Journal of Contemporary Urban Affairs

2024, Volume 8, Number 2, pages 364–384

Original scientific paper

Adapting Mobility Infrastructure to the Needs of a Liveable City: The Case of Beirut Street Markets

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ARTICLE INFO:

Article History:
Received: 14 June 2024
Revised: 18 August 2024
Accepted: 15 August 2024
Available online: 5 September 2024

Keywords:
Residential Neighborhood,
Street Markets,
Urban Public Space,
Walkability,
Livable City.

ABSTRACT

Beirut's policies in the last decade or more contributed to the creation of a highly car-dependent city with almost 2 million vehicles dominating the streets and causing high traffic congestion. Yet, Beirut's informal street markets carry the potential for the enhancement of a liveable sustainable city, which previous studies have overlooked. To approach this problem, urban planners need to re-think and restructure the existing street network in Beirut to decrease the distances between the suburbs and the centre of the city. The aim of this research is to formulate a rational system that assigns markets and pedestrian areas to certain streets where cars can have no or limited access. This system adopts a parametric tool based on fuzzy logic which analyzes the current street network and filters out streets that fulfil certain criteria such as parking availability and proximity to public transportation, hence decreasing centrality in the city. This method is applied to both fixed and temporary food markets that are characterized by highly dynamic pedestrian movement. The final results show a series of maps of Beirut with different scenarios identifying streets that fulfil the defined criteria as potential street markets, which can be the blueprint for further analysis of street and transportation planning creating more liveable and sustainable places.

JOURNAL OF CONTEMPORARY URBAN AFFAIRS (2024), ***8***(2), 364–384.
https://doi.org/10.25034/ijcua.2024.v8n2-5

www.ijcua.com

Highlights:	Contribution to the field statement:
- Increasing pedestrian areas in Beirut will enhance the overall livability of the city. - Introducing street markets in selected urban areas will reduce traffic congestion in Beirut. - Proximity to public transportation positively affects the success and footfall of urban street markets. - Restructuring the street network to prioritize walkability will increase social inclusion and community well-being in Beirut.	This research sheds light on urban planning in Arab cities that are often overlooked, especially where public spaces are considered scarce resources. It also induces a philosophical framework of the capability approach that paves the way for studies on walkability in Arab cities.

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How to cite this article:
Askar, Y., & Abdel-Ghani, T. (2024). Adapting Mobility Infrastructure to the Needs of a Liveable City: the Case of Beirut Street Markets. *Journal of Contemporary Urban Affairs*, 8(2), 364–384.
https://doi.org/10.25034/ijcua.2024.v8n2-5

1. Introduction

1.1 Background and Context of Beirut's Urban Challenges

Beirut is Lebanon's densest city with very few unbuilt plots. Additionally, it is a car-oriented city, where transportation is exclusive to private automobiles, hence most of the public space in the city is dedicated to vehicles. This generates a great deal of car pressure on the public space, especially since there is no efficient public transport network in the city. This comes in complete contrast to the city's foundational potential for a walkable city regarding its mixed land-use patterns and compact urban form (Sevtsuk et al., 2024).

Throughout the history of urban development in Beirut, one can notice the urban fabric changes that led to the current urban challenges. The Danger Brothers Masterplan set in 1932 proposed three phases: The first was a multi-nodal development phase that linked Beirut with nearby cities such as Tripoli and Damascus, the second was establishing an East-West major axis and organizing a peripheral road, and that is to clear the old town that was stuck with traffic, and the third phase was defining several areas and separating them according to social classes (Yassin, 2012). By the 1940s, Michel Ecochard's proposal, which is considered to be the most representative of the state's effort, focused on the circulation system through a main road that connected North and South Lebanon, lateral roads that connect East and West Beirut, and terminal roads that penetrate the urban fabric linking to downtown (Barakat, 2004). Modernized planning continued in Beirut till the post-1991 Gulf War which caused major destruction in the city. Rafik Hariri's government attempted to reconstruct and reshape the image of the city, yet it came at the expense of other cities.

