Analysis of Xuancheng City Transportation Network based on Multi-source Data

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Introduction

For transport network analysis, Xuancheng City, which is located in the southeast of China, is a perfect case study because of its quick expansion and advantageous location in the Yangtze River Delta economic zone. Studies have indicated that transport infrastructure is a major factor in China's urbanisation processes, impacting patterns of spatial development in cities of various sizes (Liu and Su, 2021).

In line with recent approaches used in research on Chinese urban transport networks (Tung et al., 2024), we use complex network theory to analyse Xuancheng's transport system. This medium-sized Chinese city, which has a population of over 2.5 million and occupies 12,340 square kilometres, exemplifies the difficulties in striking a balance between sustainable urban transportation and economic growth.

Research Aims

- **Reveal Spatiotemporal Characteristics of the Transportation Network**

  Analyze temporal variations in vehicle counts across different roads to explore the dynamic patterns of traffic flow and provide insights into the operation of the transportation network.

- **Optimize Traffic Planning and Management**

  Analyze temporal variations in vehicle counts across different roads to explore the dynamic patterns of traffic flow and provide insights into the operation of the transportation network.

- **Understand Travel Behavior and Mobility Patterns**

  Visualize vehicle trajectories to study the spatiotemporal characteristics of typical vehicles and uncover travel patterns and road usage behaviors.

Dataset -

	Data Name	Data Source
1	Loop data	Wang, Y., Chen, Y., Li, G., Lu, Y., He, Z., Yu, Z. and Sun, W. (2023). City-scale holographic traffic flow data based on vehicular trajectory resampling. Scientific Data, [online] 10(1). doi:https://doi.org/10.1038/s41597-022-01850-0.
2	float car data (fcd)	Wang, Y., Chen, Y., Li, G., Lu, Y., He, Z., Yu, Z. and Sun, W. (2023). City-scale holographic traffic flow data based on vehicular trajectory resampling. Scientific Data, [online] 10(1). doi:https://doi.org/10.1038/s41597-022-01850-0.
3	road network segment level	Wang, Y., Chen, Y., Li, G., Lu, Y., He, Z., Yu, Z. and Sun, W. (2023). City-scale holographic traffic flow data based on vehicular trajectory resampling. Scientific Data, [online] 10(1). doi:https://doi.org/10.1038/s41597-022-01850-0.
4	Weather data	https://www.mirror-earth.com/platform
5	Xuancheng boundary geojson	https://datav.aliyun.com/portal/school/atlas/area_selector#&lat=31.769817845138945&lng=104.29901249999999&zoom=4
6	Xuancheng road	https://download.geofabrik.de/asia/china/anhui.html
7	Xuancheng POI	https://download.geofabrik.de/asia/china/anhui.html

Data Processing

Map 1: road density distribution across Xuancheng city.

Data preparation:

Xuancheng road osm – to calculate road lengths

Xuancheng boundary osm – to generate a uniform grid

Road Density Calculation

To calculate road density, the following steps were taken:

- A uniform grid of 1 km × 1 km cells was generated across the city.
- Within each cell, the total length of roads was calculated based on the available road network.
- Finally, road density was computed by dividing the total road length by the cell's area (1 km^2), resulting in a consistent density metric (e.g., km/km^2).

Data Processing - Loop data

Loop data info

The loop dataset is collected from Sept. 1st, 2020, to Sept. 30th, 2020, which includes traffic count and speed data of 794 road segment in Xuancheng city of 5-minute-interval.

_ID	ROAD_ID	FTIME	TTIME	INT	COUNT	REG_COUI	LAR_COUI	ARTH_SPD	HARM_SPI	TURN
)024_9023	9024_9023	00:00.0	05:00.0	300	1	1	0	6.408272	6.408272	S
)024_9023	9024_9023	05:00.0	10:00.0	300	1	1	0	8.797365	8.797365	L
)024_9023	9024_9023	25:00.0	30:00.0	300	1	1	0	8.749707	8.749707	L
)024_9023	9024_9023	35:00.0	40:00.0	300	1	0	1	9.270665	9.270665	L
)024_9023	9024_9023	00:00.0	05:00.0	300	1	1	0	11.01393	11.01393	L
)024_9023	9024_9023	50:00.0	55:00.0	300	1	1	0	10.33451	10.33451	S
)024_9023	9024_9023	55:00.0	00:00.0	300	1	1	0	12.19701	12.19701	S
)024_9023	9024_9023	00:00.0	05:00.0	300	1	1	0	2.824024	2.824024	L
)024_9023	9024_9023	15:00.0	20:00.0	300	1	1	0	15.47614	15.47614	S
)024_9023	9024_9023	05:00.0	10:00.0	300	1	1	0	11.83257	11.83257	S

Map 2: data visualisation and loop data processing

- **Merging & Preprocessing**

1. Merge the loop detector data with the road network segment data using the ROAD_ID and cid columns.
2. Assign weather codes and mark the weekday for each row based on the FTIME column.
3. Filter the data to include only records between 6th and 12th September 2020.

