Mobile data for studying public space, and trips in Mexico City: A study case of six suburban zones: Supplementary Material

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1 Parameters used for the isochrone computation

Pedestrian isochrone. In theory, pedestrians can walk in any part of the city network. However, infrastructure limitations often discourage individuals from utilising certain routes. For instance, urban highways or primary streets may lack sidewalks, forcing pedestrians to navigate alongside vehicles posing safety concerns and discomfort. Additionally, obstacles such as footbridges or wide streets can hinder pedestrian movement. In computing realistic pedestrian isochrones, Valhalla considers specific factors:

- The pedestrian speed is 4 km/h, a standard speed according to Transportation Research Board (2022).
- A 5-second penalty accounts for steps, acknowledging footbridges or similar impediments.
- An adjustment factor modifies travel time when encountering highways, prioritising designated footpaths or sidewalks, thus avoiding routes deemed unsafe for pedestrians.

Bicycle isochrone. Like pedestrians, cyclists avoid high-speed traffic and roads congested with buses, cars, or trucks. However, unlike pedestrians, cyclists adhere to street directions, and road conditions significantly influence their route choices. In computing realistic bicycle isochrones, Valhalla incorporates various factors:

- Cyclist speed is set at 13 km/h, based on the Mexico City study by Secretaría de Movilidad (2019).
- A 5-second penalty is applied for each manoeuvre.
- A 0.4-factor represents cyclists' preference for roads alongside other vehicles, ranging from 0 (preferring cycleways and paths) to 1 (comfortable riding on roads).
- A 0.4-factor accounts for cyclists' willingness to tackle hills, where 0 avoids steep grades, and 1 does not shy away from them.
- A 0.15 factor aims to avoid poor surfaces. As the factor increases, roads with sub-optimal surface conditions are penalised, prioritising better surfaces to improve travel time. A minor penalty factor is applied in these cases because the suburban areas of Mexico City often have roads with potholes or unfavourable conditions.

Transit isochrone. Transit in Mexico City lacks schedules or official frequencies, so it is hard to compute accurate waiting times. The transit administered by the Mexico City Government has GTFS information available. However, it is difficult to trust the frequencies reported in the GTFS. The only reliable information in the GTFS is the routes and stops. Also, around 80% of the transit routes are small franchises with little government supervision. So, there is no reliable information about these franchises' routes, stops, and waiting times. In particular, no public information exists on transit routes for Zones 2, 5, and 6. The following restrictions are assumed to compute the transit isochrones:

- Transit speed aligns with the average speed of the street, considering traffic dynamics (TravelTime 2023)
- Where GTFS information exists within the isochrones, details such as routes, stops, and waiting times are extracted from the GTFS data.
- In cases where GTFS data is unavailable within the isochrones, waiting times are assumed to exceed 15 minutes. Consequently, transit is not considered a viable option for trips shorter than 15 minutes.

Vehicle isochrone. Congestion poses a significant challenge in Mexico City, impacting the extent of the vehicle isochrone. To create these isochrones, the TravelTime API accounts for average congestion levels during peak hours.

2 Isochrone areas

Table 1: Isochrone areas for the pedestrian, bicycle, transit and automobile modes for each zone

Zone	Name	*Isochrones area in* $km2$			
		Pedestrian	**Bicycle**	**Transit**	**Automobile**
Central	San Rafeal	3.1	20	4.4	173
2	Chimalhuacán	3.3	16	2.7	111
3	Magdalena Contreras	3	17	2.2	55
4	Milpa Alta	2.9	20	2.2	69
5	Chalco	3.1	17	2.9	106
6	Neza	3.3	17	2.6	110
7	Iztapalapa	2.5	17	3.0	120

3 Herfindahl–Hirschman and the Entropy index for all isochrones

The entertainment venues considered in this study align with the categorizations outlined by the National Directory of Economic Units (Instituto Nacional de Estadística y Geografía 2023). The list includes a diverse array of establishments:

