Analysis on Yerevan's Public Transportation: Observations and Solutions

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***Abstract*—Public transportation plays a key role in the daily life of Yerevan's residents, but the system still faces many serious challenges. Some steps have been taken in recent years to improve the situation, but many important issues still exist. The goal of this paper is to study how the current public transport system works and to find out what parts are working well and what parts need to be improved. In this project, different types of data were collected, processed, and analyzed. Some of the methods used include data scraping, geographic analysis, and creating isochrones to show walking distances from stops. The project does not only look at the current system but also shares ideas and tools that can help improve it in the future. This work is the first step in a bigger project that aims to design better public transport routes for Yerevan.**

I. Introduction

As cities grow and change, their transportation systems must also improve to meet the needs of people. In a city like Yerevan, where many areas are developing quickly, it is very important to have a public transport system that is reliable, well-planned, and easy to use. When buses are late, stops are hard to reach, or routes are confusing, people lose time, get frustrated, and may even completely avoid public transport.

Yerevan has started working on transport reform, but one of the main problems is the lack of detailed public data that shows how the system really works. Without these data, it is hard to make smart decisions. This is why analyzing the current system using open source tools and custom data collection can give real value. By building our own dataset and using tools like Python and geospatial libraries, we can see things that are not visible in official reports.

This paper focuses on understanding how well the current public transport system covers the city, how accessible it is by walking, and how stop connections are organized. The work combines geographic data analysis, isochrone mapping, and custom code to find patterns, gaps, and possible ways to improve the system.

The findings of this research can support future planning of transport routes, especially in areas where people walk long distances to reach a stop, or where routes do not serve key parts of the city. The tools and methods used here can also be reused in other cities with similar problems.

II. Literature Review

Analyzing public transportation systems involves examining both accessibility and route efficiency. Isochrone mapping is a valuable tool in this context, illustrating areas reachable within specific timeframes and highlighting coverage gaps. For instance, Bhellar et al. (2023) utilized GIS-based isochrone models to assess travel accessibility in congested urban centers, identifying areas lacking adequate public transport facilities [1].

Complementing isochrone analysis, route performance evaluation is crucial for understanding service quality. Karim and Fouad (2023) conducted a systematic review focusing on measuring urban public transport performance at the route level, emphasizing the importance of assessing individual routes to identify inefficiencies and areas for improvement [2].

In the context of Yerevan, the public transport system comprises buses, minibuses, trolleybuses, and a metro line. According to the Yerevan Municipality, there are currently 64 bus routes, 11 minibus routes, and 10 trolleybus routes [3]. Despite recent efforts to enhance the system, challenges such as outdated infrastructure and limited route coverage persist.

This study builds upon existing methodologies by integrating isochrone mapping and route analysis to evaluate Yerevan's public transportation network comprehensively. By identifying areas with limited accessibility and analyzing route performance, the research aims to provide actionable insights for optimizing the city's transport system.

III. Methodology

A. Data Sources

Two main sources of data were used in this study. The first and primary dataset was obtained from Yandex.Maps. Although Yandex does not offer an open dataset for public transportation, detailed route and stop information is made available on their website in visual form. The second dataset was provided by the Yerevan Municipality. This dataset included GPS coordinates and timestamps for bus line 29, collected over a two-week period. It allowed for comparison between live bus movement and the route data extracted from Yandex.Maps.

B. Data Collection and Scraping

The process of data collection began with copying the URLs of each bus line from Yandex.Maps. Upon inspecting the page source, it was found that key data—such as stop coordinates, route paths, and metadata—was embedded within the HTML in the form of JSON-like dictionaries. These scripts were part of the client-side logic responsible for rendering bus routes and stops on the map interface.

Python scripts were developed to extract and process this information. Three types of structured data were prepared:

- **Stops:** Each stop was recorded with its name, stop ID, and geographic coordinates. These were stored in a geospatial format to enable spatial analysis and visualization.
- **Routes:** Route data was saved as individual line segments, each representing a connection between two stops. The start and end stop for each segment were recorded, along with the geometry of the path.
- **Items:** Each item represented one pass of a bus line and contained identifiers for the set of stops and segments that formed that pass. Typically, two items were stored per bus line: one for the forward direction and one for the return.

