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The role of the MATSim model in assessing Paratransit performance in a data-scarcity context

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The study context

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Paratransit System characteristics

Figure 1: Alexandria main street vehicles composition.
Source: *Author elaboration based on https://bit.ly/3KG1IY8*

Paratransit definition

"transportation service that supplements larger public transit systems by providing individualised rides **without fixed routes or time tables**"
Merriam-Webster Dictionary, 2022

Figure 2: Mode shares of travelers across different categories of cities.
Source: *UITP, 2015a, 2015b; CAF ; Alliance for Biking & Walking, 2016.*

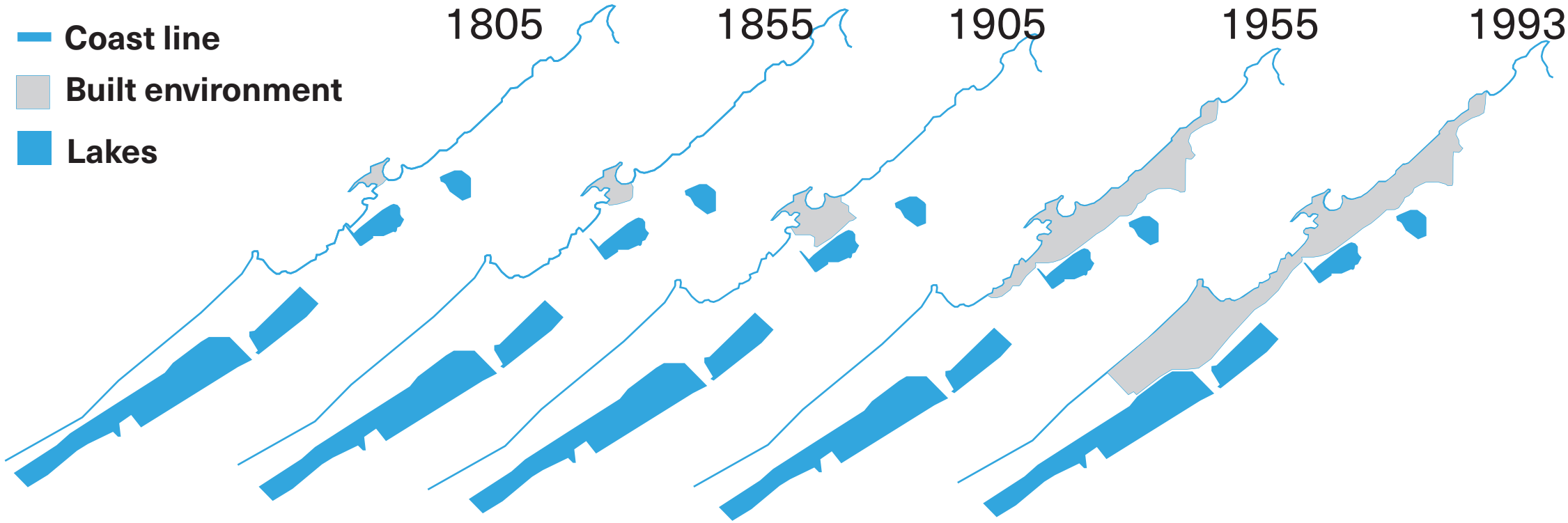
The City's infrastructure

The mediterranean sea Alexandria in the north and the Mariout lakes from the south bounds the bulit environment in Alexandria, which make the city sprawl on that 5 km wide corridor that affected the city's infrastructrure, which is aligned between the two waterscapes.

The main street is aligned a along the seaside, and in parallel, another critical corridor for the vehicles, and then, the intercity railway, which links the main hub to the western extension with 20 stops.

Figure 3: Alexandria linear infrasrcture.
Source: *Author elaboration based osm.org*

Un-planned Sprawl



Alexandria faced an unplanned urban sprawl in 200 hundred years. The started to sprawl from the tiny peninsula till it reached its beak sprawl nowadays between the two waterscapes.

Figure 4: Alexandria - Characteristic stages of growth during the last 150 years.
Source: *Author based on Lotfy Kamal Abdou Azaz, 2004, p6*

The negative impacts of urban sprawl in Alexandria, Egypt include air pollution, fragmentation and irregularity of the landscape, low development density, low population density and economic output in newly developed areas, and negative impacts on agriculture, environment, and city life (Fang et al., 2007).

The rapid population growth and growing demand for urban lands are the main drivers of the accelerating urban sprawl into agricultural and arable lands in Egypt (Mostafa et al., 2021).

Un-excpected Population

The unplanned population growth in Alexandria, Egypt has been a significant challenge for the city. According to the UN report for the State of the World's Cities in 2013, the population growth rate of urban agglomerations in Alexandria has consistently been higher than that of Cairo since 1990 (El-Shanhorey, 2021). This rapid population growth has put immense pressure on the city's infrastructure, services, and resources.

