Article

“Unparking”: How Can Smart Mobility Reduce Parking Demand in Our Cities to the Minimum? (Beirut Case Study)

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Abstract: Beirut is a car-dependent city, with 80% of Beirut citizens using their private cars to move across the city (the rate of car ownership is higher than regional and global benchmarks: 627 cars/1000 in Beirut, 550/1000 in Dubai and 170/1000 in Singapore). This reality causes two related impacts: an increased parking demand and decreased public transportation usage. Furthermore, in order to discuss these aspects, our study addresses the following question: How can the municipality’s interventions and mobility system reforms, such as smart public transportation systems and shareable mobility, reduce parking demand? As our methodology, it consists of three sections: (1) determine Beirut’s parking problems by estimating parking demand and supply; (2) assess the potential effects of Beirut municipality policies in comparison to international experiences; and (3) evaluate the potential impacts of the smart public transportation system and shareable mobility in reducing parking demand. This paper studies parking growth in developing countries, such as Lebanon, and can help planners, decision-makers, and the Beirut municipality to make more informed decisions about parking policies, and to meet growing parking demand by introducing smart interventions that have high local potentials.

Keywords: unparking; parking demand; parking supply; parking management; parking policies; smart mobility; smart public transportation; shareable mobility

1. Introduction

Jane Jacobs said in her significant book *Dark Age Ahead* “Not TV or illegal drugs, but the automobile has been the chief destroyer of American communities” [1]. This sociologist’s perception clarifies the severe impact that cars have on human life in cities, and the fact that cars take up more space than people, especially in public areas. Streets, public squares, parks, and other spaces all become parking spaces, which prompts municipalities to adopt parking policies. At first, parking spaces are merely expanded to meet increasing parking demand and to attract more and more cars. However, contemporary parking policies intend to reduce private car trips, mitigate air pollution, and improve city life. For example, on the one hand, several European cities, such as Copenhagen, have an annual reduction in the number of parking spots in order to motivate people to use soft and sharable mobility. On the other hand, many cities, in particular in Southern European countries, are still preserving, if not increasing, their parking lots.

Parking is the subject of deep research and urban studies around the world—including in America, Europe, and Singapore. From these works of literature, we present interesting approaches such as *The High Cost of Free Parking* by Donald Shoup in 2005 [2]. It deals with the costs of free parking policies on society, and it is structured as a criticism of how parking is planned and regulated, especially in relation to the use of parking minimums and off-street parking requirements. In his book, Shoup showed the

impact of parking policies on city life and determined the main problem of parking in America: 99% of parking is free. Additionally, he recommended three parking reforms: (1) remove off-street parking requirements, (2) charge the right prices for on-street parking, and (3) spend the meter revenue on improving public services in the metered streets. Another book, *Parking, An International Perspective*, edited by a group of writers (Dorino Pojani, Jonathan Corcoran, Neil Sipe, Iderlina Mateo-Balbiano, and Dominic Stead) and published in 2019, takes a planetary view of parking policies in 12 cities across five continents: Auckland, Bangkok, Doha, Los Angeles, Melbourne, Nairobi, Rotterdam, Santiago, Sao Paulo, Shenzhen, Singapore, and Tokyo [3]. The discussion of parking is placed in the context of transport, mobility, land-use, society, technology, and planning in each of these cities. Besides, "Unparking" is a research project that aims to explore and understand a city's real need for parking spaces to reclaim land from cars with smart enabling tools such as Smart Public Transportation System, Soft Mobility, Smart Parking, and Shareable Mobility [4].

Indeed, we extend the unparking analysis started by MIT Senseable City Lab to our cities that suffer from the common urban challenge of high parking demand in order to discuss how smart public transportation and shareable mobility can reduce high parking demand in car-dependent cities, such as Beirut. To achieve this, this paper will conduct three principal phases: (1) determine parking problems in Beirut Municipal boundaries by estimating parking demand and supply (paid parking spaces); (2) assessing the potential effects of Beirut municipality policies, such as the building of multi-story parking buildings, providing parking meters, and others, in comparison to international experiences; and (3) evaluating the potential effects of the smart public transportation system (informal model) and shareable mobility modes such as Carpolo, Uber, and Careem in reducing parking demand.

2. Methods

The number of parking spots and lots in Beirut is obtained; these are data that the municipality has not had until today because it is hard to gather a comprehensive list of spots, not only the ones on the streets, but also those in garages and on private land. This study extracts and collects data from satellite maps, the UTDP report (Urban Transport Development Project), the World Bank report, and geospatial maps (Google Maps) to generate inventories of parking lots and street parking structures. It enables us to understand how parking works in Beirut, the types, and how widespread it is.