The extracted data was cleaned to remove duplicates and ensure accuracy in spatial coordinates. All data were organized into structured files for stops, routes, and items, forming the foundation for later geospatial and statistical analyses.

C. Isochrone Analysis

A central part of this project was the measurement of how accessible different areas of Yerevan are by walking from public transport stops. This was done through the creation of isochrones, which show the areas that can be reached on foot within a certain number of minutes from a given location. Isochrone maps make it possible to evaluate the real coverage of transport services and to identify zones that are underserved.

The Python library `OSMnx` was used to download the walkable street network of Yerevan from OpenStreetMap. This network included streets, paths, and walkways that are accessible to pedestrians. It allowed for a more realistic analysis than using straight-line distances, since it reflected the actual paths people would take while walking.

Isochrones were generated for each public transport stop, showing areas reachable in 5, 7, 10, 12, and 15 minutes. These time intervals were chosen to reflect typical walking efforts of users, based on an assumed average speed of 1.4 meters per second.

The process followed these main steps:

- **Downloading the street network:** The pedestrian road graph of Yerevan was obtained using `OSMnx`.
- **Matching stops to nodes:** Each stop coordinate was mapped to the nearest node in the street network graph.
- **Generating travel buffers:** For each time interval, network-based buffers were created to define the maximum walking range from a stop.
- **Constructing isochrones:** Reachable areas were saved as GeoJSON files for each stop and each travel time range.
- **Analyzing spatial coverage:** Isochrones were later compared and visualized to assess which neighborhoods had overlapping coverage and which remained inaccessible.

Through this analysis, it was possible to identify differences in accessibility across the city. The isochrones formed the basis for understanding spatial equity in the public transport system and can support future improvements in route planning and stop placement.

D. Route Usage Analysis

To better understand how the city's public transport network operates, a detailed route usage analysis was performed. Each route segment between two stops, as extracted from the Yandex data, was stored as a line string. For every such segment, the number of distinct bus lines that pass through it was counted. This allowed identification of the most frequently used corridors in the network.

The route density was then visualized using QGIS. A color gradient was applied to represent how many buses share each segment, with darker colors indicating higher traffic. This visualization helped to highlight main transit corridors as well as low-frequency areas that may require service improvement.

E. Stop Pair Matching

Since data from Yandex included separate stops for each direction of travel (for example, stops on opposite sides of the same street), an effort was made to identify and pair these stops. A custom Python function was implemented to detect spatially close stops with similar names or matching route logic, and classify them as pairs.

This pairing was important for improving the quality of later accessibility and coverage analyses, by avoiding double-counting or misinterpreting bidirectional services as separate lines.

F. Line 29 Real-World Data Analysis

To validate the accuracy of the scraped data and gain insights into real route behavior, a deeper analysis was performed using real-time data from the Yerevan Municipality for bus line 29. Two datasets were provided: one containing GPS coordinates of the bus over time, and another recording the timestamps of ticket validations via the TELS-LT system.

The goal was to understand how the bus moved through its route during the day and how validations were distributed along its path. To determine the direction of travel at each moment, buffers were created around the start and end points of the route in both forward and backward directions. Each recorded GPS point was then checked against these buffers to identify whether the bus was closer to the forward or backward endpoint. Based on this spatial check, the direction of the route at a given time was defined.

This allowed a full directional classification of the bus movement over the two-week period. By combining this with validation data, the number of authentications at each segment of the route could be counted, providing insight into passenger activity and how it relates to specific segments and directions of the line.

IV. Results

A. Stop Accessibility through Isochrone Analysis

To assess how easily people in Yerevan can access public transport on foot, isochrone analysis was performed. An isochrone is a geographic area that shows how far someone can travel from a point within a given amount of time. In this case, the goal was to map which areas of the city are reachable by walking from any bus stop within 5, 7, 10, 12, and 15 minutes.

Fig. 1. Walkable routes of Yerevan

Isochrones were calculated using OpenStreetMap street data and the OSMnx library. The code used a walkable road network and estimated distance by multiplying time (in seconds) with average walking speed (1.4 meters per second). For each stop, the script found the nearest street node and calculated the walkable area from that node using Dijkstra's shortest path algorithm. The individual walkable zones were then saved either separately (per stop) or merged together (unioned) depending on the purpose of the visualization.