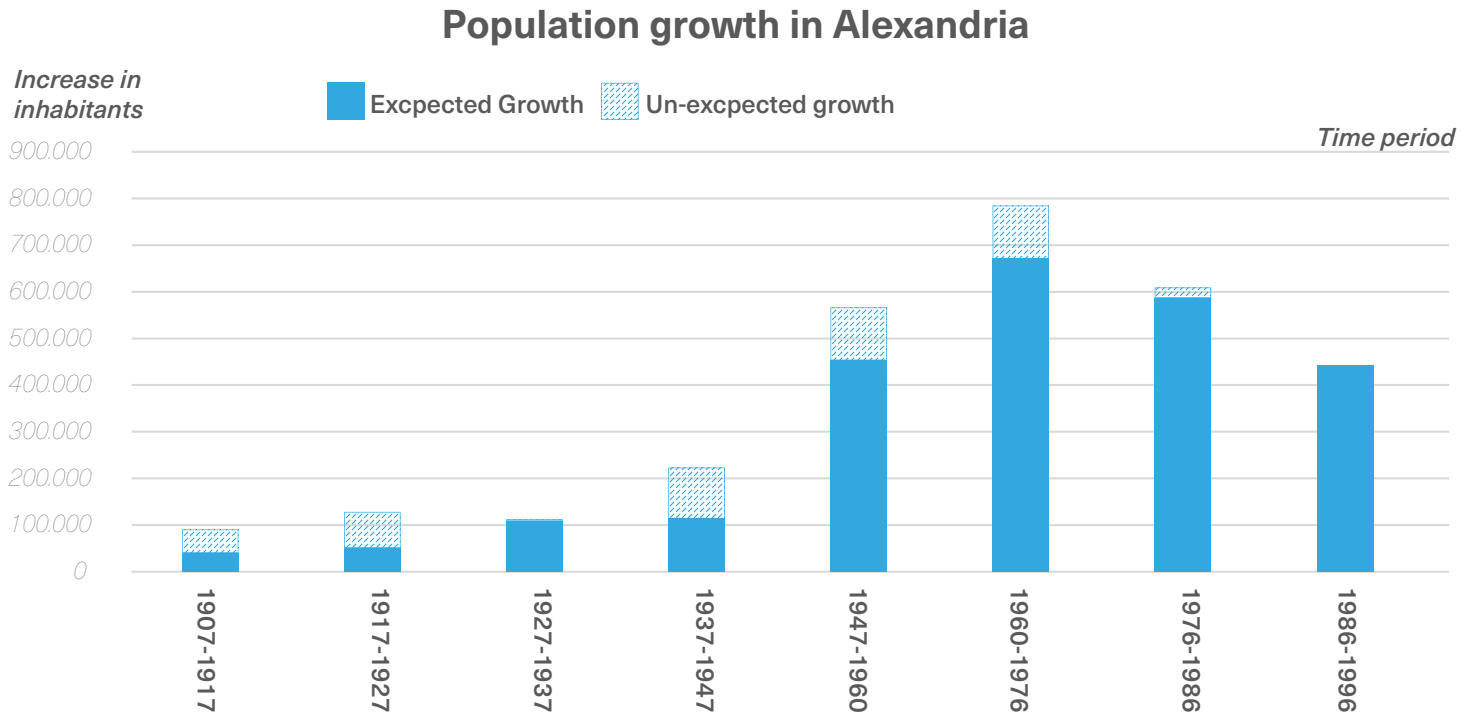


Figure 5: Natural and migratory increase of population.
Source: *Lotfy Kamal Abdou Azaz, 2004, pp. 61–62*

Realising MATSim's synthetic population

Assigning Legs' **location**

Assigning Legs's **departure time**

Assigning Legs' **activities type**

Assigning Legs's **model split**

Figure 6: Alexandria's MATSim model.
Source: *Author based on MATSim and OSM*

Assigning Legs' location

The Facebook data is clustered into tiles (Bing Map Tiles), and these tiles are called QuadKeys. Each rectangle has a unique code that identifies its location and size.

At the beginning of the research, Facebook offered the OD data at a very aggregated scale of 15 square kilometers. However, this aggregation level needed to be increased to be used as a baseline for the study. Therefore, communication was established between the researchers and META to request the data in smaller squares. A few weeks later, the data was regenerated in a 250-meter square.

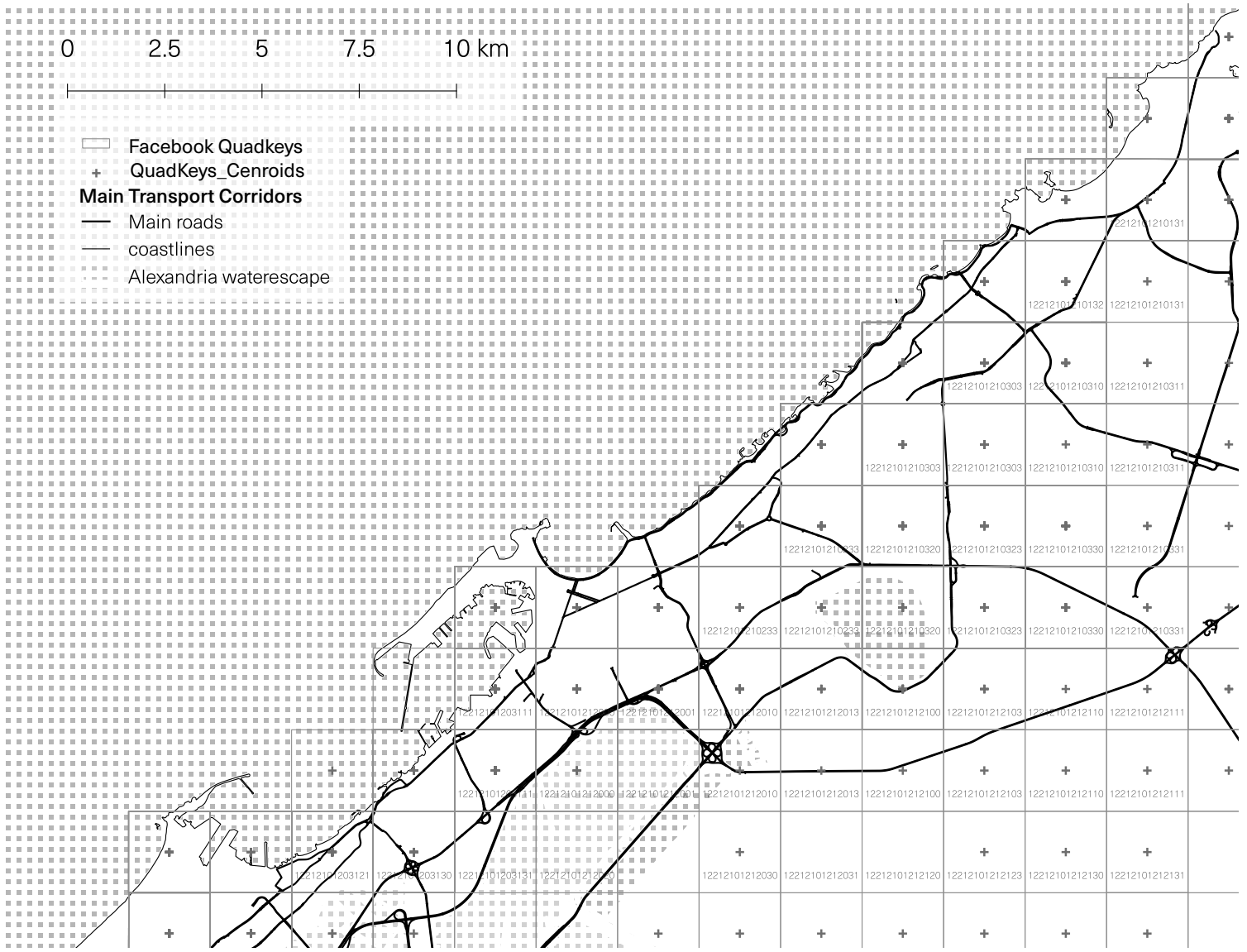


Figure 7: Alexandria's facebook OD Matrix
Source: *Author based on osm and META's data for good*

Assigning Legs' location

The data in raw format of OD Matrix of the movement were centered around the QuadKey center. To make the synthetic population more realistic, an SQL code was developed to randomly generate the points to make the demand quite more realistic.

