DAR
URBAN RESEARCH
SEED FUND
REPORT
05

COMMUNITY STREETS
Reconsidering Street Design and Non-Motorized Mobility in the Aftermath of the Beirut Blast

LCAU
NORMAN B. LEVENTHAL
CENTER
FOR
ADVANCED
URBANISM

MIT

Since 2019, the Dar Group and MIT have collaborated on an initiative to catalyze innovative, interdisciplinary research that addresses the design and planning of new and existing urban landscapes in the MENA region, and other comparable arid, semi-arid regions. Through the Dar Group Urban Seed Fund at MIT Norman B. Leventhal Center for Advanced Urbanism and organized through two seed grant calls, the Dar Group has supported nine research projects undertaken by faculty and students from MIT's School of Architecture and Planning. In the first seed grant cycle, projects presented a wide range of research interests addressing equitable heat-resilience at the neighborhood scale to advanced manufacturing of structurally optimized concrete housing. In the second seed grant round research focused on various facets of the recovery, planning, and reconstruction effort in Beirut. These reports share the findings of the nine research projects.

With thanks to the Dar Group for their generous support of this research endeavor, with specific acknowledgment to Mustapha Madi and Daniel Horner for their continued support, guidance, and collaboration.

DAR
URBAN RESEARCH
SEED FUND
REPORT
05

Andres Sevtsuk and Maya Abou Zeid

COMMUNITY STREETS
Reconsidering Street Design and Non-Motorized Mobility in the Aftermath of the Beirut Blast

LCAU
NORMAN B. LEVENTHAL CENTER FOR ADVANCED URBANISM

EXECUTIVE SUMMARY

- Estimated pedestrian flows in Beirut between different origins and destinations (e.g. homes to schools, etc.)
- Developed a comprehensive building-level spatial database of central Beirut
- Built and calibrated a preliminary pedestrian flow model of the city using findings
- Implemented a two-day, in-person "Community Streets" participatory design workshop at the American University of Beirut
- Analyzed how three different urban design intervention scenarios will impact pedestrian mobility in Beirut and summarized the findings in a journal article for JAPA

5.1 INTRODUCTION

Many cities are setting ambitious targets to increase non-motorized transportation and mobility. Despite broad support, policy and planning frameworks for analyzing how such targets will be met are often unclear. To help mitigate these shortcomings in planning, this project studies Beirut to propose a measure-analyze-pilot methodology that seeks to document, understand, and promote pedestrian mobility and active street life across the city. In the aftermath of the August 2020 explosion at Beirut's Port that resulted in loss of life, personal injury, and severe damage, this project will develop novel data about Beirut's streets and public spaces with a focus on the pedestrian experience, with particular attention paid to vulnerable street users like children and the elderly. The project will focus on the neighborhoods in the vicinity of the port explosion and will build on existing data with novel measurement and analysis techniques in order to identify a network of community streets where walking and non-motorized transportation options should be prioritized in order to reinvigorate street life and communal culture, support retail businesses, and encourage sustainable and healthy mobility. The following steps are undertaken to achieve this mobility:

Key Objectives

1. Collect and analyze data about the built environment in Beirut to improve pedestrian mobility
2. Build a predictive model of pedestrian flows in the city for representative periods throughout the day (AM, lunch, PM peak)
3. Use the model to determine where community streets would most benefit users
4. Organize a local stakeholder workshop to propose a community streets network in areas affected by the Beirut Blast
5. Analyze the pros and cons of alternative urban proposals using the model
6. Develop a common proposal of Community Streets improvements together with AUB and neighborhood partners to be submitted for consideration by public authorities

Objectives in Detail

Data will be sourced for the intended modeling exercises through an innovative set of camera-based technologies that employ computer vision AI techniques to automatically identify and categorize pedestrians, bicyclists, and vehicles. Edge computing is utilized to protect individual privacy and generate real-time longitudinal data. The resultant pedestrian flow model of the area will inform the selection of Community Streets for improvements, and offer an evidence-based platform for examining the accessibility benefits of alternative street choices and implementation scenarios. Based on the results, a co-generative process is proposed to design short-term pilot programs and physical interventions that bring the network of Community Streets to life, encouraging the return and growth of Beirut's active street culture and commerce.

By working in collaboration with professors and students from AUB as well as neighborhood organizations, the project will equip local stakeholders with the technology, means, and methods to expand the use of pedestrian modeling techniques in Beirut and lay the groundwork for permanent and long-term improvements as they relate to walking conditions on the city's streets. While traditional automobile traffic measurements guide urban development processes in Beirut and the greater Middle East, this project will introduce unique pedestrian measurement and traffic modeling tools to the city that will promote the shift to a more walkable, sustainable, and commercially active urban realm.

5.2 PROCESS

Beirut's high population density, mixed land-use patterns, and compact urban form have set the foundations for a highly walkable city. Yet, car travel remains the dominant mode of transportation, accounting for an estimated 80.6% of motorized trips in the Greater Beirut Area, with the remainder fulfilled by walking, minibus, and shared taxi services.[1] Beirut's relatively poor walking mode share and heavy reliance on private cars is due to several factors. The existing informal public transportation system is largely unregulated, perceived as low quality, and ill-suited for longer commutes.[2] Sidewalks and crosswalks in Beirut suffer from poor quality and connectivity, coupled with the complete absence of a cycling network. A lack of sidewalks along motorized roadways, the shortage of pedestrian signals and safety islands, the absence of adequate shading, and the dearth of parks and green space suppress pedestrian mode share throughout the city. With the recent waves of refugee populations from Syria, Beirut's streets have also become vital spaces for the unhoused and families with over-crowded homes.[3]

Beirut's high population density, mixed land-use patterns, and compact urban form have set the foundations for a highly walkable city.

Despite these challenges, there exist several factors which, if leveraged effectively, could unlock a latent demand for walking throughout the city. With an average of over 14,000 residents per square kilometer,[4] Beirut is denser than any large U.S. municipality, including New York City. A historic laxity in zoning enforcement has resulted in a visibly diverse land use pattern, with homes, jobs and small businesses closely interspersed throughout the city center.[5] Beirut's density and land use diversity constitute two of the three "D's" commonly posited as structural prerequisites of walkable cities (the third being the urban design of streets, where the city falls short).[6,7] Moreover, the city boasts a pleasant Mediterranean climate that supports walking all year round. At present, the high gasoline prices and an economic downturn, which have made vehicular travel unaffordable to many, also suggest that interventions targeting non-auto modes of travel in Beirut would be timely.[8]

To explore these opportunities, this research was realized in partnership between the MIT City Form Lab and the American University of Beirut, focused on improving walkability in the blast-affected areas of Beirut. Our research includes the development of a pedestrian flow model as a decision-support tool, a participatory design process involving local stakeholders to identify interventions to improve walkability, and the testing of these interventions to assess their potential impacts. This analysis is organized into three scenarios of varying complexity and timeframes to examine how selected interventions would affect pedestrian accessibility to key destinations, impact pedestrian trip generation, and restructure pedestrian trip distribution on city streets.To demonstrate how urban design interventions—in the form of both land use changes and street quality improvements—can impact pedestrian travel demand, the following research was undertaken:

A. Data Collection and Setup

Given that pedestrian travel demand models need detailed data of the pedestrian environment, our data gathering effort in Beirut was substantial, spanning over six months. This was largely due to the fact that little official data could be obtained from public sources. Instead, most data was assembled from academic groups, prior study reports, online maps and street imagery, and in-person observations by the local research team in Beirut.