- Bowling alleys
- Golf courses
- Arcade houses
- Gyms (public and private)
- Sports clubs (public and private)
- Amateur sports leagues
- Dance companies (public and private)
- Theatre companies (public and private)
- Music venues (public and private)
- Caves, natural parks and other sites of the nation's cultural heritage
- Botanical gardens and zoos (public and private)
- Tourist marinas
- Museums (public and private)

- Water parks and spas (public and private)
- Amusement and theme parks (public and private)
- Promoters of artistic, cultural, sporting, and similar shows with dedicated facilities (public and private)
- Historical sites
- Other artistic performance groups and companies (public and private)
- Other recreational services (public and private)

The Entropy index, denoted as EI, is formulated as follows. Let P_j represent the percentage of each entertainment place j within an isochrone, where $k = 29$ denotes the total number of entertainment places. The Entropy index calculation, depicted in Equation 1, is derived using the equation:

$$\mathrm{EI} = \frac{-\left(\sum_{j=1}^{k} \left(P_j \ln\left(P_j\right)\right)\right)}{\ln\left(k\right)} \tag{1}$$

Similarly, the Herfindahl–Hirschman Index, denoted as HHI, is formulated as follows. Like before, P_j represents the percentage of each entertainment place j within an isochrone, with $k = 29$ as the total number of entertainment places. The HHI computation, detailed in Equation 2, is expressed as:

$$\mathrm{HHI} = \sum_{j=1}^{k} (100 \times P_j)^2 \tag{2}$$

4 Walkability index

The walkability index for all seven zones was estimated using a methodology drawn from several sources (Gutiérrez-López et al. 2019, Institute for Transportation and Development Policy 2018, Leticia et al. 2022). This index relies on a scoring system that incorporates various parameters. Each parameter is assigned a score between 1 and 3, with 1 indicating the lowest rank and 3 signifying the highest. These scores were derived from comprehensive data from field studies and GIS-based network analysis. After assigning scores to each parameter, the sum of these scores yields the walkability index for each zone. A breakdown of each parameter's score and the corresponding walkability index for each zone is in Table 2. Next, the parameters considered in calculating the index are detailed.

Table 2: Walkability index for all zones

Parameter	**Central** San Rafeal	2 Chimalhuacán	3 M. Contreras	4 Milpa Alta	5 Chalco	6 Neza	7 Iztapalapa
Urban grid	regular	regular	irregular	irregular	regular	regular	irregular
Land mix	3	1	2	0	0	1	2
Accessibility / Proximity	3	2	2	1	2	2	3
Distance between intersections	3	1	2	2	1	1	3
Block density	3	3	2	1	3	3	2
Accessibility public transport network	3	1	2	1	1	1	3
Sidewalk width	3	1	1	1	1	2	1
Accessible facades	3	1	1	2	1	1	3
Access to green spaces	3	0	3	3	0	0	1
Pedestrian crossings	3	2	1	0	2	2	1
Urban canopy	3	0	2	2	0	0	1
Slope	0	0	-2	-2	-1	0	-2
Vehicular stream surface	2	1	2	2	1	1	1
Lightning	2	0	1	1	0	1	1
Pedestrian flow	3	1	2	1	1	1	3
Maximum speed	2	1	1	1	1	1	2
Walkability index	**39**	**15**	**23**	**17**	**13**	**17**	**25**

Urban grid. The urban grid parameter assesses walkability by examining the number of trips made on foot, considering the existing infrastructure. This criterion classifies the urban grid into two categories, regular and irregular, based on distinct characteristics and the layout of the urban area.

Land use mix. Neighbourhoods boasting mixed-use tend to encourage activity and pedestrian movement along their streets. Conversely, predominantly residential or industrial areas lacking commercial or recreational spaces might lead to no pedestrians in the streets, feature blind walls, and foster limited interaction. Regarding the mixed-use parameter, a rating of 0 was allocated to areas dominated by a single land use. A rating of 1 is assigned to streets characterised by mixed-use areas primarily consisting of residential space. Areas integrating residential spaces alongside commercial establishments received a rating of 2. Finally, areas hosting 2 to 3 different types of land uses per block were assigned a rating of 3.