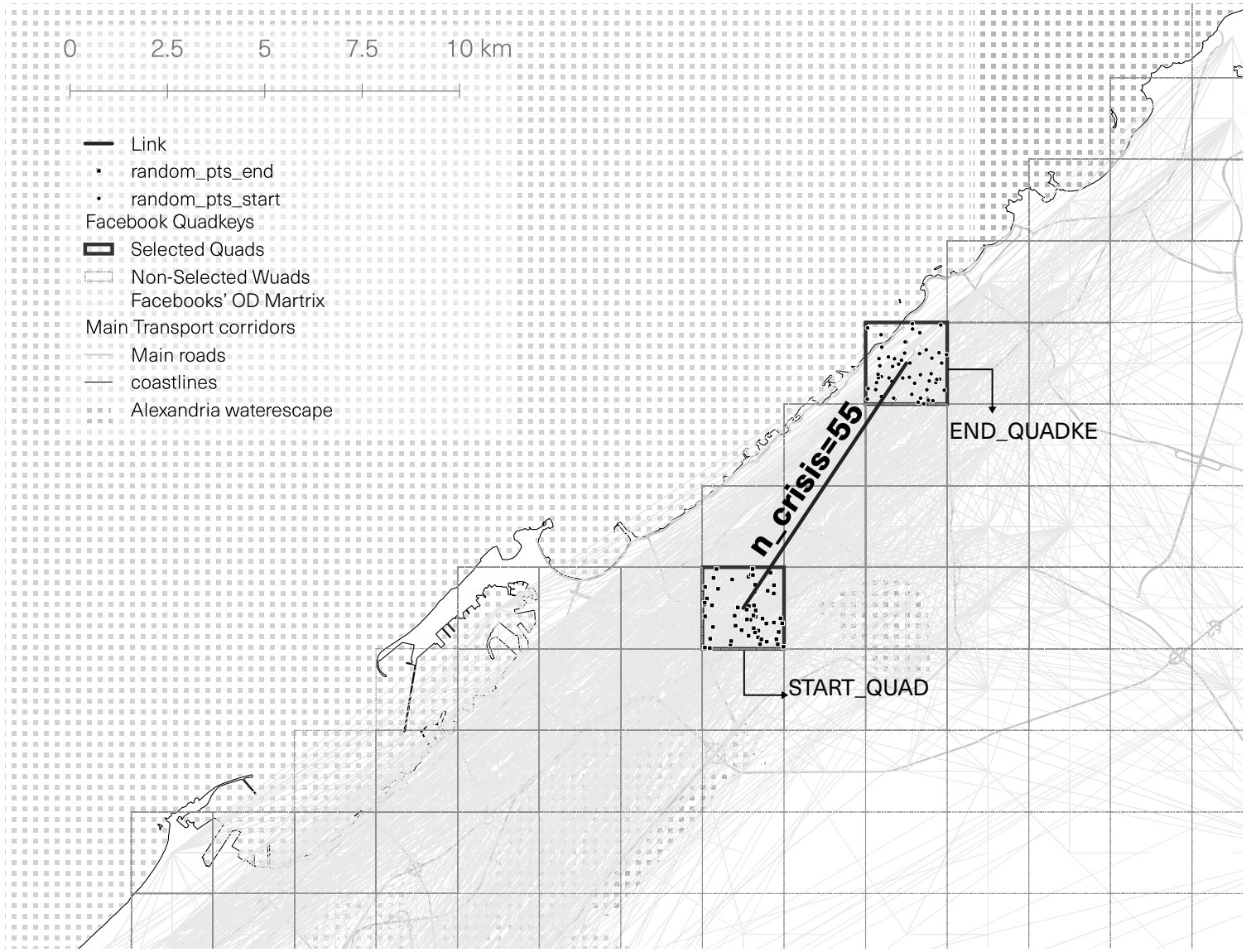


Figure 8: AggregatingAlexandria's facebook OD Matrix
Source: *Author based on osm and META's data for good*

Assigning Legs' departure time

Due to privacy concerns, META doesn't offer the actual timeframe for each movement; rather, the data is clustered into three-time frames every eight hours, from 00:00 to 08:00, from 16:00, and from 16:00 to midnight.

The data is generated in Central Pacific Time, which is 10 hours ahead of Alexandria time; this required a remapping of the entire time stamps.

The last aim of the study is to measure the morning rush hours in which all vehicles are mainly going to more serious activity work, education... , so the trips along the 8 hours were squashed into from 7:00 to 10:00 Alexandria time, a random departure time was randomly assigned to the OD matrix movement.

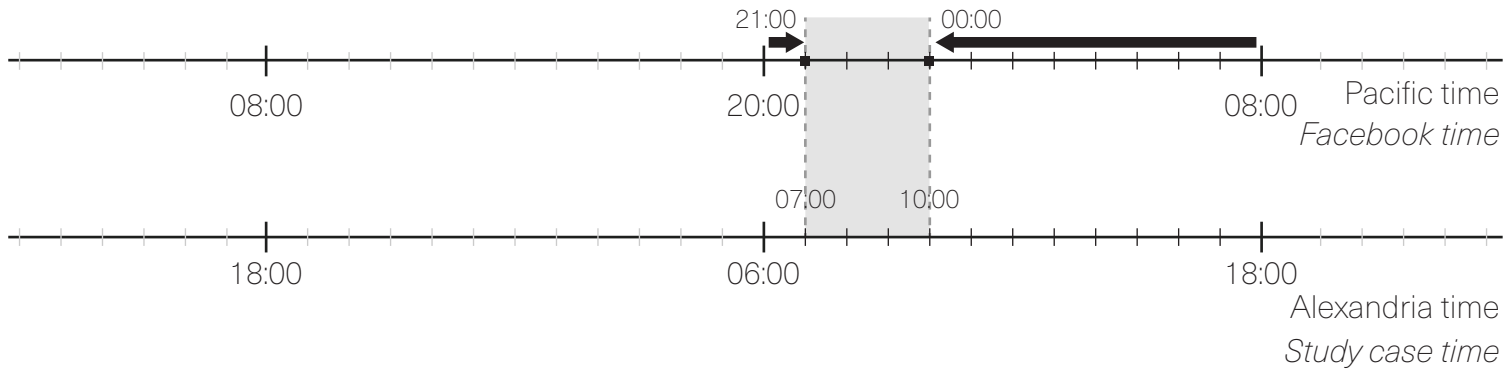


Figure 9: Assigning a corresponding random time frame
Source: *Author*

Assigning Legs' activities type

The same method was replicated in activities; only one study collected a 2,999 Sample of questions asking a participant about when and what kind of activities they do; the data was quantified and remapped to the data frame.