First of all, we need to understand the types of parking that exist in cities today. There are four types of places that we can park a car:

1. On-street (paid or free): a parking space on the street.
2. Public off-street (Parking lots): a car park not on the street, in which any citizen can park their car, subject to complying with any regulations (maximum stay, or paying a fee).
3. Private nonresidential off-street: car parking dedicated to a particular building, such as a shopping center or an office building.
4. Private residential parking: a parking space in the garages of houses or flats. Only the residents of these houses or flats should be able to use the parking.

After reviewing these parking types, the subsequent analysis will focus on public parking and is limited to two types of paid parking in Beirut: on-street parking (metered parking) and public off-street parking (parking lots). As it is hard to obtain an estimate of the number of parking spaces in garages, multi-story parking undergrounds, and others, there is no data. Besides, we created two different methods in order to estimate parking demand and supply, which includes paid and free parking spaces: (1) estimating the parking lot footprint and on-street paid parking across Beirut Municipal boundaries (paid parking supply); and (2) estimating parking demand based on population, car ownership and the number of cars entering Beirut per day.

2.1. Parking Supply Inventory

In the first method, to estimate the parking lot footprint, we used 27 high-resolution aerial photographs (orthophotos), extracted from Google Earth Pro 2020, and continued to combine these maps via Autocad (Autodesk software) in order to prepare the Beirut master plan. Further, these parking lots were digitized (Figure 1) to estimate the number of parking spots and areas. As for metered parking (park meters), we used World Bank data (map of park meters implemented on Beirut streets) to determine their location, and we finally present all the results in one map (Figure 2) [5].

Figure 1. Digitizing parking lots in Beirut city (white outline), based on high-resolution aerial photographs (orthophotos) extracted from Google Earth Pro 2020.

Figure 2. Mapping paid parking spots (parking lots footprint and metered parking) in Beirut City, Lebanon.

The parking supply is the sum of on-street (metered parking) and off-street parking (parking lots) available to the public. Besides, parking provided by private institutions or privately (underground facilities or garages) owned by residents is not considered in the parking deficit estimation because it is very challenging to estimating the global provision of parking spaces both on-street and inside the apartment blocks. However, there is no data to quantify the global parking supply in business premises. The previous map (Figure 2) presents the distribution of parking lots and metered parking (paid parking) in Beirut, which seems rather sparse and has many significant roads not accounted for in relation to parking. The greatest parking lot concentrations were around urban centers, like the BCD (Beirut Central District) and context, Hamra and Achrafieh, where communities show high parking demands. Beirut has 460 parking lots (according to Shoup, parking lots are not a public good and is the worst use of land in cities), occupied 1.037 km square, and 937 park meters concentrated in commercial neighborhoods such as Hamra and the BCD. For parking lots, the total area is calculated from satellite images, and then the number of spaces is calculated by dividing this area by an assumed average size of a parking space (25m^2 for each parking space). As a result of previous research in France, a parking space in a parking lot is equivalent to 25 m^2 , taking into account access ways and maneuver areas [6]. This ratio was confirmed in Beirut by the researcher's work on several samples of parking lots with different patterns. Additionally, to calculate the number of parking spots existing on all parking lots, we use this equation:

Number of parking spots in parking lots = Total area of parking lots/area of one parking space in a parking lot = $1,037,251.93\text{ m}^2/25\text{ m}^2 = 41,490$ parking spots.

As for on-street paid parking, the UTDP report in 2013 has confirmed that the number of parking spots covered by 937 units of park meters is 7500 spots [7]. As a result of our work, each on-street parking space (one parking spot) occupies 12.96 m^2 of street space ($2.4\text{ m} \times 5.4\text{ m}$). We combine these data to calculate the area occupied by metered parking in Beirut through this equation:

Area of metered parking in Beirut = Number of parking spots $\times$ area of each on-street parking space = $7500\text{ spots} \times 12.96\text{ m}^2 = 97,200\text{ m}^2$. Thus, the total area of estimated paid parking is the sum of metered parking area ($97,200\text{ m}^2$) and parking lot area ($1,037,251.93\text{ m}^2$) = $1,134,451.93\text{ m}^2 = 1.13\text{ km}^2$.

In Table 1, we collect all data and results from previous calculations to present the total estimate number and revenues of two paid parking types; parking lots and on-street metered parking.

Table 1. Estimated number and cost of paid parking spots in Beirut City. (Source: Personal collection based on extracted data). Note: A parking spot is a space needed to park one car.