First, we assembled a detailed pedestrian network for central Beirut. Most streets were represented with road centerlines, based on street network data from OpenStreetMap. Wider arterial roads that are challenging to cross on foot, were represented as two parallel sidewalk segments, connected with crosswalks at four-way intersections. Existing foot-bridges over highways were added to the network, where present. Unwalkable highway segments and ramps were removed from the pedestrian network. For each street, the research team approximated sidewalk presence, width, and quality based on open street-view imagery analysis from Mapillary (Google Street View is very limited in Beirut), prior studies,[9] and in-person observation. We found that 6% of streets lacked sidewalks completely, while roughly 17% of existing sidewalks had permanent obstructions. Approximately 20% of all sidewalks were narrower than the minimum comfortable passing width of 1.2 meters.

Second, we collated land use and point of interest data, creating multiple layers to represent population, employment, schools, amenities and public parking lots at an address-point level. This data was sourced from local studies, Open Street Map, Google Places, video analysis, websites, and field visits. We obtained an initial building footprint dataset from the Beirut Urban Lab at the American University of Beirut, who had assembled the data in the aftermath of the 2020 blast. The parameters surveyed included height estimates and primary use classifications (e.g. residential, commercial, mixed). Given that no official census information is available in Lebanon, population and job distribution was estimated at a building resolution by interpolating and disaggregating a number of different neighborhood-level estimates, using a benchmark of 30 square meters of gross floor area per person. A local study by TMS Consult provided residential and job totals at the neighborhood level. Jobs were proportionally assigned to buildings by type, size, and adjacent street characteristics, with higher allocations on streets with greater levels of commercial activity to capture job clustering. Residents were allocated to the remaining floor areas throughout the city, ensuring that total counts by neighborhood remain consistent. Amenities, such as retail, food-service, personal service and entertainment businesses found on building ground floors, as well as mosques and churches were included as points from Google Places and OpenStreetMap data. School locations were also largely obtained from Google Places and verified by the local team with their size capacities gathered from their respective websites. Parking lots (including capacity) and public parks (including size), were mapped from aerial imagery, local studies, and data from the Beirut Urban Lab. In order to avoid arbitrarily designating each park as a single point centroid, parks were represented as point-grids, where each point represents a portion of the total park area. This allowed our pedestrian travel models to more accurately capture park access at different distance bands. Data on the informal bus network, including the frequency of service, was sourced from a recent study by the American University of Beirut.[10] Since informal bus routes do not feature designated stop locations (stops are flagged on demand), we simulated points at 50-meter intervals throughout the entire route network, assigning each point a variable weight depending on the number and frequency of routes that pass through it.

Between December 2021 and May 2022, our team gathered pedestrian counts from 90 locations during weekday morning (7:30-8:30 AM), noon (12:30-1:30 PM), and afternoon (4:30-5:30 PM) peaks. Weekdays on which counts were conducted included Mondays, Tuesdays, Wednesdays, and Thursdays. Count locations were sampled so as to capture a wide range of land-use interactions and

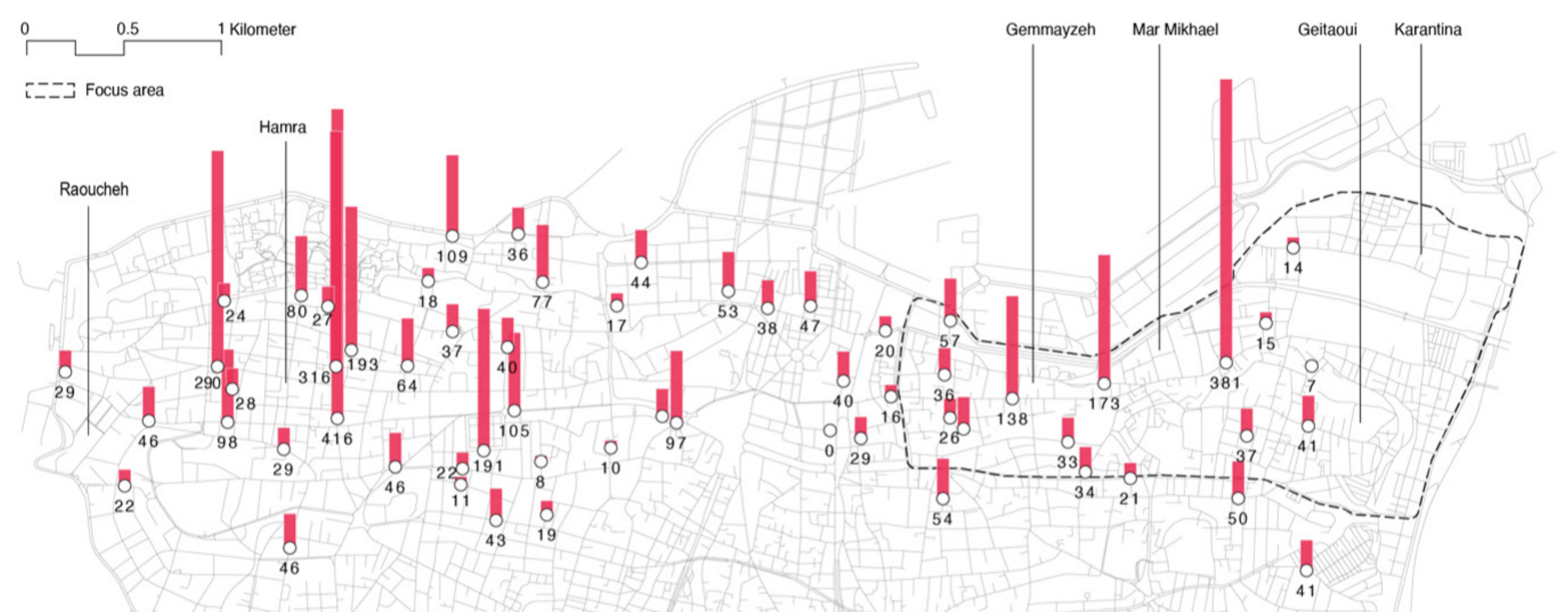


Figure 1. *Map of Beirut Study Area and average observed pedestrian counts on a weekday afternoon (4.30-5.30PM). The dashed line indicates the intervention areas used as part of scenario analysis below. [Source: Andres Sevtsuk, Community Streets, 2023.]*

pedestrian flow volumes. Since the streets located in the neighborhoods of Karantina, Mar Mikhael, Gemmayzeh, and Rmeil were expected to exhibit abnormal pedestrian patterns due to their particular levels of damage caused by the August 2020 explosion, we expanded our study area to include Hamra and Raoucheh. These western neighborhoods, unaffected by the explosion, were expected to exhibit more representative pedestrian behavior for model calibration. Count data at each location was captured on at least three different days to produce more reliable average estimates. Figure 1 illustrates average hourly pedestrian counts for a weekday afternoon (4.30-5.30 PM). The hourly counts for weekday afternoons ranged between 7 and 416 across all surveyed streets, with an average of 69.8. The highest foot-traffic levels were observed in the Hamra neighborhood.

B. Preliminary Estimates

We used the Urban Network Analysis (UNA) framework to estimate pedestrian flows in Beirut,[11,12] while also adding several methodological innovations over previous specifications. The UNA pedestrian flow estimates were generated using Madina–a new open-source Python library developed for modeling pedestrian activity in our research group.

Pedestrian trips in the UNA framework are generated from specific origin points, with the trip generation rate corresponding to a numeric weight of each origin, such as the number of residents in a building. We initially generated trips between a variety of origin and destination types, depicted in Figure 2. Trip distribution from each origin considers all available destination points within a specified distance range (e.g., 800 m), allocating trips between different destinations based on their accessibility using the Huff destination choice model.[13] Destinations with greater weights (e.g., bus stops with more frequent departures) and destinations that are closer have higher accessibility and obtain a larger share of trip distribution, while the total number of trips generated is limited by the trip generation rate at the origin.