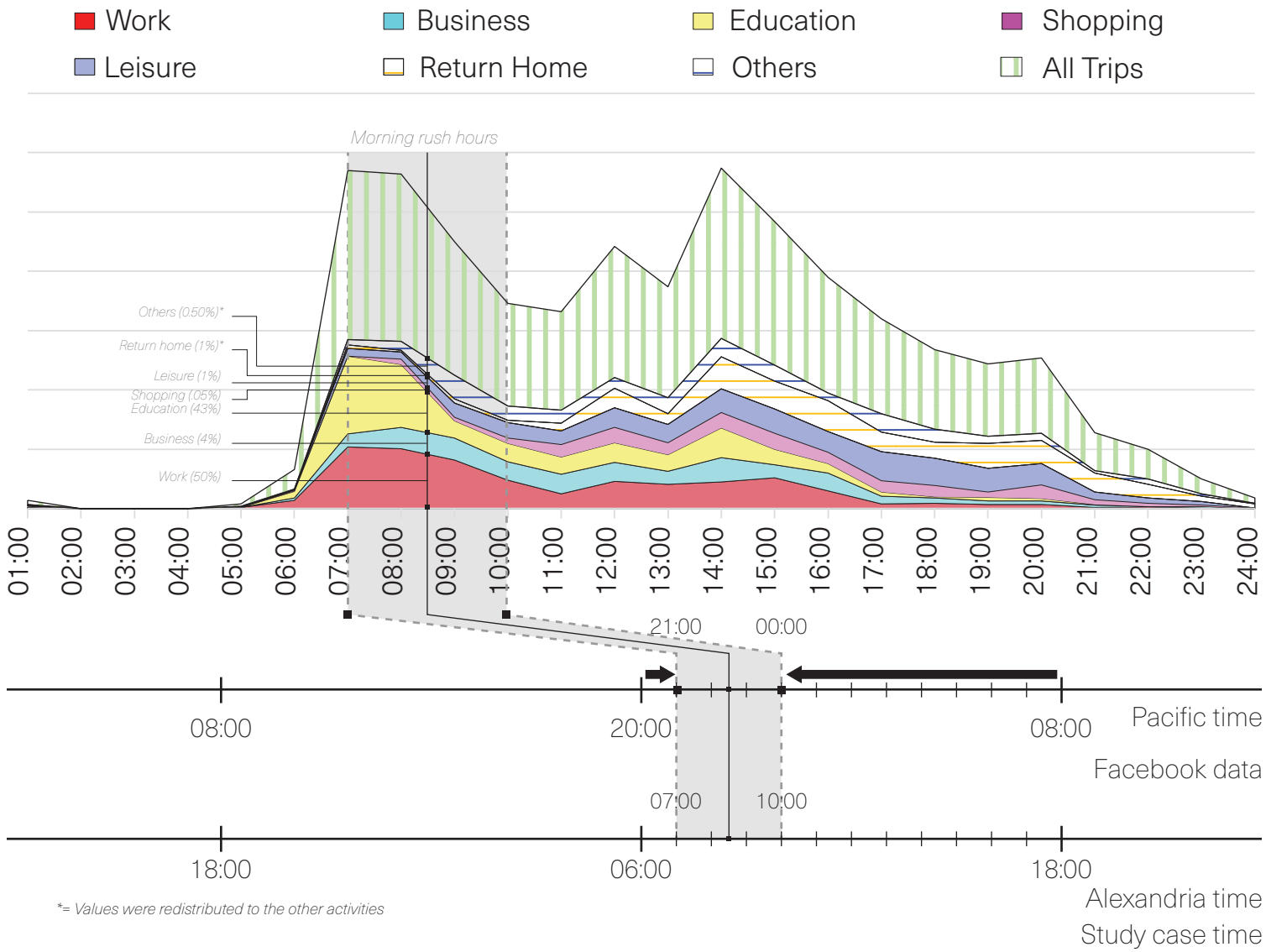


Figure 10: Assigning a corresponding random activity
Source: *Author based on Darwish et al., 2019, p. 63*

Assigning Legs' model split

The model split studies were conducted through an MNL (Multi Nominal Logit model), which calculates the utility of each transport mean, and then, based on the utility, the percentages are distributed to the model split.

The original study was conducted on Private cars, minibuses, Taxis, and Public transport. However, due to the absence of available data about taxis and public transport, the values of these modes were equally distributed to the minibusses and the cars, which will be examined inside the model.