1.2 Problem Statement

Beirut, like other developing cities in the Middle East, became the centre of attraction for inhabitants causing rapid urbanization, environmental damage, and the concentration of urban transportation along the main highways. This led to, according to the IBI Group & TEAM International, an estimated 80.6% account for the dominance of vehicles in the streets, approximately 1.7 million vehicles (Hatoum & Barraj, 2023). A 2021 report by UN-Habitat on the city of Beirut stated that policies on the importation of used and new cars and the lack of alternative means of transport, in addition to inadequate infrastructure and high traffic congestion, all contributed to making Beirut a highly car-dependent city. This results in 70% of travel times experiencing delays. On another level, most of the urban blocks in Beirut are considered relatively small, creating more streets than needed, from which, some are insignificant to the mobility network in the city.

1.3 Research Questions

The current networking system illustrates a blurring of boundaries between formal and informal modes of transportation, with increased distances between the suburbs and the centre of the city (Mady, 2021). The street network tends to have a larger number of streets than usual and urban blocks are smaller than urban planners prefer them to be for more compactness and optimal use of land. Furthermore, the policy of centralized administration that the government has been adopting for past decades has added a lot of pressure on the city from non-residents as most of the legal/official documents, personal official paperwork, are requested and done personally in Beirut.

Hence, this article poses two important questions:

- How can the restructuring of street networks contribute to urban vitality and community well-being?
- How can such changes address broader societal challenges, such as social inclusion and adaptive responses to environmental and economic stresses?

These questions take us to the core problem of this paper, food accessibility and security. According to a study conducted by the UN regarding food security, in 2016, when Lebanon was relatively financially stable, around 16% of the country was within a margin of moderate food insecurity. Today,

this figure reached around 26%. One can draw a similar conclusion when observing the number of welfare aid requests the Government received during March and April 2020, which is around 300 000 requests according to the Ministry of Social Affairs, noting that only one family member is allowed to apply for such support systems, and all employees of the public sector are deprived of this social support. This crisis turned attention towards farmers and increased awareness of urban gardening. Despite the pro-activeness of Lebanese society, it is challenging for them to promote their products given that agricultural lands are at great distances from the city. This takes the reader to another problem which is the lack of sustainable transportation modes in Beirut. A study conducted by the World Bank in 2017 confirms this, the study elaborates how 80% of the Lebanese community prefers to use a private car when moving around Beirut, leaving 20% to buses and taxis (Anas et al., 2017).

1.4 Significance of the Research

Here, the authors seek to induce Beirut's urbanization problem of the current street networks, and through the application of a parametric model, analyze it as a form of public space that can be rethought and transformed from a car-oriented infrastructure to pedestrian spaces for optimal use of space in the dense city. These spaces could host functions the city needs today such as markets, which in this research are interpreted to have a greater impact on the surrounding environment. This aligns with the severe economic crises Lebanon is going through where people are losing their jobs and all types of goods are becoming unattainable. This crisis became more vivid following COVID-19 and the August 2020 explosion, where more than 70% of the population lost their jobs or saw their salaries reduced. Today, people need access to affordable goods and adopt a new way of trading, and for this, they need suitable spaces, most importantly free outdoor spaces in urban/dense areas.

2. Literature Review

The theoretical paradigm of liveability has been the subject of several writings as a result of the increased social, political, and economic challenges facing contemporary cities. Hajialiakbari et al. (2022) put forward the term obsolescent neighbourhoods referring to deteriorated living conditions in places due to several reasons, among which is the lack of planned public spaces that can serve the local community. Tracing back to the writings on urban space, e.g. Jane Jacobs, Gordon Cullen, and Kevin Lynch, postmodern perception of urban space rejected modernists'' negligence of the complexity of the city and their reductionist approach that "a city cannot be reduced to its quantitative dimensions without running the risk of killing its urban vitality" (Badami, 2022:2; Dovey & Pafka, 2016). This relationship between the user and the space is a morphological analysis that provides insights into the urban fabric. Morphology, a term used extensively to describe the conscious and unconscious patterns and compositions of the physical city (Maretto et al., 2023), has been integrated into different fields to address citizens' needs. The study of urban forms has become an integral part of a holistic approach to tackle the challenges of contemporary cities in its ability to integrate social and environmental perspectives.