	Number	Number of parking spots	Cost of one parking spot LBP/day	Total revenue LBP/day
Parking lots	460 lots	Around 41,490 spots	3000 L.L–7000 L.L [8] Average 5000 L.L	208 million LBP (139,000 \$/day)
Park meters	937 units [7]	7500 spots [7]	8000 L.L [7] (5.34 \$)	60 million LBP (40,000 \$/day)
Total	-	48,990 spots	6500 L.L	268 million LBP (179,000 \$/day)

2.2. Parking Demand Estimation

In the second method, “Unparking” propose a data-driven methodology for estimating commuter parking needs by focusing on home-work commuting, i.e., the most daily trips. Private cars are stationary 95% of the time; a single car usually occupies two parking spots: one at home and another at work [4]. In this work, we estimate the number of parking spaces needed (parking demand) in Beirut depending on two simulated scenarios (Sc) for commuting (N_p is the number of parking spaces needed for each car):

- (1) No sharing, each person uses a private car and has a private reserved parking space at their home and work location. In this case, a car needs two parking spots ($N_p = 2$ parking spots/car) [4].

- (2) Private cars, shared parking—in this scenario all parking is shared, with people taking the closest available spot to their destination at the end of each trip. In this case, $1 \leq N_p \leq 2$, depending on the number of shared parking spaces in the city (especially on-street parking) [4].

We note that currently, most cities have a mix of scenarios: Sc.1 and Sc.2. On-street parking typically contributes to Sc.2, while most larger employers who provide on-site parking contribute to Sc.1, i.e., their garages are not utilized in any manner beside employee parking [4]. Furthermore, many car owners prefer to have their designated spot at home if they can afford it (either a private garage, driveway or reserved space in a parking lot or garage), which is then left unused during the day, or underused but guarantees convenient parking when they arrive home in the evening. While our current work only assumes commuting between work and home, and thus the number of parking spaces per car is maximum two, in other cities the number of total available parking per car can be as high as 3.3 [4]. However, in Beirut, the results of estimation based on Sc.1 show that the number of parking spaces needed per car is two (inside Beirut) $\leq N_p \leq 3.2$ (adding the cars coming from outside Beirut). As for Sc.2, there are no data about the number of shared parking spaces daily, therefore it not possible to calculate the number of parking spaces needed in Sc.2, where results will be less than 2 parking spaces/car. In order to obtain numerical results more realistic in the Beirut case, we estimate the parking demand based on Sc.1 (Private cars, No sharing parking) by using the following equation:

Parking demand from inside Beirut (spots) = Number of private cars $\times$ 2 (cars use two parking spots daily, one at home and another at work) = $257,070 \times 2 = 514,140$ spots (It seems reasonable to suppose that all private cars move daily to estimate the maximum parking demand inside Beirut city according to previous scenarios).

As for the car fleet entering Beirut daily, a study by the IPT Energy Center and UNDP claim that 230,000 passenger cars enter Beirut from the north highway daily, and 85,000 do so from the southern highway [9]. Thus, the total number of cars is 315,000 cars. In Table 2, we combine collected data and calculations to estimate the total parking demand in Beirut's municipal boundaries.

Table 2. Parking demand in Beirut's municipal boundaries. (Source: Personal collection based on the 2013 UDTP rapport). Note: A parking spot is the space needed to park one car.

	Beirut municipal city-boundaries	Cars coming from outside municipal boundaries per day
Number of private cars	627 cars/1000 person [10] 257,070 cars/410,000 Beirut citizens [7]	315,000 cars [9]
Number of parking demand (spots)	514,140 spots	315,000 spots (One parking spot needed at the destination for each car comes from outside Beirut)
Number of parking demand (spots) in Beirut's municipal boundaries	514,140 + 315,000 = 829,140 parking spots/day Served by parking lots, garage and on-street parking.	

2.3. Discussion

The results of the previous urban analysis highlight the following points:

1. Parking lots currently occupy 5.75% of the land in Beirut, at 1 km² in area (2.44 m of parking space per person). This is more than green spaces, which is limited to 0.328 km² (Beirut has 0.8 m of green space per person when the minimum number should be 9 m per person, according to the World Health Organization (WHO)) [11]. The parking space in Beirut is three times more than green space. However, the total land area occupied by parking can be drastically higher, with this estimated area (1 km²) only a minimum, and is also an attempt to give estimates of the exact numbers.