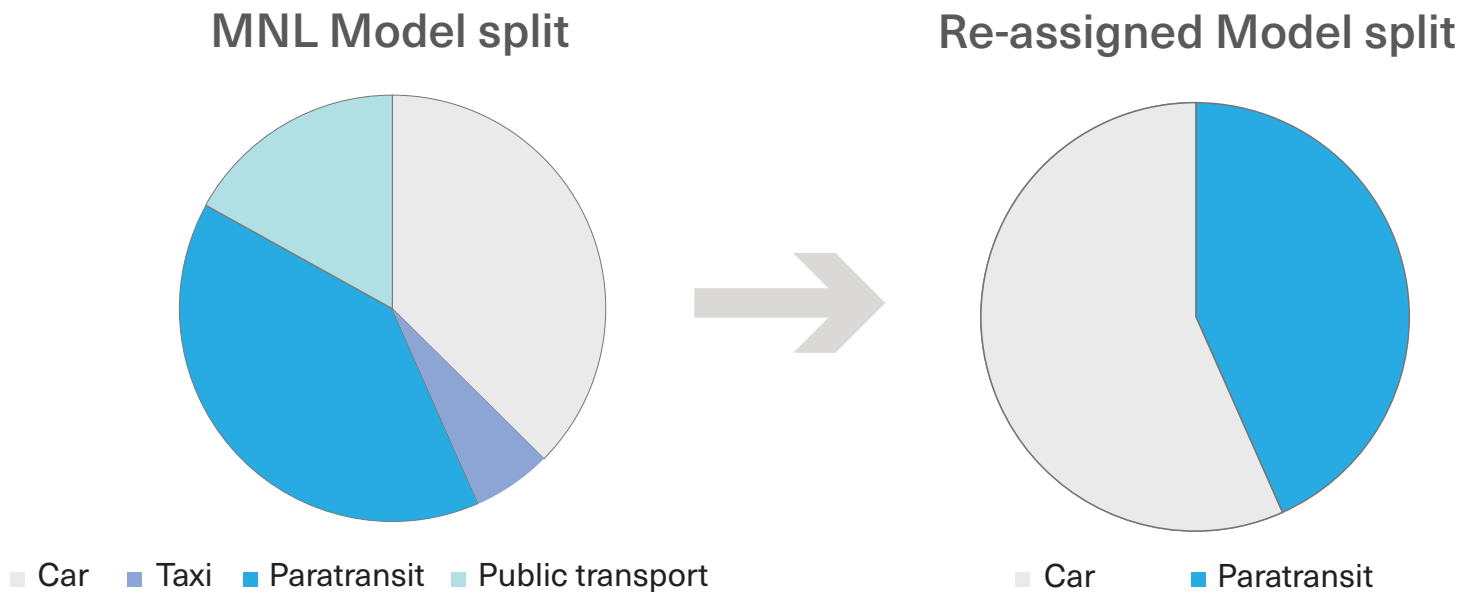


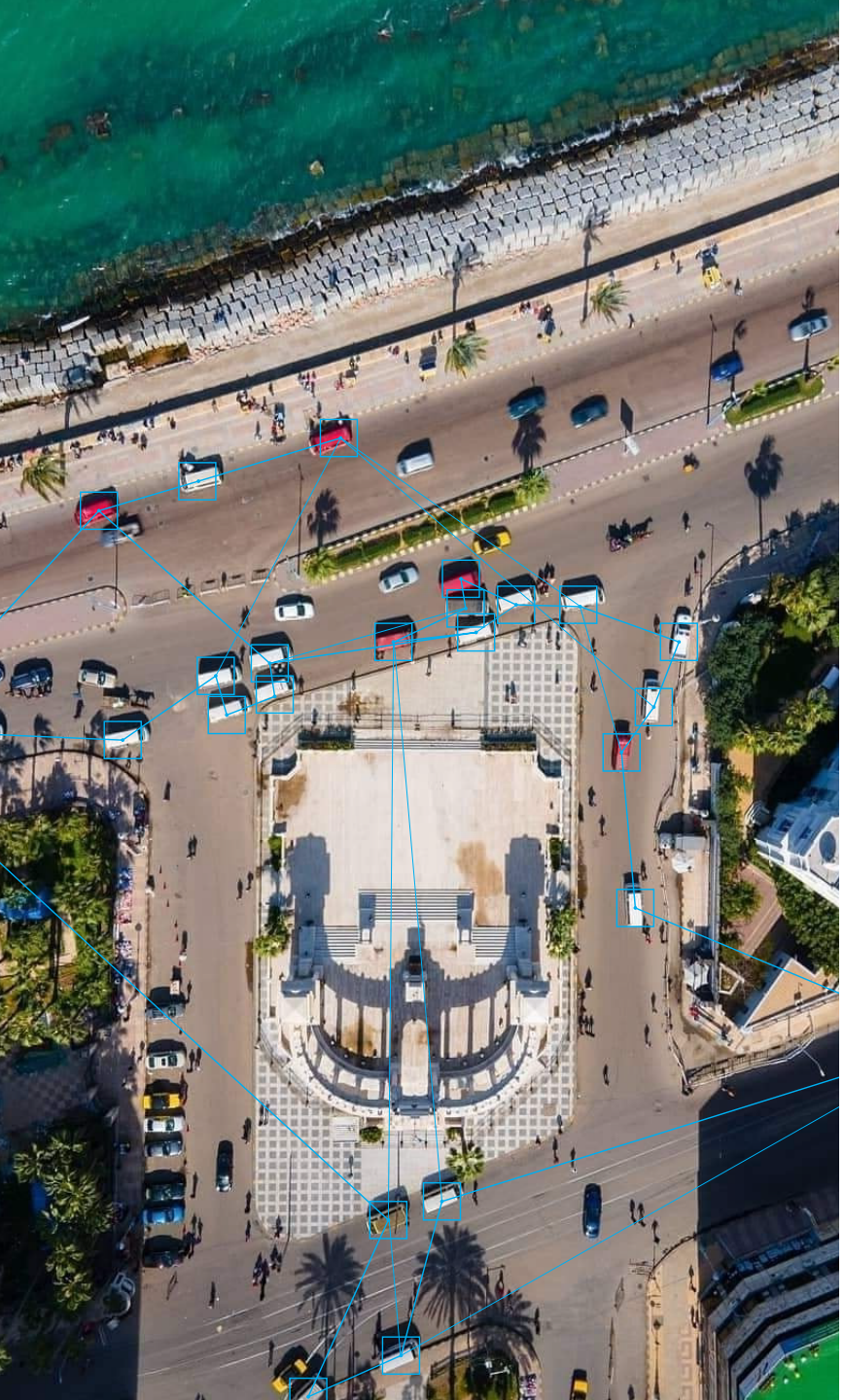
Figure 11: Assigning a corresponding model split
Source: *Author based on Darwish et al., 2019, p. 63*

Synthetic population properties

The final data frame of the synthetic population consisted of
agent_id: a unique number of each agent
line_id: the original OD matrix unit from META data
x1: the latitude of the starting movement
y1: the longitude starting movement
x2: The latitude of the ending movement
y2: the longitude ending movement
startquadkey: the Bing square of the starting movement
end_quadke: the Bing square of the ending movement
time_stamp: where the activity starts
n_crisis: how many movement repeated within the same Line_id
trans_mode: used mean of mobility
act_type_origin: where activity begins to simplify, all activities were picked as home.
act_type_destination: type of activity assigned to destination.

agent_id	line_id	x1	y1	x2	y2	start_quad	end_quadke	time_stamp	n_crisis	trans_mode	act_type_origin	act_type_destination
0	0	3340868.331	3660044.634	3334415.075	3660811.842	12212101210323	12212101210233	9:18:08 AM	56	pt	home	education
1	0	3340324.142	3660593.835	3334863.619	3659357.839	12212101210323	12212101210233	9:39:49 AM	56	car	home	business
2	0	3339374.1	3659416.99	3335674.027	3661320.806	12212101210323	12212101210233	8:53:45 AM	56	pt	home	work
3	0	3339552.066	3660342.149	3334181.332	3660350.35	12212101210323	12212101210233	9:31:33 AM	56	pt	home	work
4	0	3340528.515	3661468.84	3334403.248	3660036.947	12212101210323	12212101210233	9:41:10 AM	56	pt	home	work
5	0	3340979.89	3660144.205	3336103.431	3659592.587	12212101210323	12212101210233	7:26:25 AM	56	car	home	education
6	0	3340011.891	3661241.829	3335389.329	3661078.36	12212101210323	12212101210233	7:50:05 AM	56	pt	home	education
7	0	3339786.234	3661379.543	3334323.696	3660322.082	12212101210323	12212101210233	8:15:13 AM	56	car	home	education
8	0	3339212.1	3660309.39	3335356.573	3659371.709	12212101210323	12212101210233	9:23:39 AM	56	pt	home	work
...	...	...	...	...	...	...	...	...	...	...	...	...
869774	795	3316008.589	3647648.888	3312487.284	3645162.162	12212101203211	12212101203212	8:44:03 AM	123	pt	home	leisure
869773	795	3315949.123	3648275.846	3314141.867	3644703.757	12212101203211	12212101203212	8:53:14 AM	123	car	home	work
869774	795	3316008.589	3647648.888	3312487.284	3645162.162	12212101203211	12212101203212	8:44:03 AM	123	pt	home	leisure
869775	795	3315329.462	3648465.879	3312298.391	3645471.942	12212101203211	12212101203212	8:13:43 AM	123	pt	home	education
869776	795	3315147.827	3649324.753	3313865.248	3645921.259	12212101203211	12212101203212	9:56:39 AM	123	pt	home	education
869777	795	3314908.294	3649390.484	3313923.632	3644673.255	12212101203211	12212101203212	9:06:02 AM	123	car	home	education
869778	795	3314947.108	3647747.706	3314076.745	3646920.933	12212101203211	12212101203212	9:22:20 AM	123	car	home	work
869779	795	3315541.092	3648212.959	3312746.774	3644752.281	12212101203211	12212101203212	8:52:30 AM	123	pt	home	education