For this matter, the literature review explores an intricate relationship between walkability and urban spaces. In the historical background sense, the field of urban design had little to consider regarding the quality of life and the environment of the inhabitants, prioritizing vehicles over pedestrians. Stakeholders can propose a variety of changes within the infrastructure of the city and introduce new policies that can protect cyclists and pedestrians to achieve sustainable urban planning decisions (Ros-McDonnell et al., 2024; Dragović et al., 2023). Hellberg et al. (2021) assert that the concept of walkability is not only associated with the inhabitants' attitudes and their usage of public space but also their choice of travelling short and safe distances which in turn stimulate non-motorized traffic over motorized ones. Previous renowned urban theorists such as Jan Gehl emphasize the importance of social activities in streets that can enhance walkable areas, hence developing the quality of urban space (Gehl, 1987; Hussein, 2018).

The effect of walkability on the quality of urban life can be promoted through the adoption of the compact city model (Mouratidis, 2017), which gives space to a wide range of activities and uses within the urban fabric. The compact city is known for its heterogeneous and multifunctional features that use few material resources, utilize less energy and a system that can work well with historic cities, such as Beirut, for better conservation of its old buildings, neighbourhoods, and old streets. In other words, walkable urban areas have an intrinsic socio-economic value. In a 2018 report released by the NSW Government, Landcom, established a toolkit for defining the economic and social values of societies and the different stakeholders involved in planning and development, whether public or private sectors (Cohen et al., 2018).

This approach can be situated within the scope of this paper by studying street markets as a vital element of planning. Street markets can be perceived as a form of tactical placemaking created through the organic behaviour of community members. Placemaking emphasizes the uniqueness of identity resulting from successful linkage, image, and sociality of the place (Nouri & Costa, 2017; Sukasta & Winandari, 2020). In the context of Beirut, placemaking is perceived as a tool for tackling socio-economic and geographical inequality. Hence, these renewal projects are mostly based on the notion that such places are occupied by marginalized communities, often looked at as the 'other' (Yatmo, 2008; Balarabe et al., 2019). Yet, has this image emerged out of the level of success of these markets?

2.1 Towards Successful Urban Markets: A Theoretical Framework

Several studies have addressed the modern urban movement 'New Urbanism', sometimes referred to as 'Neo-traditional design methodology' that favours the pedestrian over the automobile (Al-Hagla, 2008). Its main core of work relies on creating a dynamic urban realm where several stakeholders, architects, urbanists, community members, and local and central governing bodies function together for the benefit of the whole. Street activities are one of the forms of urban dynamism that can enhance efficiency and vitality through everyday social interactions. This implies that streets can "operate as social places" (Rui & Othengrafen, 2023:9). This article highlights street markets as crucial focal points for urban economic and social life. Markets by definition are spaces where goods are offered for a reasonable price, usually cheaper than stores and supermarkets. Moreover, the goods in the case of markets of edible products are usually fresher since storage is not that common nor needed in most markets.

Situating markets within a theoretical stance introduces the reader to the capability approach developed by economist Amartya Sen (1999). The capability approach, often used in economics and social policy, focuses on enhancing individuals' well-being through three approaches: 1) the various things that a person values doing, 2) the opportunities to achieve these doings, and 3) the ability of a person to act upon his/her own value. In the field of urban studies, researchers have defined urban capabilities as a set of capabilities that "depend on urban and environmental opportunities intended as combinations of contextual factors that can be modified with a public policy" (Blečić et al., 2015; Fancello et al., 2020:7). In this matter, there are certain elements that influence inhabitants' choice to develop urban walkability in the city. The authors of this article highlight Beirut's street network as the main element to explore the vitality of public markets being utilized to enhance walkability.

In light of the current challenging socio-economic conditions in Beirut, urban markets can offer a great deal of relief to the community. On one hand, Flea markets can help people sell products they don't need to someone who does for affordable prices. Beirut is a suitable host to such markets as many people move temporarily to the city for education, job opportunities or to experience the city life. This fast-paced movement of residents can generate a need to sell or buy items frequently which flea markets can offer. On the other end, food markets can address the most serious issue threatening the city which is food safety. Food markets can intervene and offer themselves as a public platform for farmers to promote their products instead of supermarkets. Simultaneously, buyers will have the chance to shop from a variety of fresher products for more affordable prices. These markets can include

livestock, vegetables, fruits, and dairy products. The main aim is to provide a holistic vision for well-established markets that can encourage people's engagement, coming from different backgrounds (Agboola et al., 2018), with a diverse range of activities.