2. The estimated total revenue from parking lots and metered parking per day is 268 million LBP/day (\$179,000/day), however, Beirut does not benefit from these revenues despite parking impacts on the city's economy, life, and environment.
3. The estimated number of paid parking spots in Beirut is 48,990 spots, while parking demand is 829,140 parking spots (17-fold difference). These results were compared to determine Beirut's parking problems—high parking demand, with 94.1% of parking spaces served by free on-street spaces, in garages, and multi-story facilities (Shoup discussed, in 2005, the same case of American cities, where 99% of parking is free). Besides, if we focus on home-work commuting, the lack of underground parking facilities in most residential buildings in Beirut prompted residents to use on-street parking at home. Even at work, there are many options to park: paid parking lots (41,490 spots), metered parking in the specific districts (7500 spots), free on-street parking or limited free underground parking provided by employers, which means that the majority of parking is on the streets and is free. On the other hand, not all cars might have a dedicated parking space close to work; some might use on-street parking that is used by other cars at night. Even with these considerations, the number of 2 parking spaces/car seems low; this measure is between 2 and 3.3 in other cities, for example, Singapore has 2 parking spaces/car [4]. Adding the cars coming from outside Beirut results in a ratio of 3.2 parking spaces/car, which seems more reasonable. We acknowledge these uncertainties, understanding that having an accurate estimate of parking supply and demand is very challenging, especially in third world countries.
4. 94.1% of parking needs covered by other types of paid parking are privately owned such as: Parking garages provided by private developers in commercial centers and malls and others; for example, in Beirut, there are three malls with a capacity of 5400 paid parking spaces, split respectively, 2500 spots at Beirut Souks in BCD [12], 1700 spots at ABC Verdun and 1200 spots at ABC Achrafieh [13]. As for other free types, there are free parking spaces provided by a limited number of firms for their employees in Hamra district for example, while Beirut does not have free underground parking for the public. Furthermore, many shop owners reserve a free on-street parking space for their clients, which reduces parking sharing on Beirut streets.
5. Table 2 illustrates that two factors produce parking problems in Beirut: high usage and the ownership of private cars (it increased from 424/1000 people in 2012 to 627/1000 in 2018) [7,10], and the increased number of cars entering Beirut per day from outside (315,000 cars per day at the very least, which is equal to 38% of parking demand).

3. Potential Effect of Beirut's Municipality Policies

In Beirut today, for most decision-makers, a discussion of parking policy only focuses on how to make parking more available and accessible. Beirut municipality does not have a clear vision or plan to confront high parking demand challenges, and it continually resorts to expanding parking spaces as a response to the citizen's needs for parking spaces. While Shoup recommended that policymakers should reduce demand through parking policies that lead people to pay for parking, he explained, in 2005, the high cost of free parking on city life and experiences in an in-depth discussion of the socio-economic impact. Several American and European cities, like Copenhagen, tested Shoup's policy recommendations, such as making on-street parking paid and more expensive to reduce parking demand and private car usage. Based on the previous estimates, the majority of parking spaces are free, and they are not managed to respond to high parking demand, which is 829,140 spots/day; this is caused by two factors: car usage (high rate of car ownership 627/1000) and the fleet of cars entering Beirut every day. Moreover, Beirut municipality proposed to expand parking spaces by building multi-story facilities that will be located in the city center (Ras Beirut, Achrafieh, and Mazraa), and in many residential areas, where shops at the ground level will be introduced, thus naturally attracting more cars. This plan was in lieu of making a strategic plan to replace car use with public transport, by pushing parking buildings to peripheral locations where people leave their cars at the entrance of the capital and enter with public transport.

Parking policies are more effective in the digital era. There is more of a capacity to control and manage parking spaces on-street, to charge free parking and to calibrate it, based on demand sensitivities. In Beirut, for example, on-street parking is governed, not by the municipality, but by a private company that collects significant revenues from cars parked in on-street parking without justification or interest given to the Beirut municipality. Indeed, this company invests public spaces (streets) for its benefits. Conversely, Shoup recommends spending meter revenue on improving public services in the district where they are located in order to make it more acceptable to residents and shop owners, for example, in Barcelona, where 100% of revenue goes to operating the public-bike system. Additionally, at the same time, local governments in London use their parking fees to provide free transit passes for seniors and the disabled [14]. Locally, we need to charge free on-street parking, but to be acceptable, citizens need to perceive its impact to be enhancing city life. We present, in Table 3, the potential effects of the current municipality's policy in comparison with Shoup's parking policy recommendations.

Table 3. Assessing the potential effect of Beirut's municipality parking policies. (Source: Personal collection).