Figure 12: Top and bottom eight agents in Alexandria's synthetic population.
Source: *Author.*



Modeling Alexandria’s Paratransit Network

Paratransit type

Paratransit’s OD

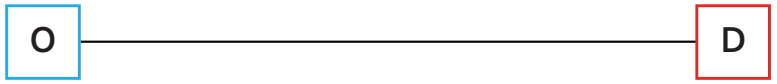
Modeling routes and stop-overs

Figure 13: Alexandria’s Al Manchya Square
Source: *Facebook I Nour Jackson*

Paratransit type

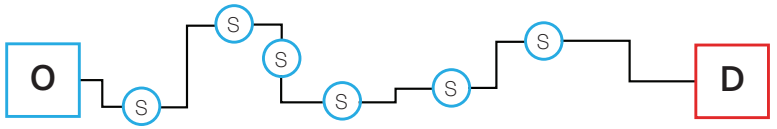
i. one-to-one

Where minibuses have only one origin and strictly go to one destination



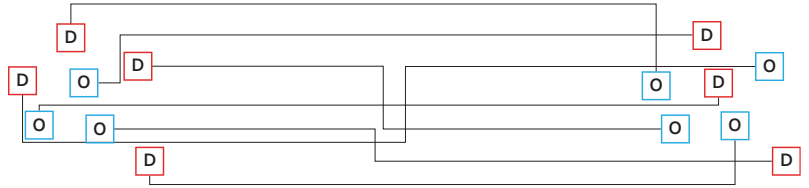
***ii.* corridor with mulitaple stops**

Where Minibus has a fixed origin and destination but, at the same time, can have multiple stopovers.



iii. many-to-many

Where the minibus works almost like a taxi.



iv. one-to-few

Where the minibus has a very clear starting point, but the endpoint might vary depending on dynamic circumstances.

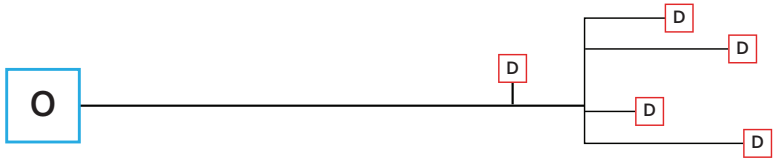


Figure 14: Different route patterns.
Source: *Author based on Andreas, 2014, p. 23*

Paratransit origin-destination

The starting point of modeling the paratransit network is the origin and destination of each station; these stations have a fixed location and can be easily identified from a satellite image.

Then, these stations need to be connected if there is a working route between the two hubs. These links are crucial in identifying the importance of a station based on its main destination. This will help create how many buses will depart from a certain station to another based on the origin-destination rank.

Figure 15: Alexandria's Minibus OD
Source: *Author based on OSM data.*

Modeling routes and stop-overs

MATSim requires a detailed description of the paratransit line, such as when it leaves, where it stops, which route it takes, etc.
Minibuses routes are formulated around two main major attributes (where most of the demand is located – the fastest route between the two points).
To mimic this nature of the movement, multiple stops were placed at an equal pace (100 meters) along the minibus route to force the ESRI Traffic network to simulate the movement pattern within a time frame.
The 100-meter segmentation will help to understand and evaluate the demand on the minibus routes regarding different mobility scenarios.

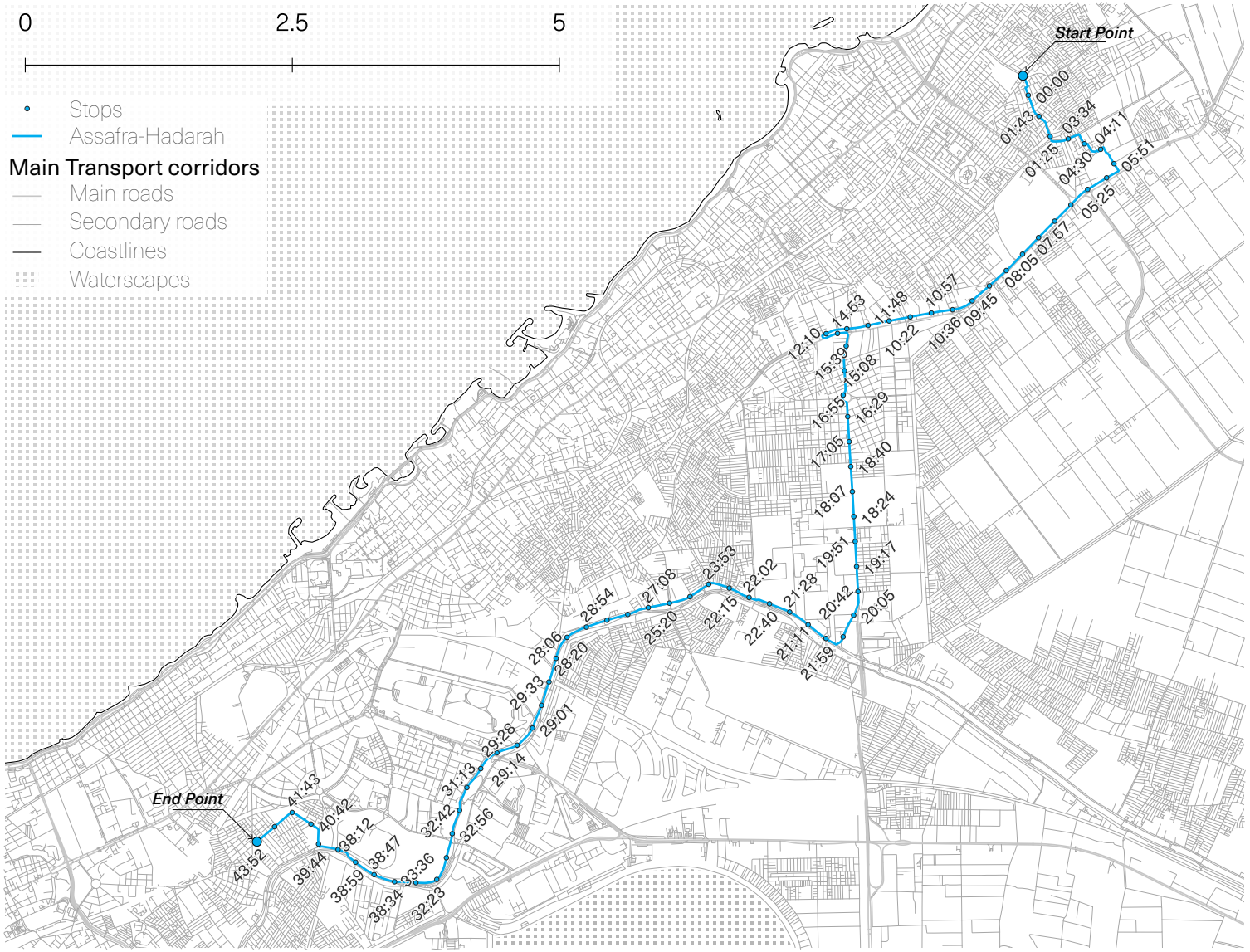


Figure 16: Minibus route modeling.
Source: *Author based on OSM, GPS data and ESRI Premiun Street network*

Conclusions

Estimating the demand on the network

Mesuring the performance of Paratransit

Results

Conclusions

Figure 17: Traffic jam in promandate avune.
Source: *ESMEE https://bit.ly/36KJfpb.*

Estimating the demand on the netwrok

The results show a relatively high demand on the main corridors of Alexandria's street network, which already match the reality and do not have too much additive value. The model can give a deeper insight into the origin and destinations of these high-demand corridors and give more precise insights about what activities are associated with the movement pattern.