This analysis helps identify which parts of Yerevan are well-connected to the transit network and which parts may require additional services or new bus stop placements. It is especially useful for long-term urban planning and improving equity in service distribution.

At 5 minutes of walking time, isochrones mostly cover the central city and a few surrounding areas. Many neighborhoods remain outside of this range.

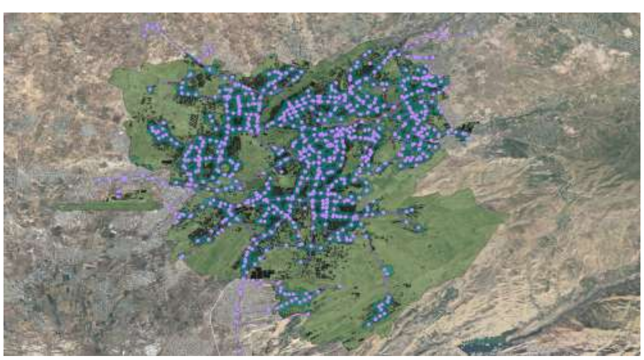


Fig. 2. Isochrone coverage for 5-minute walk

A 7-minute threshold shows moderate improvement, with noticeable expansion especially in the mid-density areas (see Figure 3).

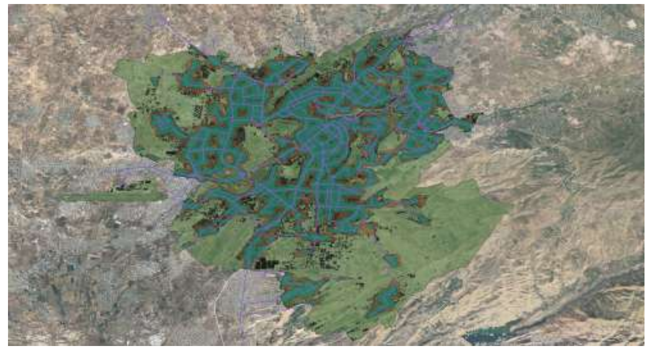


Fig. 3. Comparison of 5- and 7-minute isochrones

By 10 minutes, a large portion of the urban area becomes reachable. Comparing 5 and 10 minutes ischrone results the difference becomes noticable.

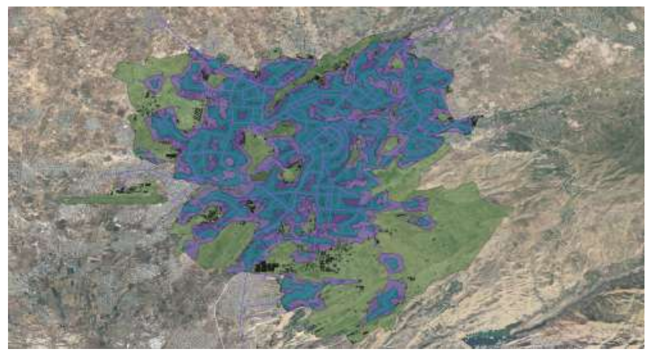


Fig. 4. Comparison of 5- and 10-minute isochrones

The union of all 10-minute isochrones confirms broad coverage across the city, especially in central and semi-central districts.

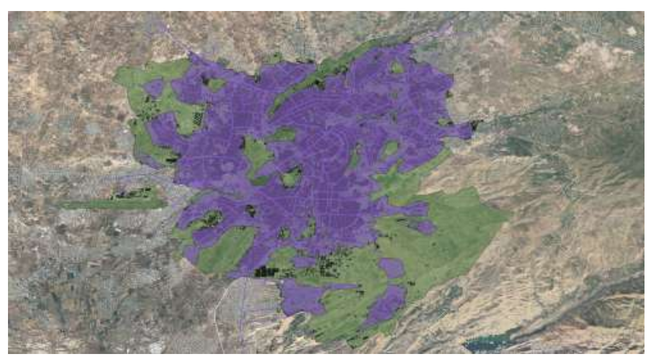


Fig. 5. Unioned isochrone coverage for 10 minutes

In addition to merged isochrones, separate per-stop isochrones are shown for the 10-minute case. This allows deeper insight into which individual stops provide the most coverage. Denser clusters in the center produce overlapping coverage, while isolated stops on the edges serve small, individual areas.