	Beirut Municipality Parking Policy in 2018	Potential Effect	Shoup's Parking Policy Recommendations [15]
Off-street parking	1. Intend to build 10 parking projects with capacity of 5638 cars (3 building in high parking demand districts Ras Beirut, Achrafieh and Mazraa, and the rest are underground in parks and square) *	1. Increasing paid parking supply by 11.5% to become 54,628 spots, while it is still slight in comparison with parking demand (829,140 spots). 2. Adverse impact on district life where these multi-story buildings and garages will attract more and more cars increasing congestion and pollution, without addressing parking problems.	1. Select the right locations of parking projects at the city entrances can reduce parking demand at the city center by lowering the car fleet entering Beirut daily.
Park meters (on-street paid parking)	1. Implementation of park meters in high parking demand districts like Hamra, BCD, and Achrafieh. 2. Fixed pricing on all metered parking regardless of high parking demand in districts like Hamra (1000L./1hr or 0.66\$/1hr)	1. Good selection for locations but is limited where many major roads not accounted for. 2. Park meters in Beirut are operated and managed by a private company that benefits from significant revenues (40,000\$/day) while Beirut's municipality and districts do not benefit from it. 3. Make metered parking with more competitive spaces in peak hours.	1. Add more park meters and charge free on-street parking because it is available to drivers on a "first-come, first-served" basis, where free parking suffers the problem of communal ownership. 2. Spend the meter revenue on improving public services on the metered streets (parking benefits districts and helps make metered parking more palatable to curbside shop owners and residents). 3. A public-private partnership allows for on-street parking to be managed more efficiently by using smart systems for monitoring and controlling. 4. Charge the right prices for on-street parking, and calibrate it based on demand sensitivities (charge more for parking spaces in high demand districts such as Hamra).

* Khoury, M. Beirut Municipal Council progress report, 2018; pp. 21–27.

In Beirut, the municipality and national decision-makers focus on the cars when they are moving (expand roads) and when they are standing (more parking spaces). In contrast, they should focus on the human movement "Walkability". In relation to this, Beirut does not have a good walkable experience; its streets are insecure, do not have sidewalks, and when they exist, they are occupied

by parked cars. Improving walkability in Beirut can reduce parking needs, and vice versa; therefore, parking spaces would be reduced. Additionally, focusing on sustainable solutions, such as walkability for short distances, and smart public transportation for moving through the city, changes the daily urban experiences of citizens.

Indeed, Beirut needs to reduce parking demand, and public policies should address this problem through parking reform, based on international experiences, such as the fact that several European cities have shifted from private car trips to a new model of soft and shareable mobility. Some local initiatives and experiences prove the high potential for reducing car usage, and thus decreasing parking demand, such as informal public transportation and shareable mobility. However, Beirut municipality excludes these known and tested policies and resorts to traditional solutions that have proven fail and deficit based on the previous analysis. In contrast, the proposed policies can achieve broader socio-economic goals.

4. Public Transportation Potentials

4.1. Informal Model Potentials

The use of public transportation, thus reducing the number of cars, is the most effective solution, in both developing and developed countries, to make cities more dynamic. However, the ineffectiveness of public management drives people in cities, such as Beirut, to create solutions that meet their needs to move through the city. According to a World Bank study published in 2017, 81% of Lebanese people prefer to use their private cars over vans (11%) and taxicabs (6%) [16]. For a deeper understanding, we will try to answer these questions: Why do Beirut citizens not use public transportation? Additionally, how can we make this transport mode more accessible?

The reality of public transportation in Beirut has been the subject of many previous studies; however, this research will focus on the real potential and opportunities that can be developed in the public system to replace private car usage. In Beirut, like many cities, there are two models of the public transport system: formal and informal. The formal model exists in most developed cities where a government or a private entity operates and manages the flow of public vehicles on all streets. While in developing cities, the informal model is more effective and popular, with many versions of it across the world that meet citizens' needs to move, such as small buses, three-wheelers, or motorcycles. They are known by different names: rickshaws in India, tuk-tuks in Iraq and Egypt, matatus in Kenya, and "vans" in Beirut. According to Chadi Farraj, co-founder of the Bus Map Project, "Van 4 operates wherever there is demand, is organic, and makes the best use of what exists. There is no schedule or bus stop in the informal system, and it does not have a unified operator but rather a series of individual operators" [17].

The lack of public service prompted the private sector and citizens to find adequate alternatives, such as a self-management system to provide most public services in parallel with government services. To profit from informal model capabilities in the sector of transportation, Beirut needs a smart public transportation system that is based on public-private partnership (PPP) to develop the formal model and to integrate the informal models that exist through a smart management system that is more responsive.