On the other hand, the model can simulate the change in mobility behavior upon a new emergent that could happen or a newly adapted urban mobility/transport policy. To sum up, it adds quantitative insights about qualitative insights already known to the city.

Figure 18: Alexandria live traffic data
Source: *Google maps*

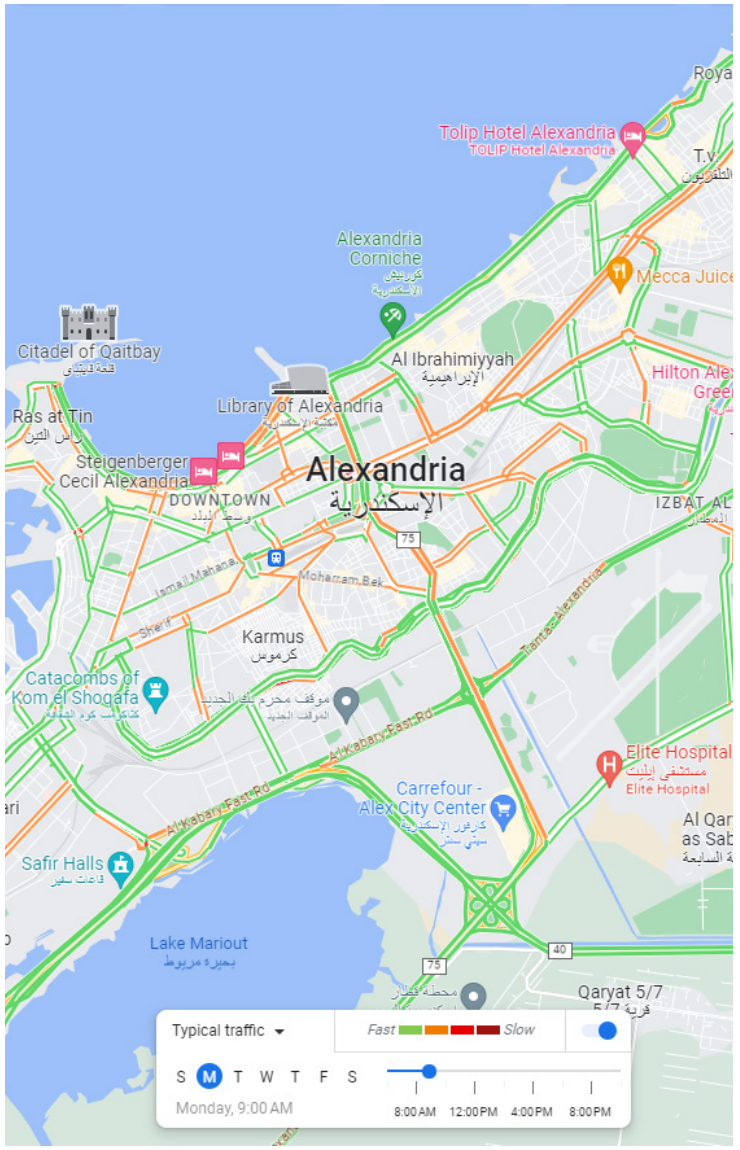
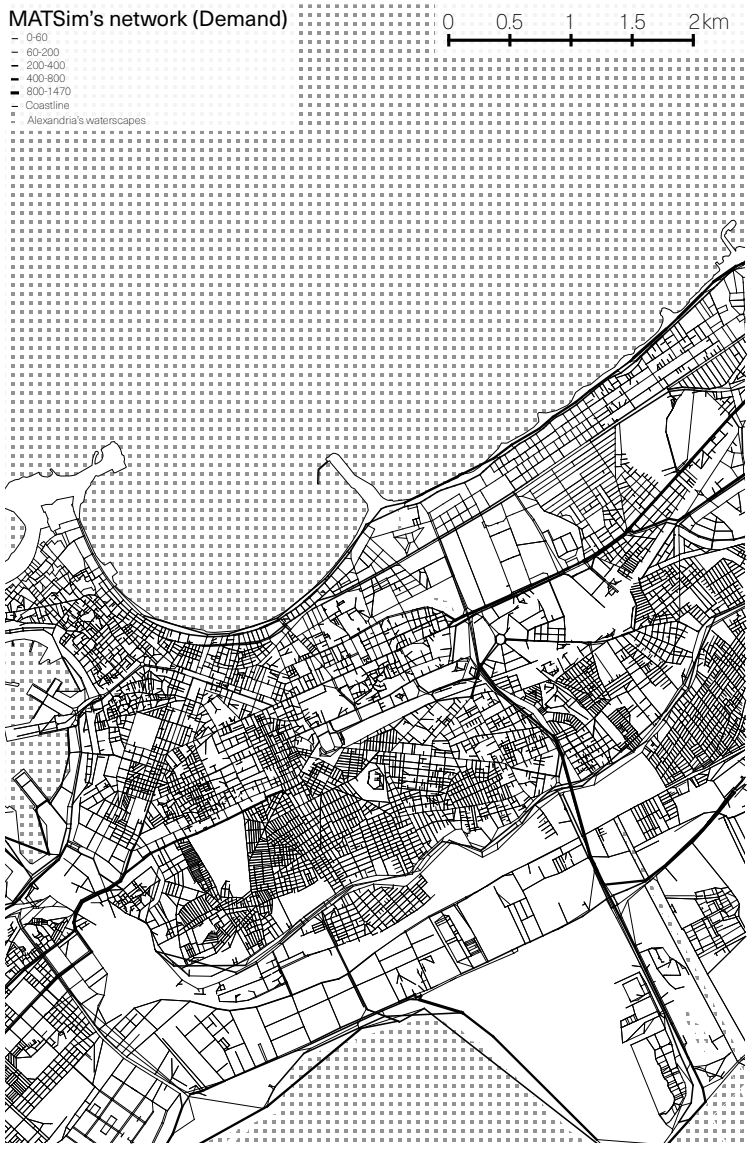
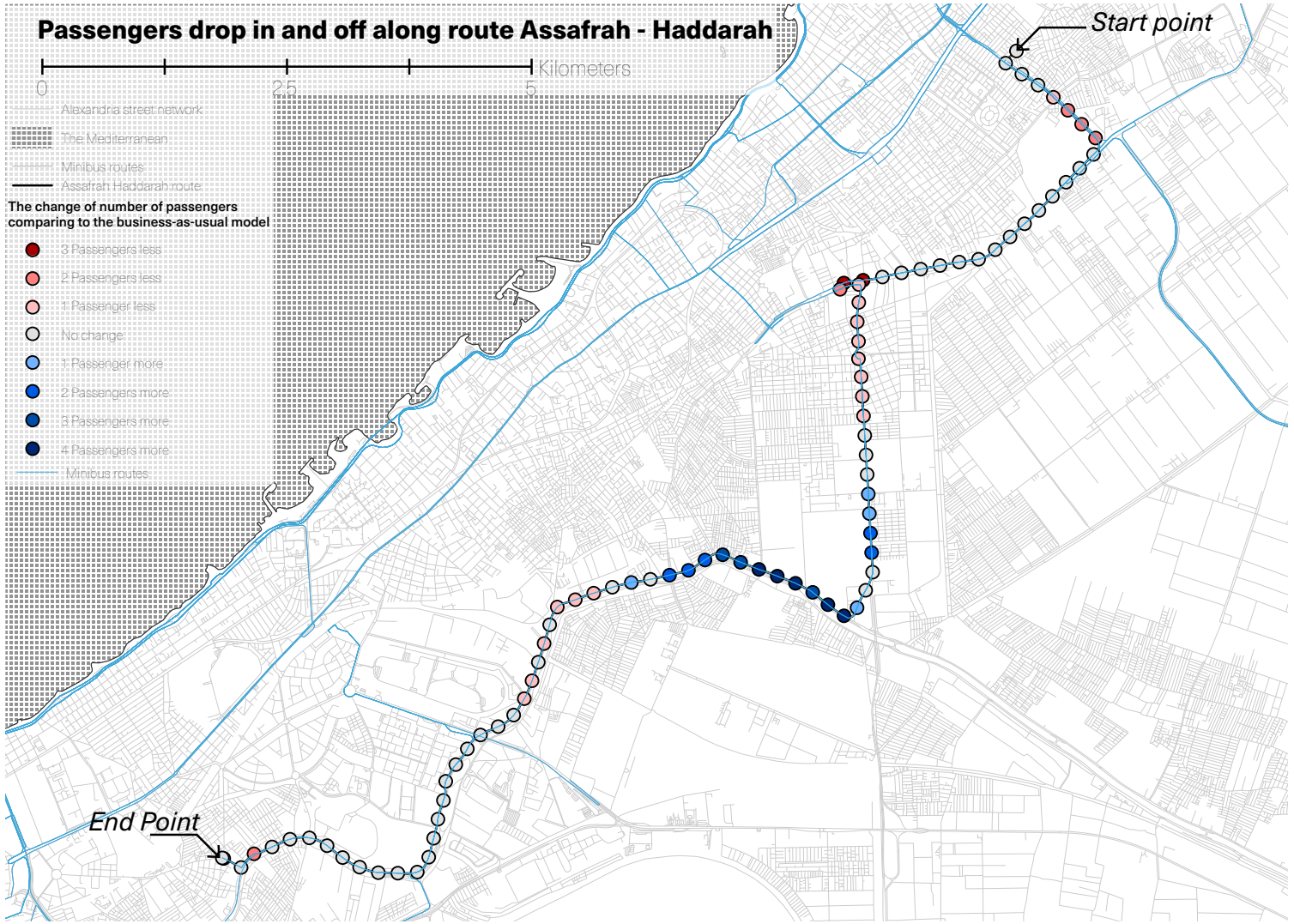