For any origin-destination pair, pedestrian trips are routed over the network along all plausible routes that are up to a certain percent longer than the shortest available route. If ten trips are generated from a particular building to a particular bus stop, for instance, we do not assume these trips to take the shortest route. Instead, we find all available routes to the destination that are up to 15% longer than the shortest route and proportion the ten trips over these route alternatives with an equal likelihood of being chosen. But since many of these alternatives overlap at certain segments (e.g. the first and the last segment of each route are necessarily used by all trips), the estimated flows at individual segments are summed, resulting in a spatial probability distribution for different segments for the same trip. The equal likelihood approach in probabilistic route assignment has been shown to approximate actual pedestrian route choice reasonably well.[14]

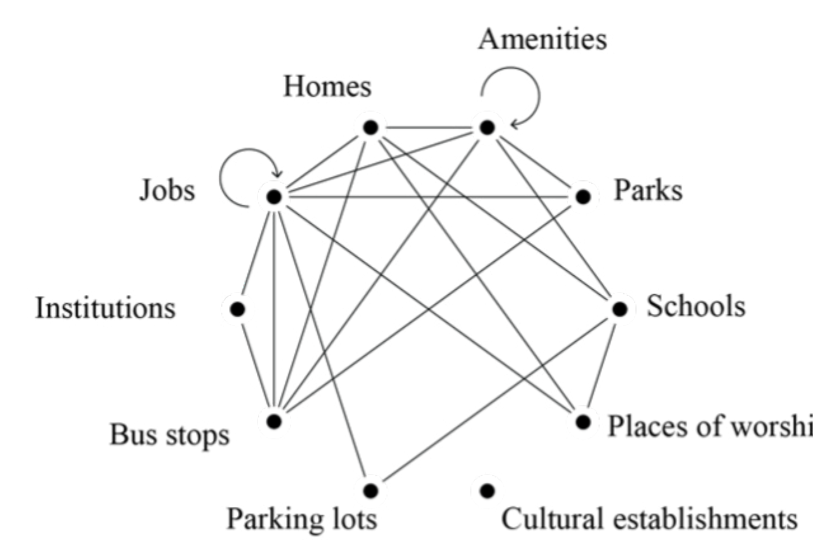


Figure 2. *Set of initial O-D trips modeled. [Source: Andres Sevtsuk, Community Streets, 2023.]*

Our trip generation rates are also elastic with respect to destination availability, producing more trips from origins that have more destinations of a given type nearby. To determine these elasticities, we first measured gravity accessibility from each origin to each destination type (e.g., home to bus stops), and capped the accessibilities with pre-assigned k-nearest weights. For trips to bus stops, for instance, we measured accessibility within an 800-meter network radius counting up to three destinations, weighting the closest destination more than the other two: [0.5;0.25;0.25]. If three or more destinations are found around an origin within 400 meters (a plateau effect), the origin is assumed to have perfect walking access to bus stops (1.0) and all the origins's weights (e.g., ten people) are assigned as part of trip generation (e.g., ten trips). If only one bus stop is available within a 400-meter range, half the trips are generated from that origin to bus stops (e.g., 10*0.5=5 trips). And if any of the three destinations is further than 400 meters but still within the 800-meter search radius, an exponential distance decay effect is applied.[15] This is analogous to computing a WalkScore that ranges from 0-100 from each origin to each destination category and multiplying original trip generation values with this score. Note that the k-nearest caps on accessibility make the approach comparable between various neighborhoods, so that origins in the densest or most accessible areas do not necessarily produce more trips than origins with equivalent weights in less dense areas.

In order to account for the characteristics of street segments, we used the concept of "perceived length" to characterize travel costs to each destination as opposed to the geometric length of the route. This concept, based on pedestrian route choice literature, describes how willingness to walk varies by route characteristics (e.g., sidewalk width, presence of amenities, etc.), translating each route attribute into distance-equivalent units.[16] While operationalizing such effects in Beirut would ideally require using prior route choice studies in Beirut, we could find no route choice preferences studies in the city. We therefore benchmarked our perceived length coefficients from prior pedestrian studies available from San Francisco, which despite cultural differences, is comparable to Beirut in terms of climate, density, and topography. Table 1 illustrates how our perceived lengths are determined for network segments by combining sidewalk dimensions,

Variable	Modifier	References
Traffic Volume	Geometric length * 61.5 per 1000s of vehicles [hourly average 24 hours] / 690.2	[[i]]X
Traffic Speed	Geometric length * 56.3 extra for every 16 km per hour / 690.2	[17]X
Sidewalk Width	Geometric length * -83.7 per every 3 meters of sidewalk width / 690.2	[17]X
Amenity Counts	-1.8 meters each passing 1 extra amenity	[17]
Difficult Crossing	Geometric length * 1.5	[[ii],[iii]]XX
Footbridges	+90 meters	[19]

X 690.2m is the typical road segment length in the SF data where coefficients were estimated.
XX Our factor of 1.5 is within a range of Lue & Miller (2019)'s factor of 2. The authors found that signalized crossings reduce perceived route length by 32 m on average, which roughly equals the width of an arterial road crossing in Toronto. We used a slightly more conservative factor of 1.5, which better fit our model upon testing.

Table 1. *Perceived length transformations for network segments based on attribute characteristics. Perceived lengths are found by combining geometric lengths with attributes and corresponding coefficients from prior studies.*

traffic volume, traffic speed, and the presence of ground floor amenities. We additionally introduced penalties for difficult arterial road crossings, and for pedestrian footbridges that span over a highway in our study area based on analogous studies in Singapore. Based on prior studies that have suggested an adverse impact of turns on route choice,[17] we also examined turn penalties on route assignment but found the model with turn penalties to fit less accurately to observed data than the model with only perceived segment lengths, and thus omitted turn penalties from the final model.

With these settings in place, trips were generated between all initial origin-destination. This produced a pedestrian flow estimated for each street segment and trip type, which could be further calibrated based on observed pedestrian counts at select locations.

C. Model Calibration

We used the pedestrian counts from different daily time periods to calibrate our model estimates on observed flow levels. We treated each of the estimated flow types (e.g., trips from homes to amenities) as independent variables, with the observed pedestrian counts acting as the dependent variable. Although models were separately calibrated for the morning, noon, and afternoon periods, for the sake of brevity, we only discuss the afternoon calibration results here, as this is the period with the highest pedestrian volumes. This calibration exercise aimed to align the preliminary flow estimates with actual pedestrian counts, thereby providing insight into each flow type›s contribution to the total observed pedestrian traffic on a given street during the afternoon period (Table 2).

	OLS					HAC-adjusted				
Variable	Coefficient	Std. Error	t-value	p-value	Significance	Coefficient	Std. Error	t-value	p-value	
General										
Amenities to Amenities	3.49	0.48	7.21	0.001	***	3.49	1.05	3.23	0.001	***
High amenity access										
Jobs to Homes	0.08	0.03	2.8	0.006	***	0.08	0.06	1.47	0.14	~
Parks to Amenities	0.08	0.03	2.74	0.007	***	0.08	0.05	1.58	0.116	~
Low amenity access										
Homes to Places of Worship	0.02	0.01	2.52	0.012	**	0.02	0.01	4.07	0.001	***
Fixed Effects										
Tuesday	-13.02	11.51	-1.13	0.259		-13.02	13.26	-0.98	0.327	
Wednesday	7.8	12.72	0.61	0.541		7.8	13.77	0.57	0.57	
Thursday	-18.27	12.62	-1.45	0.149	~	-18.27	15.17	-1.2	0.23	~
Intercept	61.62	9.9	6.23	0.001	***	61.62	8.46	7.28	0.001	***
Adjusted R2	**0.46**									

Note: *** p<0.01; **p<0.05; *p<0.1; ~p<0.25

Table 2. *Pedestrian flow calibration estimates for PM peak hour (4:30-5:30 PM) on weekdays.*

To account for pedestrian activity variations between commercial and residential areas, we further differentiated origin locations based on their proximity to amenity-rich areas and estimated separate model coefficients for trips that originated from high amenity and low amenity areas (Table 2). High-amenity areas were defined as address points whose gravity accessibility values to amenities exceeded a 90th percentile threshold. We also show heteroskedasticity and autocorrelation consistent (HAC) standard errors to account for potential spatial autocorrelation between nearby street segments.