Accessibility/proximity. Improved access to facilities and services tends to reduce dependence on motorised transport. Urban centres encompassing markets, shops, and schools were allocated a ranking of 3 points, whereas zones featuring some services received 2 points. Areas primarily functioning as residential dormitories without local services were assigned a score of 1.

Distance between intersections. The proximity of intersections significantly influences pedestrian accessibility. Closer intersections often yield more direct and shorter pedestrian routes, facilitating efficient movement between points. Streets with average longitudinal distances exceeding 150 meters receive 1 point, those between 100 and 150 meters receive 2 points, and streets with average distances less than 100 meters garner 3 points. Each zone has the following average distance between intersections

- Central zone (San Rafael) 100m longitudinal (100m transversal)
- Zone 2 (Chimalhuacán): 200m longitudinal (35m transversal)
- Zone 3 (M. Contreras): 110m longitudinal (53m transversal)
- Zone 4 (Milpa Alta): 130m longitudinal (50m transversal)
- Zone 5 (Chalco): 155m longitudinal (63m transversal)
- Zone 6 (Neza): 220m longitudinal (45m transversal)
- Zone 7 (Iztapalapa): 45m longitudinal (35m transversal)

Block density. The density of blocks within an urban setting impacts walkability. Increased block density, characterised by a more significant number of interconnected streets and shorter distances between destinations, enhances the convenience of walking.

Street accessibility. Street accessibility plays a role in establishing connections between secondary roads or, conversely, in being disrupted by urban highways, which, despite not imposing distance obstacles, create difficult-to-access zones without the aid of an automobile.

1. Areas featuring urban highways (controlled access roads in Mexico) allowing a maximum speed of $80km/h$ were assigned a score of 1.
2. A score of 2 is attributed to areas primarily characterised by main roads with speed limits of $50km/h$.
3. Areas boasting a robust secondary road network and tranquil traffic zones featuring speed limits between 30 and $40km/h$ that facilitate pedestrian permeability were allocated a score of 3.

Sidewalk width. Wide sidewalk space ensures comfortable and safe pedestrian movement, particularly benefiting individuals with reduced mobility, such as wheelchair users, parents with prams, or those with limited mobility. This criterion awards 3 points for sidewalks wider than 2 meters, 2 points for sidewalks measuring 1 meter in width, and 1 point for sidewalks narrower than 1 meter.

Accessible facades. Commercial and transparent facades significantly enhance the perceived safety and attractiveness of streets. A rating of 3 applies to zones with streets featuring mixed uses where 60% of facades are commercial, transparent, or engage with pedestrians. A rating of 2 applies when 40% of the facades offer permeability. Meanwhile, a score of 1 is assigned to streets with only 20% accessible facades, predominantly featuring impermeable fronts lacking direct or visual access to the exterior.

Access to green spaces. Zones with accessible green spaces enhance pedestrian-friendliness, enriching visual appeal and promoting walking and recreational activities. The scoring system in this