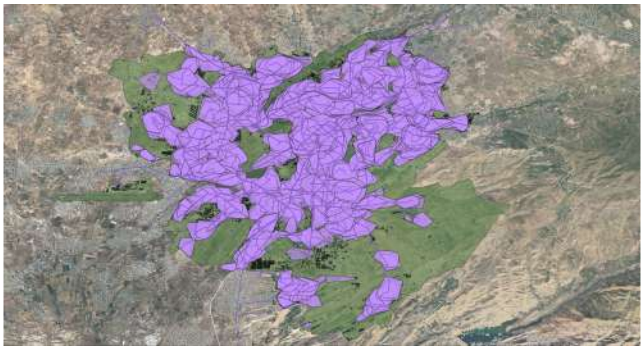


Fig. 6. Separate 10-minute isochrones per stop

With 12 minutes, even the outer zones begin to be included.

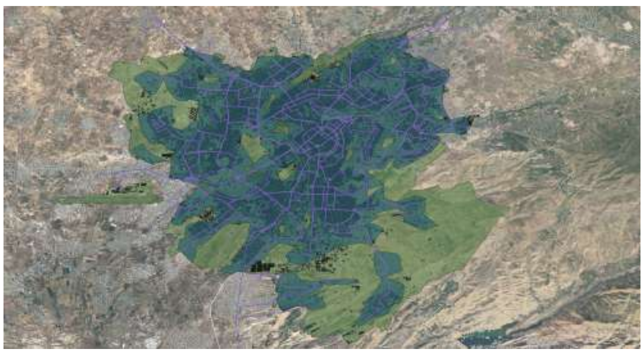


Fig. 7. Unioned isochrone coverage for 12 minutes

The 15-minute map shows that nearly the entire city is reachable on foot from a public transport stop.

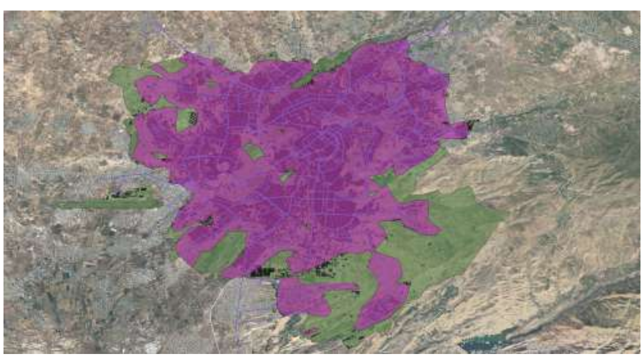


Fig. 8. Unioned isochrone coverage for 15 minutes

Based on both the isochrone results and the satellite map background, it is clear that most of the built-up and actively used parts of the city are covered within the 10- to 12-minute zones. In particular, areas with dense building footprints and visible residential or commercial land use fall inside these isochrone boundaries, confirming their practical usefulness.

The 5-minute and 7-minute intervals, while visually informative, fail to capture large portions of the populated areas and are too restrictive to be used as planning thresholds. On the other hand, the 15-minute range includes nearly the entire urban area, but may overestimate what is realistic for average walking accessibility in daily commutes.

Among all intervals, the 10- and 12-minute isochrones strike the best balance between walkability and urban coverage. These thresholds reflect a realistic level of walking effort that most users are willing to make and show alignment with where most people live and work. These findings offer concrete support for improving bus stop planning and optimizing route density in less accessible zones.

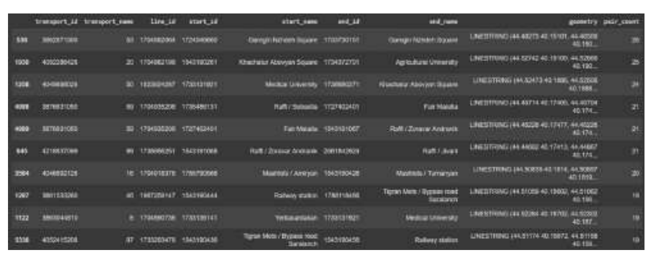
B. Route Usage and Stop Pair Analysis

Another part of the analysis focused on how often each street segment is used by different bus lines. In other words, the goal was to understand which road sections are used most heavily by public transport. To do this, each connection between two stops was extracted and counted. If the same start-end pair appeared multiple times (because of different lines), it was recorded with a higher count.