We used the estimated coefficients to adjust our initial trip generation rates for each trip type in low and high amenity access areas accordingly. For instance, we multiplied our initial trip generation coefficient of "1.00" for trips from jobs to homes in high amenity-access areas with a coefficient of 0.08, suggesting that around 8% of employees travel home on foot between 4.30-5.30PM. The model explained 46% of variation in observed PM pedestrian counts. This is somewhat lower than previous UNA model calibrations, likely due to lack of official built environment, population and employment data in Beirut. Figure 3 illustrates the estimated foot-traffic from the calibrated model for all streets in the study area.

A pedestrian flow model, once calibrated with observational data, serves as a powerful predictive tool. It can forecast the effects of changes in developmental activities or improvements in pedestrian infrastructure, such as sidewalk enhancements or urban design interventions, on pedestrian trip generation and trip distribution. This is accomplished by altering trip origins, destinations, or the characteristics of sidewalks, crossings, or public space segments in the model. We then re-estimate the flows for various time periods using previously calibrated settings, and predict changes in pedestrian traffic patterns under different conditions.

D. Co-design of Interventions

After constructing a model of pedestrian flows in central Beirut, we convened a stakeholder workshop to gather ideas for pedestrian infrastructure improvements. Participants included representatives from community groups, civil society leaders, and professionals from various academic, industrial, civic, non-governmental, and international organizations. Around 60 people in total collaborated over two days to identify key challenges impacting walkability in the study area, and proposed improvements and future urban design interventions. Our broad-based inclusion of stakeholders aimed to garner diverse perspectives on a wide array of pedestrian and built environment issues, promoting comprehensive urban design solutions.

Figure 3. *Map of calibrated pedestrian flows during weekday PM peak (4.30-5.30PM). [Source: Andres Sevtsuk, Community Streets, 2023.]*

The workshop began with stakeholders presenting non-motorized mobility initiatives they have already worked on in Beirut, followed by the formation of teams with five to six members each. Each team was assigned a specific neighborhood within the study area and presented with analytic maps of present pedestrian activity on all streets, as well as pedestrian activity of particular trip types (e.g., home to school foot traffic estimates, home to park foot traffic estimates, etc.). During the analytical phase, each team used large-scale area maps to identify specific challenges pertaining to pedestrian mobility, marking these issues directly on the map. Subsequently, teams conducted on-site visits to the neighborhoods, where they identified potential urban design interventions to address the identified issues. The interventions were geared towards achieving connected pedestrian corridors and a network of walkable community streets, rather than fragmented improvements. Finally, each team ranked various interventions based on their feasibility and importance and presented them to the whole group.

E. Scenario Analysis

Following the workshop, the project team synthesized a wide range of planning and urban design proposals from participants into three specific scenarios, based on evaluations of feasibility and priority: (1) tactical interventions, (2) permanent urban design improvements, and (3) comprehensive urban revitalization (see Figure 4). Within each scenario, interventions were specifically categorized as either (a) a measurable change on existing street properties (e.g., an elimination of a parking lane, construction of a safer road crossing), (b) a change in the pedestrian network (e.g. a new walkway through a city block), or (c) a land-use change (e.g., opening up presently closed parks for public use, new development at particular sites)—types of interventions that could be incorporated into the pedestrian model.

It was critical that urban design ideas be translated into changes in model input data to be able to estimate their impacts and effectiveness on walkability and accessibility. Any changes to existing street properties (category a) were limited to the street attributes that we used to define "perceived lengths," and for which we had assembled behavioral coefficients from prior studies (as detailed in Table 1). For instance, we had a coefficient to describe how each additional ground-floor amenity–such as a street-facing shop or restaurant–would reduce perceived walking distance (e.g., -1.8 meters per amenity) and therefore coded streets, where new active street-front interventions were proposed with proportionately lower "perceived lengths." However, for some urban design effects, like the reduction of street-parking, we lacked a predefined behavioral coefficient. In such cases, we translated this type of intervention into an analogous effect, like a wider sidewalk, for which we did have a corresponding behavioral coefficient. This categorization enabled the research team to estimate how each scenario affects both pedestrian trip generation rates and trip distribution within the study area, compared to the baseline situation. Improvements in street properties that lead to lower perceived segment costs effectively shorten routes, thus leading to higher accessibility for any journey using such segments. Given that pedestrian trip generation in the model is elastic to destination accessibility (as described in Section 3.2), a rise in accessibility leads to an increase in trip generation. This methodological innovation links street design changes to pedestrian trip generation. The impact of land use changes and network topology changes on trip generation is more direct. Land use changes can shift origins or destinations for trips, leading to changes in accessibility. Likewise, a new topological network connection can shorten the geometry of routes, decreasing impedance and increasing accessibility, thereby affecting trip generation.

Figure 4 maps the transformations implemented in Scenarios 1, 2 and 3. Figure 5 provides an illustration of some of the key changes in each scenario.

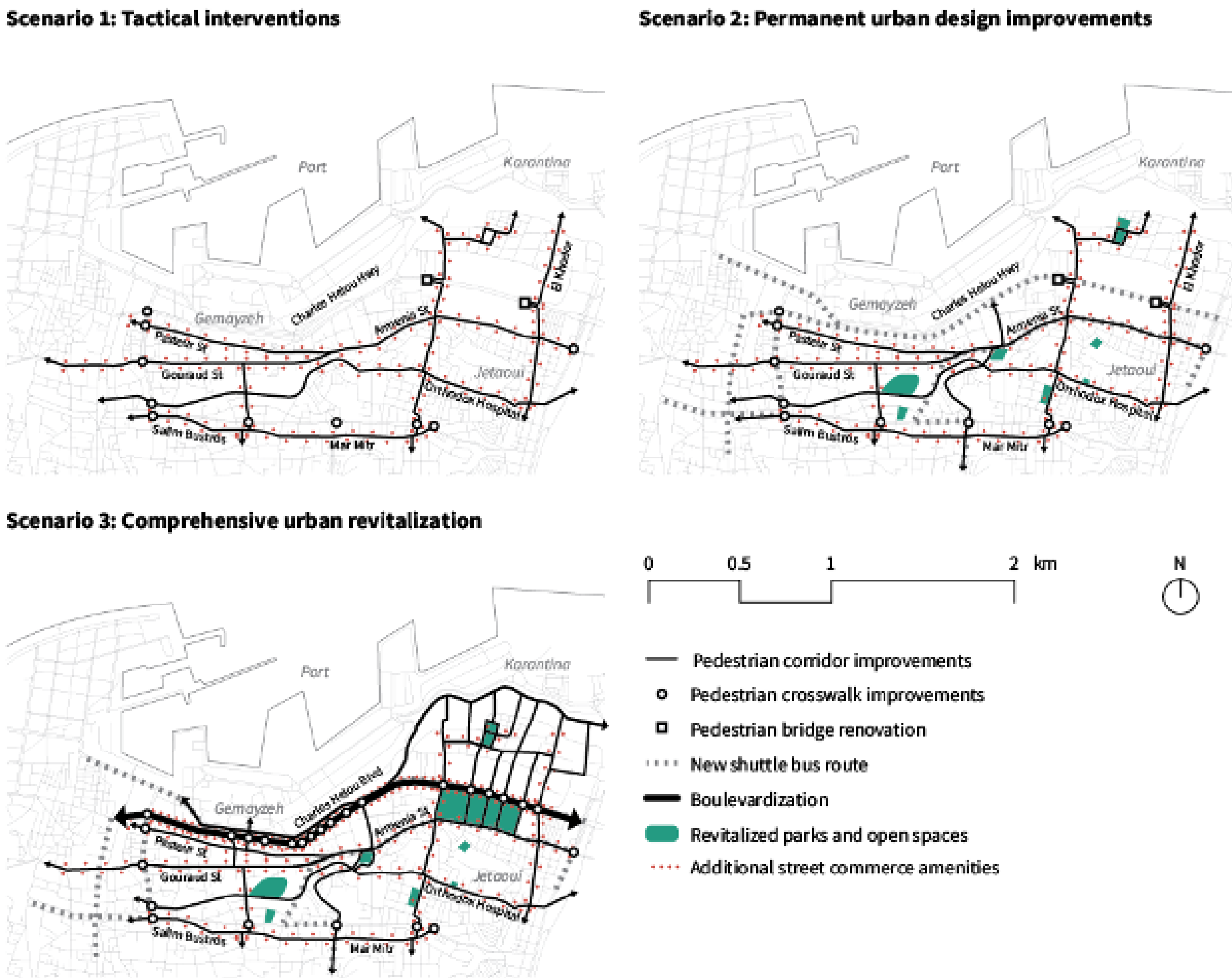


Figure 4. *Diagram of Interventions for Scenarios 1-3. [Source: Andres Sevtsuk, Community Streets, 2023.]*