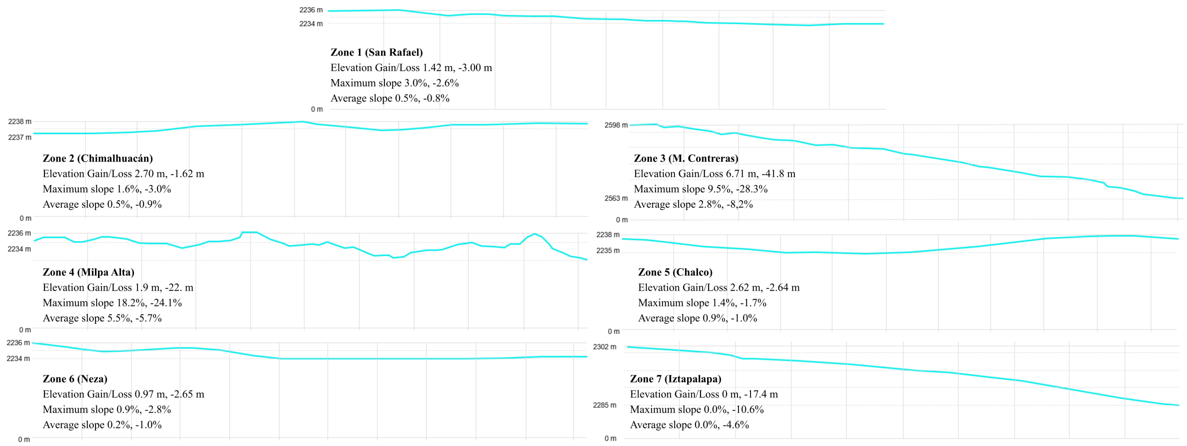

Figure 1: Elevation profile of a 500m. street segment of the main street in each zone

study awards 3 points to areas featuring green spaces within a 500-meter radius, 2 points for spaces within a 1-kilometre distance, 1 point for regions with green spaces 2 kilometres away, and a score of 0 for areas lacking such green areas.

Pedestrian crossings. Strategically positioned and well-designed pedestrian crossings significantly enhance pedestrian safety within an urban environment.

Urban canopy. Trees and greenery in urban areas offer shade, enhance air quality, and foster a more enjoyable pedestrian environment. Ratings are assigned as follows: 3 points for locations with dense tree cover, 2 points for areas boasting two to three trees per block, 1 point for streets adorned with shrubs or bushes, and a score of 0 for areas lacking greenery.

Slope. Slope significantly influences the ease and comfort of walking. Steep slopes present challenges for pedestrians, hindering longer distance walks, whereas flatter terrains offer comfortable pathways. This scoring system ranges from 0 to -2, accounting for varying elevations across the study areas. Figure 1 shows the elevation profiles of the main street in each zone.

Lighting. Street lighting significantly impacts the ease and safety of walking within a city. Studies by the Inter-American Development Bank (IDB) in New York and Santiago have shown that well-lit areas reduce crime rates by about 20% and enhance the perception of safety. In the walkability rating table of the study, the scoring is as follows:

- 0 for streets with streetlights between 70 and 100 meters apart.
- 1 for streets in areas with streetlights between 60 and 70 meters apart.
- 2 for streets with lights between 40 and 50 meters apart.
- 3 for streets with lights between 20 and 30 meters apart.

Each zone has the following average streetlight separation

- Central zone (San Rafael) 20m separation between streetlights
- Zone 2 (Chimalhuacán): 40m separation between streetlights
- Zone 3 (M. Contreras): 40m separation between streetlights
- Zone 4 (Milpa Alta): 40m separation between streetlights
- Zone 5 (Chalco): 70m separation between streetlights
- Zone 6 (Neza): 60m separation between streetlights
- Zone 7 (Iztapalapa): 30m separation between streetlights

Pedestrian flow. Streets were rated based on pedestrian traffic:

- A score of 1 for streets with foot traffic counts below 25.
- A score of 2 for streets with pedestrian counts between 25 and 50.
- A score of 3 for streets experiencing foot traffic counts exceeding 50 pedestrians per hour during off-peak hours.

Maximum speed. Speed control devices or infrastructure significantly influence pedestrian movement within an urban environment. Ratings are assigned as follows:

- A score of 3 is for areas where secondary streets primarily feature traffic control devices like traffic lights, speed reducers, or physical elements ensuring safe speeds for pedestrian traffic.
- A score of 2 is for streets with speeds ranging between 40 to 50 km/h.
- A score of 1 is for streets with higher speed limits, absence of traffic lights, and lack of speed bumps.

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