Public markets embody a great deal of benefits on the national and regional scales. Linking urban and rural economies is of course a goal in itself, but creating these one-to-one connections between rural farmers and urban residents can also have healthy impacts, such as promoting internal/rural tourism, where people have the curiosity to visit these places to purchase food produced from those areas. Several cities in the world such as Barcelona, Amsterdam, and Berlin, have famous markets that later became popular tourist destinations, which also fall within the umbrella of the benefits of the local economy.

3. Materials and Methods

3.1 Study Design and Setting

When it comes to strategically placing elements in a city, a rational ordered logic should be established to allow them to function suitably within a certain context. This logic consists of a list of parameters based on data structures, which form together the criteria threshold. Once this phase is completed, streets can be converted to markets based on the study results. In this research, a parameter list is created through which a street network performance test is conducted, and later the criteria are divided into two categories, for the fixed markets and the temporary markets. The following briefly illustrates the structure:

A. Testing the Street Network

B. Fixed Food market

1. Streets long enough to host a market
2. Streets with proximity to parking space
3. Integrated public transportation network
4. Uninterrupted access from the food source
5. Land use of the existing structures and underground parking

C. Temporary Food Markets/ Pedestrian Streets:

1. Streets big enough to host a temporary market
2. Street far from existing green or public spaces
3. Street within a walkable range of parking lots
4. Proximity to sub-centres in the city

3.2 Testing the Street Network

This phase is mainly dedicated to testing the traffic and congestion on the streets. First, to be able to properly test the traffic system in Beirut, one can rely on intelligent traffic monitoring systems. Such data is usually available in municipalities, at the Ministry of Traffic and Transportation, and at specialized traffic and mobility firms. These systems can observe data related to streets, knots, roundabouts, and highways and highlight the ones that witness the heaviest traffic flow during the day. People tend to use the streets that represent the most convenient for them to reach their destinations within the city.

3.3 Fixed Markets

B1- Streets with a minimum length

The maximum width of streets in Beirut is 12 meters, which indicates that the only way to expand the market is linearly, hence making the market longer. After observing the average street length in Beirut city street network, a well-defined range could be a set parameter, on one hand, to keep this number within the margin of the existing street width, and on the other hand to have enough stalls installed to keep the market functioning.

B2- Streets with proximity to parking spaces

The parking space can extend beyond its traditional function as a space for cars, yet it could also serve as an unloading space in the early mornings before the opening hours, as well as a loading space after hours and during waste collection.

B3- Integrated public transportation network

Accessibility is a crucial aspect that needs to be met. Although transit stops should be at the core focus of the criteria, in car-based and dense cities, the approach is more of what streets could offer rather than what is the best optimal place for a market. Connectivity to public transport is a factor of success in such environments.

B4- Uninterrupted flow of goods from the source

As an additional parameter, streets hosting food markets should have easy access to roads connecting to the rural agriculture areas without being a burden to the city. Car-dependent cities suffer from high traffic congestion, and street markets decrease pressure on the street network. Therefore, food trucks should avoid going into the city's internal grid network and limit their movement to the main highways to minimize the congestion they create as much as possible.

B5- Land use of existing buildings and underground parking

This kind of data platform could include all sorts of physical specifications i.e. which buildings are residential or office buildings, and what kind of plinth exists in the existing built structure in the city. Is it retail, and if so, what kind of retail, is it Horeca (Hotels, Restaurants, and Catering) related or not, exit and entrance of buildings as well as underground parking and whether they exist or not? For example, a fixed food market could not be located on a street where all buildings have underground parking. As a final step, a centrality study is made again to compare the best combinations of streets allowing the user to define which combination of closed streets would affect the city's spatial centrality.

3.4 Temporary Markets

C1- Streets with certain lengths

For Temporary markets, street length can be much more flexible. This comes as a consequence of the uncertainty temporary markets hold, in terms of frequency and retail intensity. Following the assessment of the street network and calculating the average street length, one can set a flexible threshold for these temporary markets, since they function as pedestrian-oriented streets when markets are not installed. For example, one can allocate multiple streets to be transformed to pedestrians and flea markets could occur simultaneously on different streets. This way a great public space network is established, out of which some streets are chosen to hold temporary markets following a certain schedule and even setting a rotation system targeting most neighbourhoods in the city.