This allowed creation of a full network of route frequencies, which was later visualized using color intensity. Figure 9 shows the complete map. The darker the line, the more bus routes travel through that segment. This helps identify important backbone routes within the city.

Fig. 9. Routes with counts

In addition to the visual map, the top 10 most-used connections were listed. As shown in Figure 10, these include roads near major centers like Garegin Nzhdeh Square, Medical University, and Fair Malatia. This confirms that the route count analysis reflects real transportation activity and priorities.



	transport_id	transport_name	line_id	start_id	start_name	end_id	end_name	geometry	pair_count
538	[illegible]	[illegible]	[illegible]	[illegible]	Garegin Nzhdeh Square	[illegible]	Garegin Nzhdeh Square	LINESTRING [illegible]	26
1930	[illegible]	20	[illegible]	[illegible]	Khachatur Abovyan Square	[illegible]	Agricultural University	LINESTRING [illegible]	25
1208	[illegible]	[illegible]	[illegible]	[illegible]	Medical University	[illegible]	Khachatur Abovyan Square	LINESTRING [illegible]	24
4088	[illegible]	[illegible]	[illegible]	[illegible]	Raffi / Sebastia	[illegible]	Fair Malatia	LINESTRING [illegible]	21
4089	[illegible]	[illegible]	[illegible]	[illegible]	Fair Malatia	[illegible]	Raffi / Zoravar Andranik	LINESTRING [illegible]	21
645	[illegible]	[illegible]	[illegible]	[illegible]	Raffi / Zoravar Andranik	[illegible]	Raffi / [illegible]	LINESTRING [illegible]	21
3564	[illegible]	16	[illegible]	[illegible]	Mashtots / Amiryan	[illegible]	Mashtots / Tumanyan	LINESTRING [illegible]	20
1267	[illegible]	[illegible]	[illegible]	[illegible]	Railway station	[illegible]	Tigran Mets / Bypass road Sasuntsi	LINESTRING [illegible]	19
1122	[illegible]	6	[illegible]	[illegible]	[illegible]	[illegible]	Medical University	LINESTRING [illegible]	19
3336	[illegible]	[illegible]	[illegible]	[illegible]	Tigran Mets / Bypass road Sasuntsi	[illegible]	Railway station	LINESTRING [illegible]	19

Fig. 10. Top routes

Another part of the project involved identifying whether bus stops were paired — meaning whether a stop on one side of the road had a matching stop on the opposite side. This is important because many lines have one stop for going forward and another for going backward. If stops are not paired correctly, it may lead to confusion during routing, misalignment in analysis, or visualization errors.

The pairing analysis was done by checking the distance between stops and comparing their names. In cases where stops were very close and had similar names, they were marked as a pair. This logic was used across multiple lines, but the result is best shown using data from Line 29. Figure 11 shows the stops that were originally not paired.

	stop_id	stop_name	pair_name	stop_geom	pair_geom
8	1787749186	Hayreniq	None	POINT (44.49898 40.15277)	None
16	1788128356	Chess House	None	POINT (44.52377 40.18021)	None
17	1985580091	Chamber music	None	POINT (44.52431 40.18469)	None
19	1733131921	Medical University	None	POINT (44.5248 40.18856)	None
21	1788095726	Bellagio	None	POINT (44.5343 40.19333)	None
31	1543189843	Marshal Babajanyan / Almaty	None	POINT (44.57774 40.2204)	None
35	1543189800	Nver Safaryan Street, 14	None	POINT (44.58432 40.21334)	None
51	1543189854	Marshal Babajanyan / Ashxabad	None	POINT (44.57602 40.22047)	None
52	3457701755	Marshal Babajanyan Street, 56	None	POINT (44.57428 40.22041)	None
55	1543189960	Mental Health Center	None	POINT (44.56719 40.21997)	None
61	1788004466	Myasnikyan Avenue, 55/5	None	POINT (44.55113 40.19895)	None
65	1734372701	Agricultural University	None	POINT (44.52584 40.18991)	None
67	3841023920	University of Economics	None	POINT (44.52315 40.18403)	None
68	1543190291	Khanjyan / Sayat Nova	None	POINT (44.52361 40.18123)	None
69	1543190305	Khanjyan / Tumanyan	None	POINT (44.52259 40.17797)	None
73	1733282021	Arshakunyats Avenue, 6	None	POINT (44.50767 40.16993)	None
81	1724546660	Garegin Nzhdeh Square	None	POINT (44.48265 40.15095)	None
82	1724546680	Bagratunyats Street, 20	None	POINT (44.48448 40.15011)	None