Figure 5. *Graphic illustrations of scenarios 1-3, comparing existing (left) and proposed (right) conditions for selected elements. (a) Scenario 1 interventions include upgraded footbridges over Charles Helou Highway, reduced speed limits, and widened sidewalks along the streets shown in Figure 4, Scenario 1. (b) Scenario 2 interventions include the removal of one parking lane along Gouraud and Pasteur streets, a widening of sidewalks and the opening of new ground floor amenities. (c) Scenario 3 interventions include a conversion of the Charles Helou Highway (i) into an urban boulevard, a new promenade along Karantina's port-facing edge (ii), and a new urban park (Mar Mikhael Station Park) (iii). Each scenario includes all elements of previous scenarios. [Source: Andres Sevtsuk, Community Streets, 2023.]*

D. Results

In the baseline scenario, we estimated a total of 10,878 pedestrian trips during the afternoon peak hour within the intervention area (Table 3). Approximately 60% of these trips are amenity-to-amenity trips, including social, recreation, and errand travel between street-facing businesses. Scenario 1 includes relatively small tactical upgrades to select streets and intersections, as well as the upgrading of two presently dilapidated footbridges linking to the Karantina neighborhood across the Charrles Helou highway. These interventions collectively increase pedestrian trip generation by 1,939 (12,817-10,878) trips during the afternoon peak hour, with the largest percentage increase for trips between amenities and parks (+40.86%). There are very few open parks in the baseline and Scenario 1 due to Covid-related policies for park closure.[18] However, access to parks that are open will increase due to tactical street interventions included in this scenario. The reason we see a decrease in estimated home-to-places of worship trips in Scenario 1 (and subsequent scenarios) is that this trip effect was significant only in "low amenity" access areas. The increased pedestrian accessibility in Scenario 1 reduces the number of areas considered "low amenity."

We illustrate a policy-relevant example of the accessibility improvements of Scenario 1 in Figure 6. The figure shows how pedestrian accessibility to the main street business cluster along the Gouraud/Pasteur/Armenia street corridor, marked in red dots, increases as a result of tactical street improvements proposed in Scenario 1. A red contour delineates buildings that are captured within an 800-meter perceived walkshed around the cluster at the baseline. A separate black contour indicates how much the 800-meter perceived walkshed area expands due to reduced travel costs in Scenario 1, including additional buildings that are now reachable. Due to better pedestrian bridges connecting over the highway, a number of presently isolated buildings in Kranatina enter the 800-meter perceived walkshed around the main street. Similarly a number of buildings to the south, across the Charles Malek arterial road, enter the walkshed due to improved crossings. Altogether, 472 buildings are added to the catchment area of the Gouraud/Pasteur/Armenia main street in Scenario 1, improving residents' access to amenities, and main street business access to foot-traffic.

	Baseline	Scenario 1	Scenario 2	Scenario 3
O(Home)_D(Places of Worship)*	347.35	335.1	329.15	309.97
delta		*-12.24*	*-18.2*	*-37.38*
%change		*-3.52%*	*-5.24%*	*-10.76%*
O(Jobs)_D(Homes)	2,823.42	3,094.85	3,111.12	3,402.48
delta		*271.42*	*287.69*	*579.05*
%change		*9.61%*	*10.19%*	*20.51%*
O(Parks)_D(Amenities)	1,628.83	2,294.41	9,572.51	14,033.35
delta		*665.58*	*7,943.68*	*12,404.52*
%change		*40.86%*	*487.69%*	*761.56%*
O(Amenities)_D(Amenities)	6,039.48	7,054.11	7,060.17	7,838.06
delta		*1,014.63*	*1,020.69*	*1,798.58*
%change		*16.80%*	*16.90%*	*29.78%*
total	**10,878.50**	**12,817.89**	**20,112.36**	**25,623.28**
delta		**1,939.39**	**9,233.86**	**14,744.78**
%change		***18%***	***85%***	***136%***

Note: * Flows were only included for low amenity-access origins. A decrease from baseline means there are fewer such origins due to a general increase in amenities proposed in the scenarios.

Table 3. *Overview of trip generation analyses in Scenarios 1, 2, and 3 for afternoon peak. Table values report the difference in total trip generation in the study area compared to the benchmark situation.*

In addition to trip generation, each scenario creates a shift in trip distribution and route assignment, leading to a geographic change in pedestrian flows. Figure 7 illustrates trip distribution changes geographically. In scenario 1 (Figure 7, a), our model predicts a substantial increase in foot-traffic along Gouraud and Armenia streets (~ +60%), where some of the key street improvements were located. For example, a proposed crossing improvement at the intersection of Gouraud and George Haddad is expected to attract an additional 120 pedestrians per hour. With the baseline figure of 173 pedestrians, this means that a safer crossing at this location would benefit a total of 293 pedestrians during the afternoon peak hour. We also note a significant increase in projected east-west foot traffic for Salim Bustros street and Orthodox Hospital street, where additional improvements were proposed (as shown in Figure 4). In the north-south direction, the greatest changes are observed along Nicholas and Moscow streets, with the latter extending all the way north into Karantina across a newly upgraded footbridge. The footbridge itself, and adjacent streets in Karantina, are projected to have a 50% increase in foot-traffic (rising from an 80-pedestrian at baseline to 123 in Scenario 1).

In Scenario 2, some of these tactical interventions were converted into permanent solutions. For instance, Gouraud, Moscow,

Figure 6. *Illustration of accessibility improvement to an amenity cluster along the Gouraud/Pasteur/Armenia street corridor. [Source: Andres Sevtsuk, Community Streets, 2023.]*