C2- Streets distant from existing public spaces

When the chosen streets are not hosting temporary markets, they will act as pedestrian spaces which the city needs. Since this action plan is dedicated to dense cities with not enough parks and public spaces, it would be best to spread new ones to neighbourhoods where public spaces do not exist.

C3- Streets with walkable distances from parking spaces

While some dense cities remain car-dependent, accommodating people's choice of transportation is vital for increased vibrancy. Parking facilities should be available for market visitors as long as the general city policy is to remain car-welcoming.

C4- Proximity to sub-centres in the city

Although main cities act as a whole and usually have one main downtown or centre, cities such as Beirut have also developed vibrant sub-centres alongside downtown where mixed-use functions take place, and would often be people's daily or weekly destinations. Allocating markets and public spaces to these areas which are proximate to sub-centres in the city would be a convenient method to attract people to the market and to activate the public spaces when markets are inactive.

3.5 Parametric Implementation: Data Availability

All the theories and proposed parameters mentioned earlier could be implemented in a case where all kinds of data and resources are available. However, in the case of this research specifically and given its time frame, and particularly in the Lebanese context where most data is collected by the private sector and is not published, the approach for executing the research theory calls for some modifications. For instance, there is no actual data, map, or document listing the existing buildings, their land use, or whether the building has underground parking or not. Hence, to acquire this kind of data, a field survey can be done, in other terms a group of people can walk along all the city's streets and take notes about building size, stories, and basement availability, digitize it, and introduce it to the current database in the research. However, within the time frame and resources of the research, this is not actually possible, therefore the parameter concerned with underground parking, and buildings' land use will be left out of the simulation. Nonetheless, it could be added later on at any point once made available. Moreover, data concerning the parking spots all over the city was collected manually using a satellite image from Google Maps, hence all public underground parking is left out of the calculations.

Furthermore, the main basis of the study is the street network. This geometry is quite complex as it contains different layers such as tunnels, roads, and bridges which could overlap in one or many spots. Since a detailed scientific traffic study cannot be made at this point, one of the alternatives would be parametric tools which can give an impression about the potential of the street network based purely on the geometry. To be able to use this alternative method properly some simplifications to the street network's geometry must be made in order to reduce its complexity so that it is usable with parametric tools. Thus, this does not mean that the method cannot incorporate complex street networks, but within the time frame and resources of this research, a simple geometry is better fitting.

Finally, to start this rational process, the first step is to assess the current street network, which is again not available to the public. It is possible that some private traffic firms/engineers have run some studies and simulations. However, all related results are still to this day inaccessible nor published. Nevertheless, many other alternatives can be used to generate an estimation that might not be as accurate and realistic as a traffic study but could serve the purpose of this research to some extent.

3.6 Applied Methods

To avoid discarding this whole research because of lack of data specifically the street network performance part, the adopted alternative method will be geometrically testing the centrality of the street network. Street networks will be considered a simple abstract geometry with no precise relation to any spatial and realistic dimensions. Hence, the result would be the potential centrality of the street network.

To start, the current street network is simplified and turned into a plane geometry formed by connecting lines, each line is a representation of the connection between two points. In this exercise, a new segment must be defined at every intersection. Now once all this geometry is prepared the actual centrality test can be performed. Therefore, centrality is how elements are related and connected to each other. The main idea is to compute relationships between different elements, (in the case of street networks the elements are the nodes of these segments) while highlighting the different degrees of importance of these connections.

There are two different types of centrality:

1. **Betweenness Centrality**: Calculates the shortest path from all nodes to all other nodes and highlights the nodes that are crossed the most. Therefore, this kind of centrality test points out the most important to the least important nodes in terms of connectivity using descending values.

2. **Closeness Centrality**: Defines for each node the distance to all other nodes in the street network. The street with the highest and shortest connections to all other nodes is the street with the highest closeness centrality value.

In addition to these measurement concepts, two scales can be used, the global scale, where all the street network is considered, meaning from all streets to all streets (destinations and origins), or the local scale where only destinations within a radius based on a metrical value are considered.

3.3 Fuzzy Logic

First, a domain must be set, in this case, the street length. In binary logic, a street is either long or short, however in fuzzy logic, a membership defines whether the item belongs or not, and if it does, to what degree of membership, having 0 as not belonging and 1 as fully belonging. Between 0 and 1 is a list of belonging values. For instance, a street having a value of 0.7 belongs more to the domain, meaning it is longer than a street having 0.3 as a value, and so on.