Fig. 11. Without pair stops line29

After checking manually and applying the pairing algorithm, most of these stops were matched correctly. This can be seen in Figure 12, where the final paired stops are displayed. These kinds of checks help ensure the accuracy of network models and improve the quality of isochrone and route overlap analysis.

	stop_id	stop_name	pair_name	stop_geom	pair_geom
0	5402422056	Frunze Dovlatyan Street	Frunze Dovlatyan Street	POINT (44.4831 40.13896)	POINT (44.483104285 40.13895635)
1	5402420976	Nerkin Shengavit	Nerkin Shengavit	POINT (44.48089 40.13938)	POINT (44.480780349 40.139194375)
2	4049882988	Shahamiryanner Street	Shahamiryanner Street	POINT (44.4829 40.1421)	POINT (44.482915007 40.14219242)
3	4315747258	Taronts Street	Taronts Street	POINT (44.48423 40.14348)	POINT (44.484097296 40.143472345)
4	4045345298	Taronts Street	Taronts Street	POINT (44.48548 40.14611)	POINT (44.485410181 40.146172609)
...	...	...	...	...	...
83	4045345198	Taronts Street	Taronts Street	POINT (44.48541 40.14617)	POINT (44.485479918 40.1461088)
84	4315747308	Taronts Street	Taronts Street	POINT (44.4841 40.14347)	POINT (44.484231407 40.143470462)
85	4049882898	Shahamiryanner Street	Shahamiryanner Street	POINT (44.48292 40.14219)	POINT (44.482896232 40.14209773)
86	4049878778	Nerkin Shengavit	Nerkin Shengavit	POINT (44.48076 40.13919)	POINT (44.480885073 40.139384704)
87	5402422056	Frunze Dovlatyan Street	Frunze Dovlatyan Street	POINT (44.4831 40.13896)	POINT (44.483104285 40.13895635)

Fig. 12. Paired stops line29

Understanding which stop pairs exist, and which route segments are used the most, provides a strong foundation for improving Yerevan's public transport system. These results can guide route simplification, identify overloaded corridors, and detect areas with potential gaps in coverage.

C. Line 29 GPS and Direction Analysis

The last part of the project focused on analyzing real data collected from Yerevan's Line 29 bus. Two datasets were used: one containing the GPS locations of the buses throughout the day, and another containing authentication data, which indicated when and where passengers validated their tickets. By merging these two sources, a detailed view was created showing how many validations occurred at specific times and locations across the route.

This matching allowed the creation of a full dataset where each row represented a point in time and space, together with the number of authentications during that interval. A simplified view of the data is shown in Figure 13, where columns like latitude, longitude, time slot, and direction can be seen.

	bus_number	location	hyperlink	latitude	longitude	week_number	weekday	date	timestamp	datetime	auth_count_in_interval	geometry	direction
0	5481	[illegible] Yerevan, AM	https://www.google.com/maps/?q=[illegible]	[illegible]	[illegible]	Week 1	Monday	2025-04-07	07:30-08:00	2025-04-07 [illegible]	4	POINT ([illegible])	backward
1	5481	[illegible] Yerevan, AM	https://www.google.com/maps/?q=[illegible]	40.21134	[illegible]	Week 1	Monday	2025-04-07	07:30-08:00	2025-04-07 [illegible]	0	POINT ([illegible])	backward
2	5481	[illegible] Yerevan, AM	https://www.google.com/maps/?q=[illegible]	[illegible]	[illegible]	Week 1	Monday	2025-04-07	07:30-08:00	2025-04-07 [illegible]	0	POINT ([illegible])	backward
3	5481	[illegible] Yerevan, AM	https://www.google.com/maps/?q=[illegible]	[illegible]	[illegible]	Week 1	Monday	2025-04-07	07:30-08:00	2025-04-07 [illegible]	1	POINT ([illegible])	backward
4	5481	[illegible] Yerevan, AM	https://www.google.com/maps/?q=[illegible]	[illegible]	[illegible]	Week 1	Monday	2025-04-07	07:30-08:00	2025-04-07 [illegible]	0	POINT ([illegible])	backward
...	...	...	...	...	...	...	...	...	...	...	...	...	...