Figure 19: Alexandria's mobility demand
Source: *Researcher based on MATSim's model*



Mesuring the performance of Paratransit



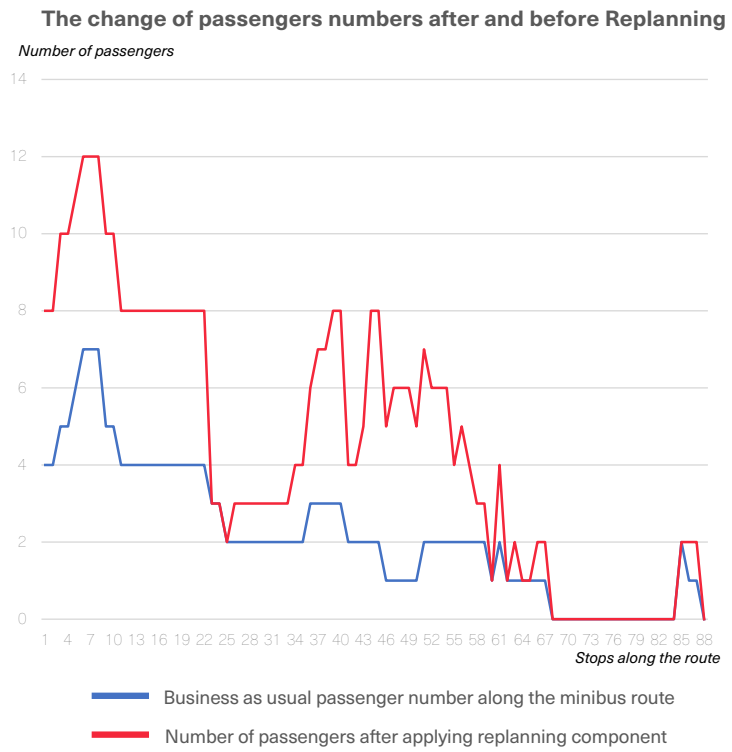


Figure 20: The change of bording behviour on route Assafrah - Haddarah after the iterations.
Source: *Author elaboration based on MATSim and OSM*

Results

Detailed visuals > MATSim simulates the business-as-usual movement patterns and spots overall mobility performance *(stuck areas, overall traffic on streets, average actual speed...)*

Sophisticated modular > In Alexandria, the model was asked to measure the impact of making public transport **five times cheaper than cars.**

Accurate measures > The model stated a **6.25% increase** in the total number of passengers who use minibuses due to the cheaper fares.

Comprehensive analysis > Despite the rise of total minibus passengers, the model shows a long queuing that could be **(1/3) of total trip time.**

Conclusion

Alexandria Minibuses:

- Local government should encourage minibus drivers to **form an organizational structure** to facilitate communication between officials, drivers, and passengers.
- In append, Government should develop a strategy to **constantly collects mobility data** that supplement urban mobility policy.

Collecting GPS data via volunteers:

- The objective of **tracking** minibus should be **clear to volunteers,** as they avoid tracking mistakes and give recommendations on the methodology.
- **Data should be public**; many resources were consumed to regenerate data that was kept private.

MATSim model:

- **Facebook population census is bais,** as the collected data represents only **52%** of all Alexandrian populations actively using the Facebook app.
- It is essential to establish a **GTFS** feed for all mobility data on navigation maps and different applications.

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Thank you!