Furthermore, this degree of membership follows a mathematical logic, hence, the calculation theory of the fuzzy logic. A crisp input is the start, for instance, a street length of 80 meters. At first, the fuzzifier transforms this into a fuzzy value following the rules that define what is long and what is not and the categories in between. If a street is below 50 it is definitely not long, if it is 100 meters and above it is definitely long, and if it is 75 it is long. Then, the logic calculates the new value based on the rules by fuzzifying the results in a way that 75 meters becomes 0.5 instead of 1, so in a way it is half true and not completely true, hence the half value. Eventually, after defuzzification, the output would be crisp again, just like traditional binary logic but instead of an ultimate 0 or 1, it presents a numerical value in between (Figure 1).

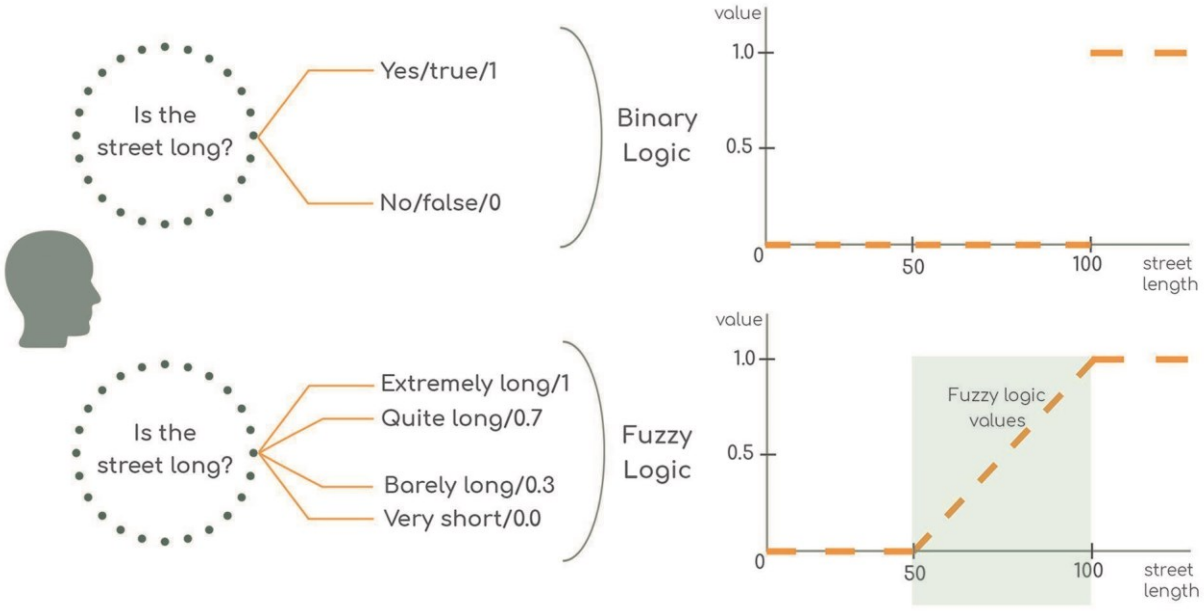

Figure 1. Fuzzy Logic.

4. Application

By using a parametric tool, this research can become more sustainable not only by creating a tool that fulfils this research purpose but also as a flexible tool for future use in different cities. As a result, any value or given data can be at any time modified, hence a new result based on the last modification. All parametric implementations are done using the software of Rhino and Grasshopper plug-in.

4.1 Fixed Markets

Here all street values in terms of performance are bound between 0 and 1. Using only binary logic, streets having values less than 0.4 will undergo the upcoming tests and classifications to have a better overview of streets' suitability for each parameter.

B1- Streets with a minimum length

Streets in Beirut are mostly narrow. Therefore, if transformed into street markets, the only possible market layout would be a linear one, hence the longer the street the more stalls are installed. In this case, streets that are less than 80 meters long are discarded, streets that are between 80 and 100 meters long are taken into consideration yet with a suitability value of less than 1, and streets that are 100 meters and longer have a full value of 1.

B2- Streets with proximity to parking space

The internal narrow streets of Beirut make it difficult for food/waste trucks to circulate and manoeuvre, therefore they need a dedicated open space to load and unload. This is why proximity is significant and the short distance between the market and the parking space is important. Any street having a parking space further than 200 meters is discarded from the study.