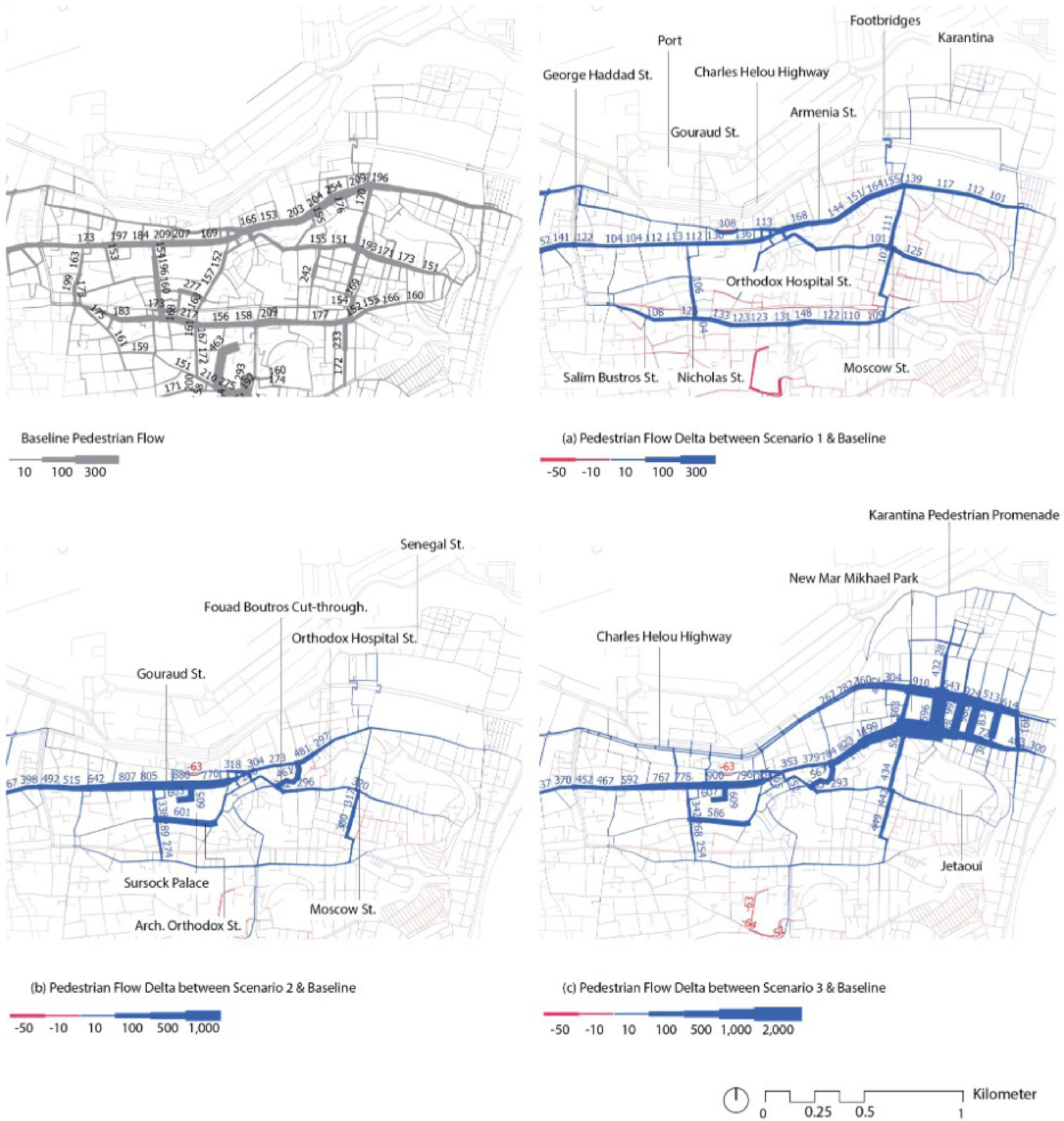


Figure 7. *Map of estimated pedestrian flow changes from the baseline during the weekday PM peak period (4.30-5.30PM) resulting from urban design intervention in scenarios 1, 2, and 3. [Source: Andres Sevtsuk, Community Streets, 2023.]*

and Senegal streets were pedestrianized while larger capital investments were dedicated to improving street quality. This scenario also opens up a number of presently closed neighborhood parks. Unsurprisingly, Scenario 2 witnessed a substantial increase (+487.69%) in park-related pedestrian trips. The home-to-jobs trips and amenity-to-amenity trips both increase at roughly the same proportion as in Scenario 1. This increase can be attributed to wider pedestrian rights-of-ways and removed traffic, both of which further decrease perceived segment lengths and enhance accessibility. However, our model is unable to differentiate qualitatively between tactical and permanent interventions. For example, the model can not distinguish between a wider sidewalk created with bollards and paint versus one constructed with a rebuilt curb-line and higher quality pavers. Such differences could potentially influence route length perception. If future pedestrian route choice studies produce different willingness-to-walk coefficients for temporary versus permanent street improvements, such effects could be incorporated.

In Scenario 2, our trip distribution analysis (Figure 7, b) indicates a notable increase (+805) in foot-traffic along the fully pedestrianized segment of Gouraud Street. The full pedestrianization is accounted for with a larger pedestrian path width, added amenities, and the elimination of traffic volume or speed, which are typically deterrents (as detailed in Table 1). Notably, we also observe a large increase in pedestrians (+601) along Arch. Orthodox street, where the Sursock Palace park is opened up in Scenario 2. Furthermore, an influx of foot traffic is expected along the newly proposed Fouad Boutros pedestrian path that connects to Armenia street, which was previously planned as a highway connection. Our model estimates an average of 461 pedestrians using this path during afternoon peak hours.

Scenario 3 envisions an ambitious transformation of the Charles Helou Highway into an urban boulevard and implements a new pedestrian promenade in Karantina that runs along the old shoreline where the neighborhood meets the port. Additionally, the currently abandoned historic Mar Mikhael train station is restored as a public building, while the green areas around it are converted to a major new park for central Beirut. This scenario also envisions the creation of several new streets in the Karantina neighborhood and a series of new crossings over the Charles Helou Boulevard.

These interventions are projected to lead to a roughly 20% increase in walking trips from home to work. This increase is due to substantially shortened routes, without adding any homes or jobs. Furthermore, we estimate a 30% increase in amenity-to-amenity trips compared to the baseline. This is attributable to both shortened routes to stores which expand their catchment areas, and the addition of amenities along the new Charles Helou Boulevard. The most significant change is expected in park-related trips due to the proposal of a major five-hectare park for Beirut around the renovated rail station. Overall, Scenario 3 projects more than doubling (+136%) of pedestrian trips in the study area compared to the baseline.

Considering flow distribution (as depicted in Figure 7, c), Scenario 3 would produce a large increase in pedestrian trips around the converted Mar Mikhael station and surrounding park. The section of Armenia street in front of the proposed station could potentially see over 2,000 additional pedestrians per hour. Similarly, the north-south connectors to the newly converted Charles Helou Boulevard could accommodate over 1,000 pedestrians per hour each. The most foot-trafficked section of the boulevard itself is expected to be closest to the newly created Mar Michael park between Karantina and the station. Our analysis suggests that such a transformation would go a long way towards improving connectivity between the presently isolated Karantina neighborhood and the rest of Jetaoui. For the coastal pedestrian promenade in Karantina, we forecast around 75 pedestrians per hour. However, since our model does not include recreational trips (e.g., leisurely walking or biking along the shore), this number likely underestimates the potential usage.

5.3 OUTCOMES

Overview of Major Outcomes

1. Created a comprehensive building-level spatial database of central Beirut that is suitable for the pedestrian model and other potential modeling efforts
2. Estimated pedestrian flows in Beirut between different origins and destinations (e.g. homes to schools, etc.) along street networks
3. Calibrated a predictive pedestrian flow model for Beirut by implementing pedestrian counts at 90 locations in the city center for weekdays and weekends
4. Produced a whitepaper entitled "Walkability and Pedestrian Conditions in Beirut: A Background Study."
5. Implemented a two-day, in-person "Community Streets" participatory design workshop at the American University of Beirut on June 22-23, 2022
    a. Findings from the workshop have been synthesized and summarized into three succinct development scenarios
6. Presented the project and its findings at the 2023 Venice Architecture Biennale

Outcomes in Detail

We have explored how pedestrian modeling can be used to estimate the effects of changes in land use, street infrastructure, and comprehensive neighborhood-scale development visions on the generation and distribution of pedestrian trips. Our methodology expands on previous implementations of pedestrian network analysis and introduces several innovations. First, we introduce the concept of 'perceived' route lengths to incorporate different street design interventions into simple and intuitive units of route length. This enabled us to incorporate sidewalk infrastructure improvements into accessibility measures that affect trip generation, distribution, and route assignment within the model. Second, we developed a new approach to estimate pedestrian trip generation elasticity with respect to destination availability, adjusting trip generation with a WalkScore-type accessibility metric for each origin point to each destination type, using k-nearest neighbor caps. Third, we used the pedestrian model iteratively within an urban design process, where baseline model results that calibrated on actual pedestrian counts were used to inform urban design decisions, and the effects of these decisions on walking activity were then evaluated in subsequent implementations of the model. This iterative process, enabled us to evaluate the pedestrian impact of three different design scenarios for the neighborhoods of Karantina, Gemmayzeh, Mar Mikhael, and Jetaoui, whose streets were severely affected by the blast of 2020.