- **Aggregation & Output**

4. Divide the day into six Time Bands (e.g., Morning Peak, Mid-Morning, Afternoon Peak, etc.).
5. Aggregate vehicle counts by ROAD_ID, Time Band and Weekday or Weather.
6. Merge the aggregated counts with road geometry to produce the final GeoJSON file for visualisation.

Data Processing-floating car data (fcd data)

1. data info

This dataset consists of GPS trajectory collected from 500 vehicles in the Xuanzhou region, with a sampling frequency of once every 10 seconds. It includes car id, time, location and speed.

cid	type	time	lon	lat	spd	turn	c
00a2b0bdbf45e8	2	14/09/2020 00:00	118.7547	31.02754	5.327326	Unknown	
00a2b0bdbf45e8	2	14/09/2020 00:02	118.7551	30.94315	6.511176	Unknown	
00a2b0bdbf45e8	2	14/09/2020 00:02	118.7544	30.94311	6.511176	Unknown	
00a2b0bdbf45e8	2	14/09/2020 00:02	118.7537	30.94307	6.511176	Unknown	
00a2b0bdbf45e8	2	14/09/2020 00:02	118.753	30.94304	6.511176	Unknown	
00a2b0bdbf45e8	2	14/09/2020 00:02	118.7524	30.943	6.511176	Unknown	
00a2b0bdbf45e8	2	14/09/2020 00:03	118.7517	30.94296	6.511176	Unknown	
00a2b0bdbf45e8	2	14/09/2020 00:03	118.751	30.94292	5.989425	Unknown	
00a2b0bdbf45e8	2	14/09/2020 00:03	118.7504	30.9429	5.989425	Unknown	
00a2b0bdbf45e8	2	14/09/2020 00:03	118.7498	30.94287	5.989425	Unknown	

2. data filtering

We selected trajectory data from September 6th to 12th, 2020. But only when we visualize the movements of each car in the last map, we shortened the time range to 6th and 7th, and randomly selected 50 vehicles with travel records within both days for display.

3. Identify O-D pairs

When the vehicle is stationary, FCD data will pause collecting vehicle information to reduce data redundancy. So we sort the data by vehicle ID and time, and calculate the time interval between every two pieces of data. If the time interval is greater than 10 minutes, mark these two pieces of data as the origin point of the previous journey and the destination point of the next journey to construct O-D pairs.

4. Match destination points with poi category

We calculated the distance from each destination point to nearby POIs and identified the type of the closest POI. This will help us simulate the purpose of travel.

Conclusion

- *Map 1: Xuanzhou District shows the highest road density, especially in central urban areas.*
- *Map 2: Vehicle counts are highest on Zhaoting Road. Weather has little impact, but traffic is clearly higher on weekdays than weekends.*
- *Map 3-4: We analyzed OD pairs and POI distribution, revealing a central high-density network and tighter southern connections. Short trips dominate centrally, while long trips occur between regions. Destinations center around transportation hubs and commercial areas, with shopping and transportation consistently leading visitation. Travel patterns peak during commutes and weekends, highlighting shifts in leisure and essential activities across different times.*
- *Map 5: The 500-vehicle GPS data reveals Xuancheng's monocentric structure with peak activity during morning (7-9 AM) and evening (5-7 PM) commutes. Speed patterns form a clear hierarchy: central areas experience congestion (<5 km/h), main corridors maintain moderate speeds (5-12 km/h), and peripheral roads show faster movement (>12 km/h). Key congestion points occur at major intersections and commercial zones, highlighting specific locations for targeted traffic management interventions.*

Challenges or Limitations

1. *A key challenge is that vehicle counts alone can't reveal congestion patterns—integrating speed data from the loop detector records and adding a playback will enable dynamic identification of when and where traffic congestion occurs.*
2. *When identifying OD pairs, the 10-minute threshold may not be suitable for all travel scenarios, potentially leading to misjudgments that could affect the comprehensiveness and accuracy of the analysis.*
3. *When visualizing vehicle trajectories, due to the large volume of data, we only selected a random sample of 50 vehicles from the two days for analysis. This sampling method may have an impact on the representativeness and reliability of the results and conclusions.*

References

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