B3- Integrated public transportation network

In this simulation, the markets are assumed to be walkable from the stops, taking no more than a 10-minute walk which would be around 750 meters as a maximum.

B4- Uninterrupted flow of goods from the source

The author presumes that two markets are needed in Beirut, one in the East supplied with goods from Bekaa governorate and the Northern parts, while the other market receives supplies from Bekaa and the Southern regions. Food coming from the North and Bekaa would ideally go to a market situated between the two sources. Food trucks create congestion in cities, especially since they arrive early in the morning (rush hour), therefore these trucks should drive as little as possible in the city. In this case, a maximum route of 2.5 kilometers is allowed, from the midpoint of the route connecting food sources. Food supplied by the south has two means of getting to the city, which are central and heavy traffic highways. Thus, geometrically, the main food source would be considered as a midpoint of a route linking all three food sources (2 from south + 1 from Bekaa). Thus, again, all routes defined between 0 and a maximum of 2.5 kilometers are possible with decreasing suitability values.

4.1.1 Overlaying Results

After generating street maps with their suitability scores, the aim is to have a final illustration mapping all the acceptable values based on the different parameters. The final goal is to have bus stops, parking spaces, street length, and accessibility to food, all listed in one map (Figures 2 & 3), and as a result, all the values from these parameters are mixed and transformed into one value.

Moreover, to explain this mathematically, every street having a value of zero in any of the previous parameters is not taken into consideration in the simulation, and only the streets with values above zero are kept in. Then all values of each street are added up and re-divided by the mass edition of parameters, which in this case, are divided by 4, ergo a new value for each street is assigned.

This mathematical equation takes place while taking into consideration all parameters having equal ratios to each other. In other words, all parameters are treated equally and have the same priority. Shall this change, the parameter is given a different value, and the number used to divide the sum of values is changed accordingly.

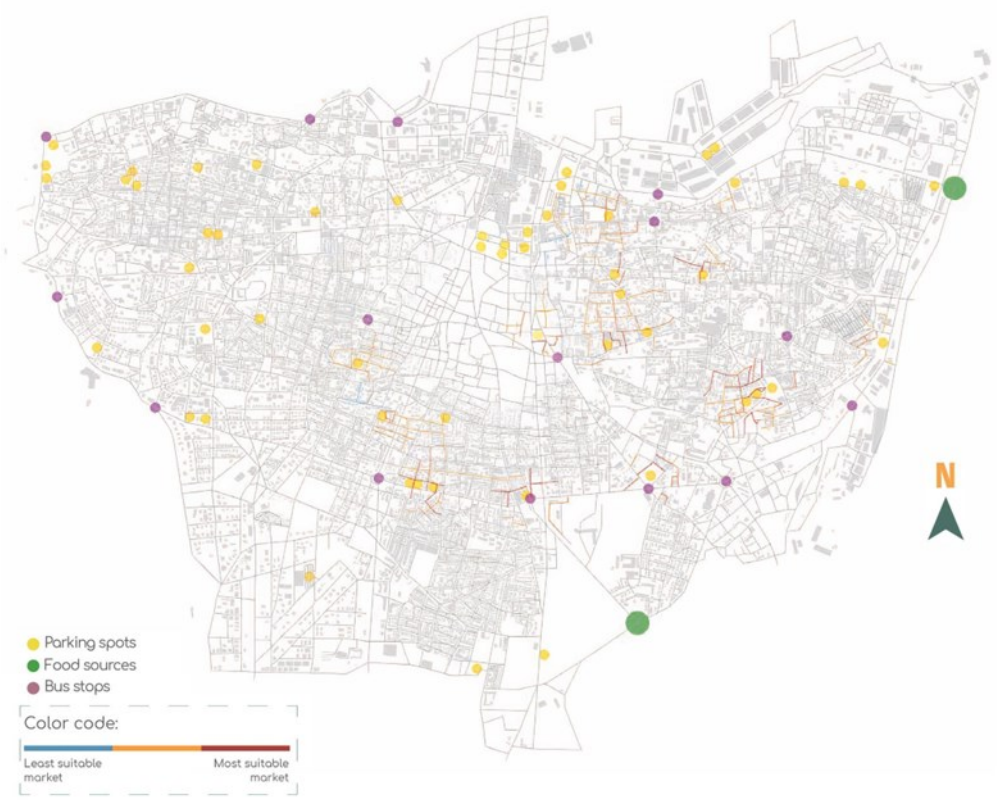

Figure 2. Combining Results for Markets in the East.