Fig. 13. 29 dir

To improve this dataset further, direction detection was implemented. This step was necessary because each line typically operates in two directions — forward and backward — and it was important to know which route segment a bus was on at any time. This was solved using a spatial method: buffers were created around the start and end points of each route direction. Each GPS point was then checked to see which buffer it was closest to. When a point entered or exited a buffer, the direction label was updated accordingly.

This method allowed the construction of a clean, direction-aware movement path. In addition to detecting direction, this process helped identify and filter incorrect or ambiguous GPS points. The updated direction data improved the accuracy of the line analysis and also made it possible to visualize the route split into forward and backward segments.

After applying the direction detection algorithm, the results were tested in GIS to check whether they matched the actual path taken by the buses. The results were visualized separately, and each direction closely followed one side of the full bus line, as seen in Figure 14 and Figure 15. This confirmed that the algorithm functioned reliably and matched real behavior.

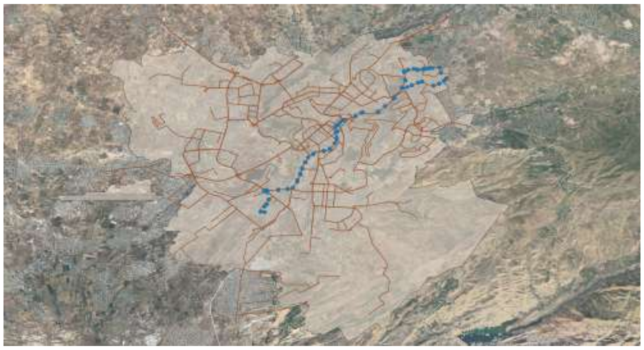


Fig. 14. Line 29 scraped

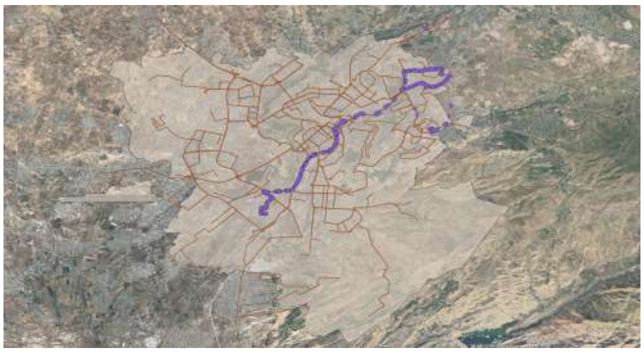


Fig. 15. Line29 real

This kind of direction and authentication analysis offers strong potential for public transport planning. It allows detection of overcrowded zones, underused segments, and gives insight into user behavior throughout the day. Line 29 served as a test case, but the same approach can be scaled to other lines in the system.

V. Conclusion

This project explored the structure and efficiency of Yerevan's public transportation system using a data-driven approach. The work began with data collection and scraping from Yandex Maps to build a detailed database of stops, routes, and transit lines. This raw data was cleaned, merged, and converted into geospatial formats suitable for analysis and visualization.

One of the main objectives was to assess how well the transport system serves the city in terms of walking accessibility. To address this, isochrone maps were generated for different time intervals — 5, 7, 10, 12, and 15 minutes — showing which areas could be reached on foot from existing stops. The results showed that 5- and 7-minute ranges were too limited, while 10 and 12 minutes offered the best coverage. Most of Yerevan's urban areas, including high-density neighborhoods, were found to be within a 10-minute walk of a transit stop.

Beyond walkability, the study also looked into how frequently each route segment was used. A segment-based count was performed to determine which roads carry the most transit lines. These high-usage segments were visualized and listed, helping to identify central corridors in the network. A stop pairing analysis was also performed to understand forward-backward routing relationships. This improved data consistency and helped ensure that each direction was accounted for in spatial models.

Finally, real operational data from Line 29 was processed. By combining bus location logs with authentication data, patterns of passenger activity were revealed. A custom direction-detection algorithm was developed and applied to this dataset. The results were then verified visually in GIS, confirming their accuracy and alignment with real routes.

Together, these steps provided a strong technical and visual understanding of Yerevan's public transport system. The tools and results created here can be reused and expanded to support city planning, detect service gaps, and improve route design across the network.

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