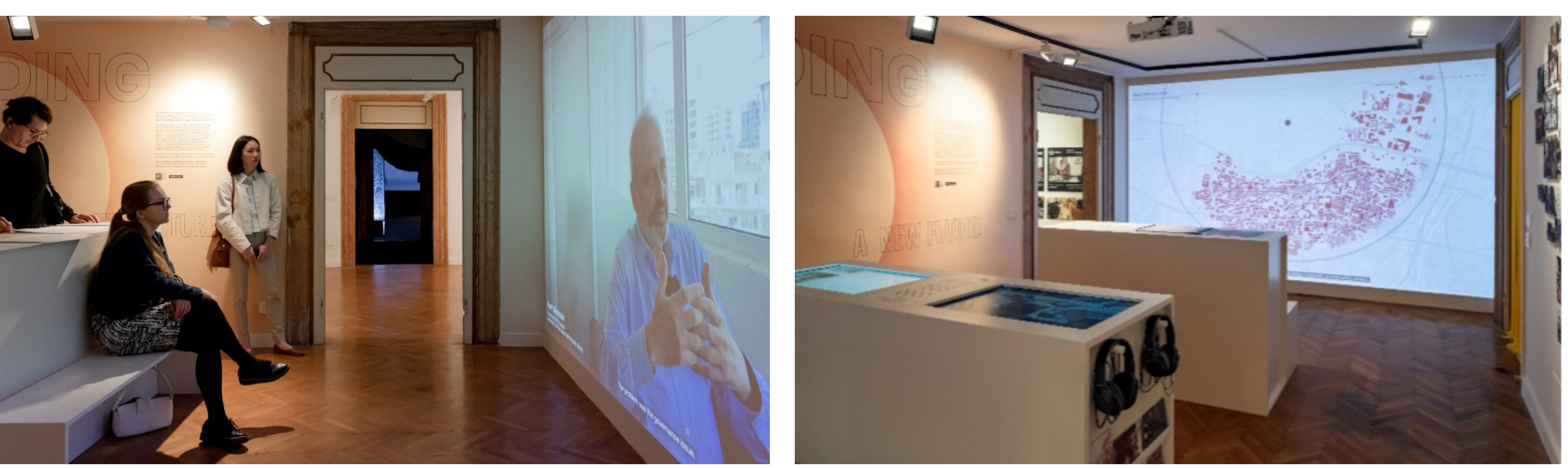


Figure 8. *Community Streets exhibition organized in conjunction with the Venice Architecture Biennale, 2023. [Source: Andres Sevtsuk, Community Streets, 2023.]*

Next Steps

Future work would benefit from incorporating other sidewalk attributes derived from additional empirical pedestrian route choice studies. Furthermore, our model's mode choice estimation could also be refined, possibly incorporating multimodal accessibility estimations to each type of destination.[19, 20] To better approximate trip generation, distribution, and mode choice, future work could also explore the use of trip diaries from more comprehensive multi-modal travel demand models, which estimate pedestrian travel demand based on complete daily tours.

Outputs

Whitepaper: Andres Sevtsuk, et al, "Walkability and Pedestrian Conditions in Beirut: A Background Study," MIT + AUB, 2023. https://www.dropbox.com/s/qnfiv5t4b0ms15g/Walkability%20and%20Pedestrian%20Experience%20in%20Beirut_V8.pdf?dl=0.

Participatory design workshop at the American University of Beirut

Article (in review with JAPA): Andres Sevtsuk, et al, "Improving Walkability in Beirut: An Approach Using Pedestrian Modeling, Participatory Design, and Scenario Analysis," *Journal of the American Planning Association*, 2024.

Project Website: "Beirut Community Streets." City Form Lab, 2023. http://cityform.mit.edu/projects/beirut-community-streets.

Exhibition Video, 2023 Venice Architecture Biennale: City Form Lab. "Beirut Community Streets." *Vimeo*, August 4, 2023. https://vimeo.com/826265967.

Exhibition catalog, 2023 Venice Architecture Biennale: City Form Lab. "Beirut Community Streets." 2023. http://media.voog.com/0000/0036/2451/files/BeirutCommunityStreets_catalog_Venice2023.pdf.

Figure 9. *Outtakes from participatory design workshop held on Community Streets initiative at AUB in 2022. [Source: Andres Sevtsuk, Community Streets, 2023.]*

Broader Impacts

- Pilot implementation of Community Street interventions and programs as part of temporary or short-term projects will produce real, practical benefits to nearby communities, particularly their most vulnerable members, bolstering on-street activity, and buoying the businesses that rely on them
- The project model serves as a valuable tool for cities, offering a framework for estimating how built environment improvements could increase pedestrian mobility
- Project findings offer a more transparent and focused pathway to decarbonizing urban transportation and assist decision-makers in weighing various implementation options by developing cost-benefit metrics for consideration
- Model predictions can guide land use and zoning changes to attract new businesses to areas where anticipated foot-traffic is expected to grow due to urban design interventions or highlight the social and economic benefits of improving accessibility for currently isolated neighborhoods
- Such analyses can also prove advantageous for ongoing community projects in neighborhoods throughout the U.S. that similarly suffer from historic highway-building and are currently prioritized for Department of Transportation funding by the Biden administration

Endnotes

1 IBI Group & TEAM International (2009). “Study for the Revitalization of the Public and Freight Transport Industry in Lebanon. Report Submitted to the Ministry of Public Works and Transport, Lebanon.”

2 Chalak, A., Al-Naghi, H., Irani, A., & Abou-Zeid, M. (2016). “Commuters’ behavior towards upgraded bus services in Greater Beirut: Implications for greenhouse gas emissions, social welfare and transport policy.” Transportation Research Part A, 88, 265-285.

3 Harb, M., Kassem, A., & Najdi, W. (2019). “Entrepreneurial Refugees and the City: Brief Encounters in Beirut.” *Journal of Refugee Studies*, *32*(1), 23–41. https://doi.org/10.1093/jrs/fey003.

4 Beirut Demography (2023). Db-City.Com. https://en.db-city.com/Lebanon--Beirut

5 UN Habitat & Relief Centre (2020). *Hamra Neighborhood Profile*. https://unhabitat.org/sites/default/files/2020/11/hamraneighbourhoodprofilebeirutlebanonoct2020_0_1.pdf.

6 Cervero, R., & Kockelman, K. (1997). “Travel demand and the 3Ds: Density, diversity, and design.” *Transportation Research Part D: Transport and Environment*, *2*(3), 199–219. https://doi.org/https://doi.org/10.1016/S1361-9209(97)00009-6.

7 Larrañaga, A. M., Rizzi, L. I., Arellana, J., Strambi, O., & Cybis, H. B. (2014). “The influence of built environment and travel attitudes on walking: A case study of Porto Alegre, Brazil.” International Journal of Sustainable Transportation, 10(4), 332–342. https://doi.org/10.1080/15568318.2014.933986.

8 Marrouch, W., & Mourad, J. (2019). “Effect of gasoline prices on car fuel efficiency: Evidence from Lebanon.” *Energy Policy*, *135*, 111001. https://doi.org/10.1016/j.enpol.2019.111001.

9 Madani, M., Abunnasr, Y., Hazimeh, R., Sibai, A., & Kharroubi, S. “Pedestrian safety and struggles with older adults’ accessibility: evaluating pedestrian infrastructure.” Working paper, American University of Beirut.