The Lebanese collective perception does not have a clear plan of how the informal system of buses and vans work. Additionally, this drives two initiatives, the Bus Map Project and YallaBus, which map out the bus lines in Beirut and make this information more available and clear for all citizens. Most people do not know the paths, tracks, and bus destinations, and because of that, they perceive it as insecure. This system started and was developed in 1995, with 22 bus lines running within the Greater Beirut Area [17]. These lines are used by the informal system, which has two types of vehicles running: buses (24 seaters) and vans (12 seaters). The second type, "vans", is proving to be more successful than buses for many reasons, despite their bad condition, according to their operators, they go faster in Beirut's narrow streets, fill up quicker, and can make more trips in less time with competitive prices of

1000 L.L. (0.66\$) per ride anywhere in Beirut. Some lines have more demand than others; for example, line number 4 is a high-demand route that connects the city center BCD to its southern suburbs, with effective informal management by a group of citizens, thus providing a functional system for the city. According to Smaha and Mohtar, two researchers at the American University of Beirut, “Van 4 demonstrates the potential of a public transportation system as a viable and strong alternative that can limit the use of private transportation in the city” [18].

Commuters need information about trips, times, and costs, which are not available today, due to the absence of a unified management system. Therefore, public transportation needs to start changing the impressions of citizens by making information more available and accessible. Moreover, the experience of “Van number 4” (Figure 3) demonstrates that the integration of the “informality” model into Beirut’s public transportation strategies can replace private car usage and therefore reduce high parking needs in the city center.

Figure 3. The Bus Map in the Greater Beirut Area, prepared by the Yalla Bus Team. (Yalla Bus App).

Table 4 illustrates the potential effect of the informal public transportation model (Van 4) on reducing the number of vehicles needed to commute 1000 persons; instead of using 627 cars in the Beirut case, the commuters need only 42 buses or 84 vans to reach their destinations.

The informal public transportation model has dynamic capabilities and real opportunities to reduce parking demand and car usage in Beirut. It provides an alternative transport mode, which needs improvement, to replace the car fleet moving through the city. Additionally, Table 4 shows the potential effect of using this model on reducing parking demand—627 spots every time 1000 people shift from private car usage to public transportation. Besides, it connects Beirut to its southern suburbs, which can reduce the number of cars entering Beirut daily from southern entrances.

Table 4. The potential effect of the informal public transportation model on reducing parking demand in Beirut. (Source: Personal collection).

Usage	Number of vehicles needed to commute 1000 persons in Beirut	Parking Demand per 1000 persons in Beirut	Experience of Van 4
Private cars	627 cars used for most trips across the city (627/1000)	627 parking spots (one spot for each car at destination)	-
Bus (24 seaters)	42 buses in case of a one-way trip 21 buses in case of round trip	0	225 vehicles (7 buses + 218 vans)
Van (12 seaters)	84 vans in case of a one-way trip 42 vans in case of round trip	0	commute 56,250 passengers per day [18]

4.2. Smart Public Transportation System

Beirut citizens and decision-makers need to change the way they think about their city, with more attention paid to smart and sustainable solutions and the capabilities of the smart system. Today, new technologies have more real opportunities and innovative solutions that are specific to developing countries; it can improve the public transportation system through a smart system that operates and manages the existing models. According to Carlo Ratti at Massachusetts Institute of Technology (MIT), “Senseable City lab shows that tomorrow’s urban problems regarding mobility can be tackled not necessarily with more physical infrastructure but with more intelligence” [19].

Many entities contribute to managing the public transportation sector, and therefore, their performance varies from region to region where some alternatives have proven to be effective over time. This reality shows that Beirut’s public transport needs a unified smart management system based on public-private partnership, leveraging advanced information technology capabilities in order to make our city dynamic and livable.

Smart public transportation is a new form of mobility that can help municipalities, especially in developing countries, to make a city in move with fewer vehicles. This system uses sensors, GPS, and ICT (Information Communication Technologies) to connect commuters and buses with real-time information that enables citizens to access any public transport mode. Smart systems can optimize and automate the flows of vehicles, and make people informed about route information with several digital platforms (mobile applications, timetable, etc.). To implement a Smart Public Transportation system in developing cities such as Beirut, we first need to understand the existing system that works today, how it has succeeded, and where it failed. Then, the available data should be read to optimize system functionality, and light technology integration should be continued to improve and manage the formal and informal models, and finally, a unified smart system should be created to manage and operate the whole of the public mobility sector.

