90	135	450	360	Inf
8->5	180	225	180	225	270	180	135	270	90	45	90	180	270	90	45	90	45	0	90	135	0	180	225	270	180	Inf

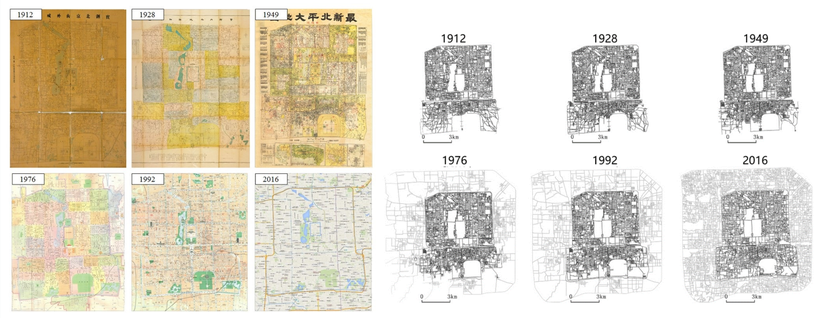
Movement Efficiency

- a new focus of graph analysis in the fields of urban planning and route planning
- A measurement of the efficiency of a network

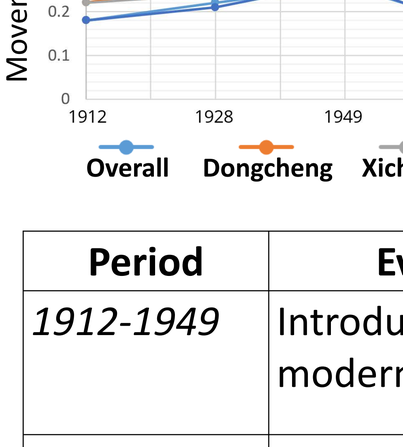
Which route is better?



Materials
(The Old Town in Beijing City in Different Time Periods)



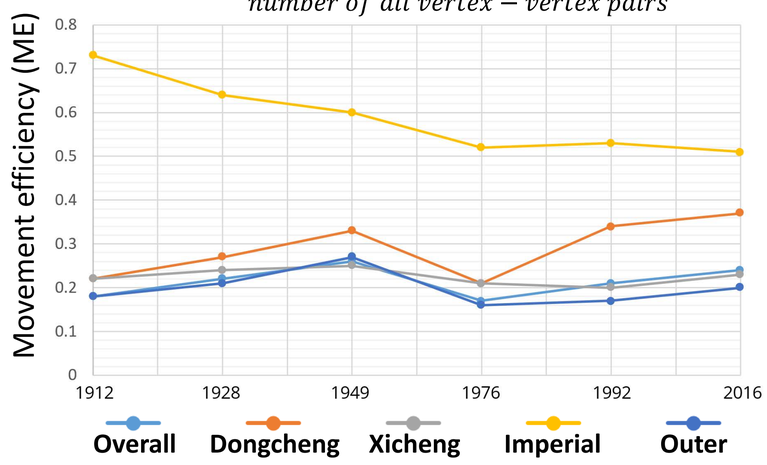
Result



Long time ago...

- **Imperial City**: strictly regulated for the emperor
- **Dongcheng** and **Xicheng** districts: nobility, governor.
- **Outer City**: ordinary people

$$\mathrm{ME} = \frac{\sum \frac{smallest\ total\ turning\ angle}{Total\ turning\ angle\ of\ the\ shortest\ path}}{number\ of\ all\ vertex - vertex\ pairs}$$



Period	Event in History
1912-1949	Introduction of western modern planning
1949-1976	Target-oriented planning VS existing configuration
1976-2016	System optimization
Imperial City	Gradual disintegration

Summary

- A novel space syntax-based strategy
- Evaluation of the efficiency of a network-like system