10 Al Otary, L., Abou-Zeid, M. & Kaysi, I. (2022). “Modeling car ownership and use in a developing country context with informal public transportation.” Transportation, 49(4), 1-36.

11 Sevtsuk, A. (2021). “Estimating pedestrian flows on street networks: revisiting the betweenness index.” Journal of the American Planning Association, 87(4), 512–526. https://doi.org/10.1080/01944363.2020.1864758.

12 Sevtsuk, A., Basu, R., & Chancey, B. (2021). “We shape our buildings, but do they then shape us? A longitudinal analysis of pedestrian flows and development activity in Melbourne.” PLOS ONE. https://doi.org/10.1371/journal.pone.0257534.

13 Huff, D. (1963). “A Probabilistic Analysis of Shopping Center Trade Areas.” *Land Economics*, *Vol. 39*(No. 1), 81–90.

14 Sevtsuk, A., & Kalvo, R. (2021). “Predicting pedestrian flow along city streets: A comparison of route choice estimation approaches in downtown San Francisco.” *International Journal of Sustainable Transportation*. https://doi.org/10.1080/15568318.2020.1858377.

15 If the same one bus stop is 600 m away (200 m from the plateau), then pedestrian accessibility to bus stops from the said origin equals (1/e^(200*0.001))*0.5=0.409. In this case, 40.9% of the origin weight or 4.1 trips are generated to the bus stop.

16 Basu, R., & Sevtsuk, A. (2022). “How do street attributes affect willingness-to-walk? City-wide pedestrian route choice analysis using big data from Boston and San Francisco.” *Transportation Research A*, *163*, 1–19. https://doi.org/10.1016/j.tra.2022.06.007

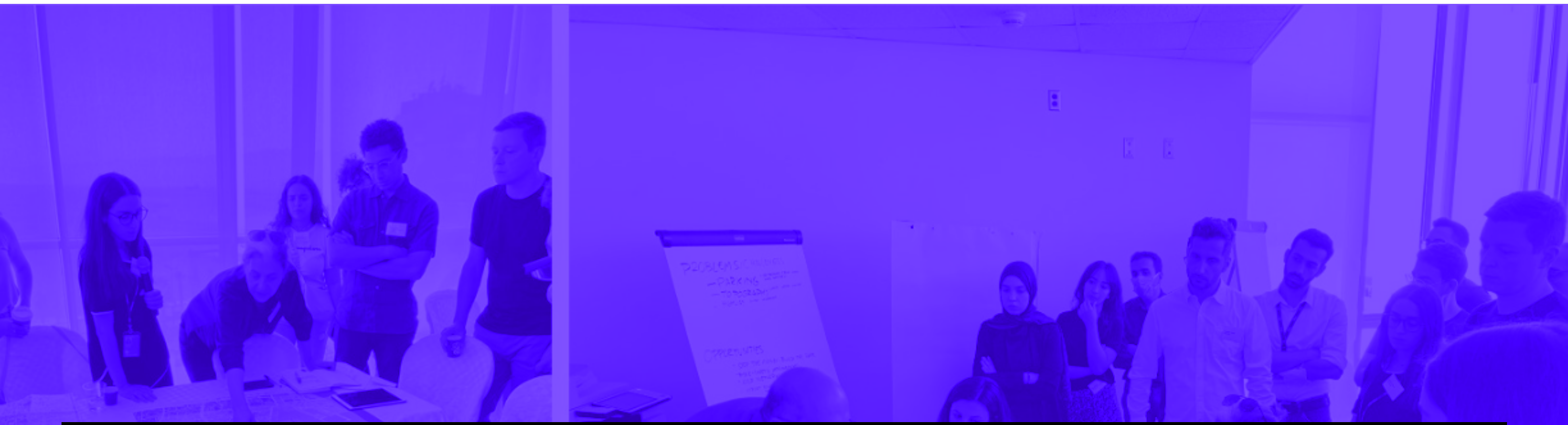
17 Bongiorno, C., Zhou, Y., Kryven, M., Theurel, D., Rizzo, A., Santi, P., Tenenbaum, J., & Ratti, C. (2021). “Vector-based pedestrian navigation in cities.” *Nature Computational Science*, *1*(10), 678–685. https://doi.org/10.1038/s43588-021-00130-y

18 The parks have been closed since the start of COVID-19, officially due to public health transmission concerns. In reality, a large presence of Syrian refugees in the parks at the outset of the pandemic, and populist sentiment about their poor behavior in the parks, has been a key reason for keeping Beirut’s parks locked.

19 Clifton, K. J., Singleton, P. A., Muhs, C. D., and Schneider, R. J. (2016a) “Development of pedestrian choice models for pedestrian travel,” Transportation Research Part A, 94, 255-265.

20 Clifton, K. J., Singleton, P. A., Muhs, C. D., and Schneider, R. J. (2016b) “Representing pedestrian activity in travel demand models: Framework and application,” Journal of Transport Geography, 52, 111-122.

DAR URBAN RESEARCH SEED FUND REPORT 05

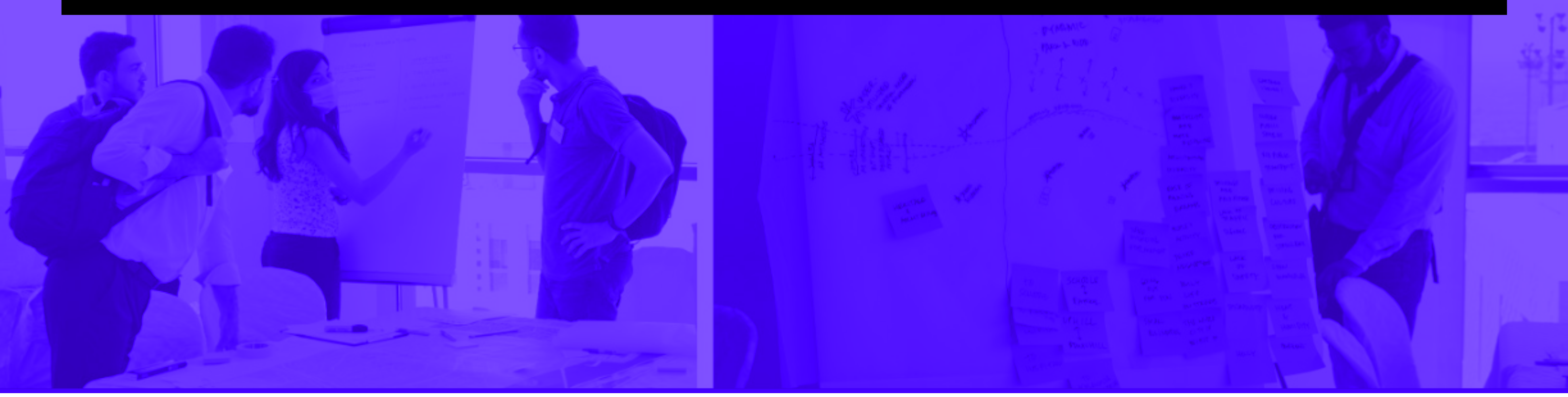


MIT School of Architecture + Planning
sap.mit.edu

At the MIT School of Architecture and Planning (SA+P), we believe that humanity's toughest problems occupy the same ground as their solutions: the space between people and their environment. This is our territory. From the day MIT opened its doors and introduced Course 4 as the nation's first academic program in architecture, our faculty, students, and alumni have explored the human landscape to discover—and deliver—better futures.

MIT Norman B. Leventhal Center for Advanced Urbanism
lcau.mit.edu

Urban environments constitute one of the most complex societal challenges of today's world. The LCAU seeks to drive collaborative, interdisciplinary research focused on the design and planning of large-scale, complex, future metropolitan environments, to advance urban scholarship and practice that makes cities more equitable, sustainable, and resilient by design.



LCAU NORMAN B. LEVENTHAL CENTER FOR ADVANCED URBANISM