A mid-sized European city has adopted this strategy to develop the public transport sector through a smart management system (smart governance), based on data and information that does not require infrastructure development. Belfort, a French city, relied on the smart management of existing resources as a way to achieve more efficiency in only four weeks through two principles [20]:

1. Reading existing big data in a new way to improve transport services. Data and information is a new resource of the digital era; it enables operators to make more balanced decisions. For example, Belfort uses collected data from ticketing and GPSs to monitor the public vehicles’ flow, congestion, and bus stops.
2. Optimize the structure of the public transport system, how buses run, instead of introducing new technologies. Belfort redeployed buses from their low-demand line to those that experience increased demand.

Beirut has had a sufficient experience of informal systems like “Van 4”, which responds to citizens’ needs from many education levels, ages, gender, and backgrounds. However, this system still needs a smart management center to develop the whole system in the city, based on real-time information.

YallaBus, a new startup in Beirut, has a methodology based on a combination of GPS and sensors to motivate and help people utilize public transportation for traveling. The user is provided with real-time information that makes the public transportation system more accessible. This initiative is developed by university students seeking to change the reality of public transportation, with new and smarter methodologies, and to facilitate the use of public buses by encouraging all possible information on these buses and putting some order in the schedules. It cannot change the whole system, but it can change collective perception and make public transportation more accessible. It can be expanded to cover "Taxi-Service" by legalizing drivers who use personal cars to provide services via ride-hailing mobile apps.

Many successful case studies, in which startup technologies manage informal transport, such as "Angkot" in Bandung (Indonesia) operated via "KIRI" application, are more responsive to citizens' needs anywhere and anytime [21]. Developing and organizing informal public transport, rather than replacing it, is a real opportunity for Beirut city; it is a socio-economic system. However, it is not replicable in other regions and neighborhoods, due to the political and sectarian affiliations of operators (for example, the bosses of "Van 4" are affiliated to the Shiite sector and its parties). For that, a unified smart system can integrate and replicate this successful experience and manage the whole mobility system in Beirut, without changing existing economic and social structures.

American and European cities use advanced technology to make their cities smarter and more responsive to their context, environment, and residents. However, in developed countries, cities can use the collective knowledge and capabilities of their citizens to make them more responsive to their needs.

5. Shareable Mobility Potential Effect

Today, car sharing is more popular and accepted, with many new operators like Carpolo, Uber, and Careem pushing into the Lebanese market. Organized shared cars will have a crucial impact on changing the face of the mobility system. Indeed, reducing the number of vehicles on the road will require people to replace their cars with a pure sharing model. Locally, Carpolo is a new technology, that as a startup, launched in 2015 by a Lebanese entrepreneur within the cooperation of the Beirut Digital District (BDD) [22]. It is the first sharing system created in Lebanon, whose primary objective is to provide an alternative transport mode for students to reduce congestion and air pollution.

According to Mohammad Nabaa, the founder of the application, "Carpolo is a smart carpooling platform with a gamified points reward system and analytics tools to promote carpooling for communities" [23]. Carpooling needs social acceptance to spread, while international experience shows that it succeeds in European cities, where society has a culture of "sharing". The veer is still ineffective and less widespread in American cities for several reasons, including social-cultural and security factors. Additionally, this is the main obstacle and challenge facing this project in entering Mediterranean societies, such as Lebanese, which are socially specific. For this, Carpolo went to selective users, friends, colleagues, and students (people who are a part of their community) to share a ride in order to reach their universities and workplaces, and this makes sharing more acceptable in Arab societies where people require trust to use it. Additionally, it currently has more than 7000 users from the public community. According to Nabaa, by using at least 3% to 5% of carpool trips, traffic could be reduced by 3% to 5%, or 6000 cars per day [24]. This shareable model has the potential effect of decreasing parking demand in Beirut by 6000 spots per day by using local shareable mobility. Beirut municipality intends to build car parks and buildings to expand parking spaces with a capacity of 5638 cars (less than 6000 cars), and that is proving to be the difference between the two interventions. The main gain, in the first case, is that one car can potentially complete more than two trips per day, depending on the number of persons sharing the same vehicle.

The local shareable mobility models provide more options for citizens to move by sharing a ride instead of owning a car; moreover, they have a different impact on reducing parking demand for many reasons: ride cost, sharing system, and social acceptance. For example, Carpolo is a free app

(community-based sharing) where people can share a ride with friends and colleagues, by using their private cars, while Carpolo helps link ride seekers with drivers who are going to the same place. It is more acceptable and efficient in Beirut and the suburbs than Uber and Careem, which allows driver requests. They may only serve specific segments of society—such as the middle and upper classes. Poor individuals are not able to easily access these services, because they typically are slightly pricier, and will still rely on other modes, such as the informal public transportation system to get around [24].

Carpolo is seeking to partner with public and private entities and universities where people within the same network can find and share rides within it. For that, it entered into a CSR partnership with Byblos Bank, as of March 2019, to form a carpooling network that Byblos Bank employees can use to find a ride to any of the bank's branches, or to the headquarters, which houses more than 700 employees [24]. Carpolo needs to replicate this model with local universities and companies, and they are seeking partnerships with organizations looking to cut their urban impact.

The Carpolo system has more potential effects in reducing car usage and parking demand by motivating and helping people share their private car to reach the same destination. It is more effective in daily trips going to work or educational institutes, and it needs more initiatives and partnerships from Beirut municipality and public sectors to change social behavior and collective awareness about the shareable mobility impact on city life. Additionally, more focus should be on home-work commuting as reserved parking at home and work locations take up a massive amount of space in cities.

6. Conclusions

In conclusion, Beirut has a high parking demand, at 829,140 spots/day, with the majority of public parking supply being free. One solution that can make our cities better and more prosperous is to find ways to reduce this demand to the minimum, by adopting parking policies to manage existing spaces, and making more balanced interventions based on data. Besides this, the conventional interventions, such as providing more parking spaces, have proven to fail in responding to high parking demand (proposed parking projects provide only 5638 spots). Moreover, this paper clarifies why this intervention is unable to face high parking demand—it is related to high private car ownership and usage. Beirut municipality should work on two factors: decrease parking demand and on-street parking pricing. Therefore, the municipality and citizens must work together to change social behavior, raise public awareness, and develop effective local alternatives. We recommend some interventions that have real potential locally to reduce parking demand, such as:

1. Beirut municipality should move away from conventional strategies and destructive policies, such as providing abundant parking and making a parking management policy to reduce parking demand, instead of increasing parking supply. Expanding parking supply is not a long-term solution to the parking deficit and congestion problems, it attracts more cars, and mobility problems worsen. Besides, Beirut does not have more empty lots that can provide more parking spaces, which leads to the municipality proposing multi-story buildings for parking. This solution is unable to meet the growing parking demand.
2. Make Beirut city more walkable by decreasing and managing the free on-street parking, and after that, pricing it to optimize the curbside in order to improve the walkable experience, and to reclaim streets as public spaces for people.
3. Change the location of the proposed parking projects, and select another at the entrances of the capital, as part of an integrated public transport plan that targets a public transport share of more than 15% (today 2% of daily motorized trips use public transport according to Lebanese Economic Report 2018). Additionally, set a limit to the increased car ownership by providing efficient alternative transport modes, which make people share rides instead of buying a car to move (car ownership rate in Beirut increased from 424/1000 in 2012 to 627/1000 in 2018).
4. Provide alternatives to private car usage, such as “shareable mobility”, and develop a new smart public transportation system that is attractive and efficient, based on a public-private partnership (PPP), develop a new formal system and integrate the informal one. However, first, starting

from existing models, formal and informal, use it efficiently and intelligently, based on data and information, and change the whole image and perception of public transportation by making data openly available. Based on a previous analysis, this paper proposes two concrete possible intervention points on the mobility system: (1) improving the service along the line connecting Beirut city center to its suburbs, and that a variety of potentials, such as line 4 connecting southern suburbs, and line 2 connecting northern suburbs (38% of parking demand comes from outside Beirut municipal boundaries); (2) improving shareable mobility services and especially Carpolo, which has proven to have high potentials to reduce parking demand (it is free, and a community-based sharing system can reduce daily motorized work-trips by helping link up to ride seekers with drivers who are going to the same place such as friends, colleagues, students, and employees).

5. Develop and launch campaigns to increase awareness of the benefits of public transportation and shareable mobility like Carpolo, which simplify the ride-sharing process and motivate students and employers to leave their private cars at home. This model has more potential and acceptance and can develop through public-private partnerships to shift more daily work-related trips to sharing mode.

Finally, to meet Beirut's urban challenges and to be more responsive to citizens' needs, including parking spaces, Beirut should be a "sensitive city". City sensing helps authorities collect, read, and analyze the urban information to assess and diagnose challenges in a scientific way, enabling planners, developers, and policymakers to innovate appropriate solutions based on data and information. Today, Beirut can learn from parking reforms in other cities, based on data collected and extracted in this paper, to understand the parking reality and to make informed decisions. European and American cities tested several parking policies and have proven efficiency in different urban cases, like the pricing of more for on-street parking based on demand.

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