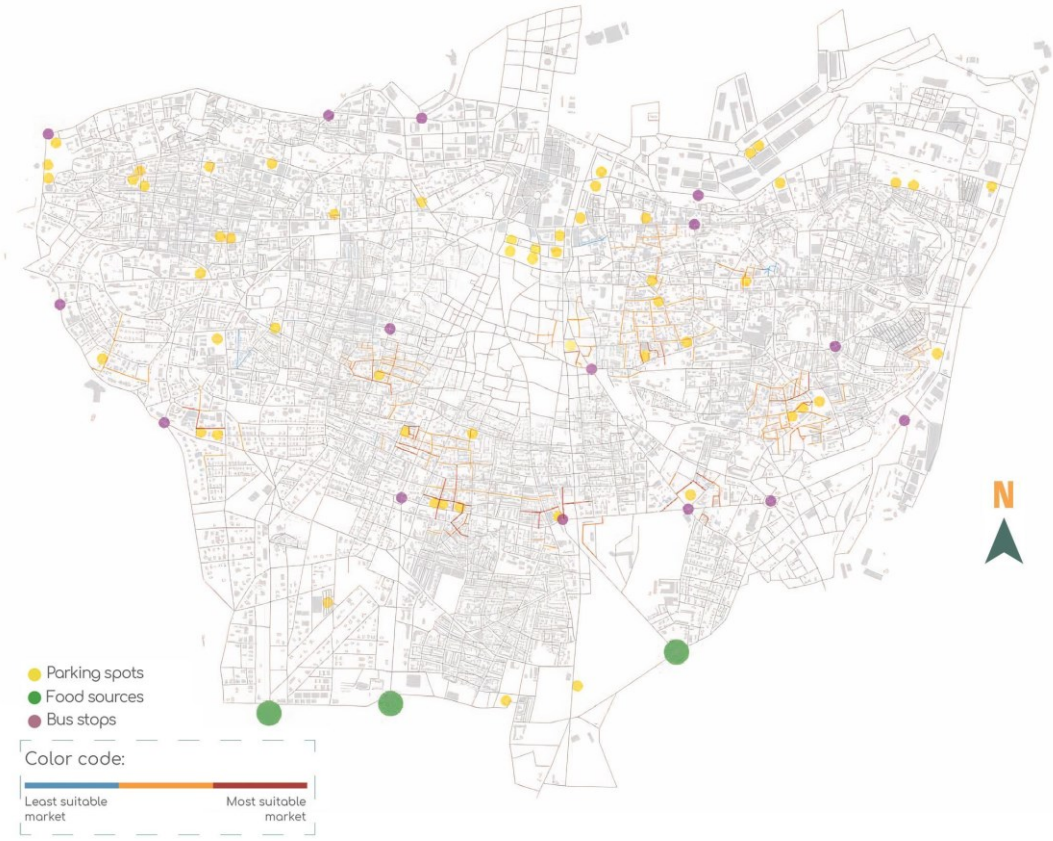

Figure 3. Combining Results for Markets in the West.

4.1.2 Adaptable Tool

The generated tool assists users in strategically placing markets within a city based on data hypothesis, however, this can be modified at any instant for one or more parameters. In the case of placing a food market in a city where accessibility to food is a minor concern, while street length, parking, and bus stops are major concerns, the assigned ratio that was 1 in the previous simulation gets downsized to 0.1, meaning this parameter decreases 90% of its influence. Hence, the remaining parameters become dominant parameters leading to a different result. This is useful since cities are in constant development, and adaptation in the urban realm is inevitable. Nevertheless, in this research, all parameters are and will be treated equally, having the same score and value of 1.

Eventually, the final aim of this research is to strategically place two markets in Beirut city, and so far, multiple options have proven to fulfil all the required criteria. Nevertheless, the question remains of how to choose one market for each area of Beirut, knowing that there are multiple candidates. One way is to create a list of possible two street combinations (1 East and 1 West), remove them from the street network, test the effect they cause, and choose the option that affects the current performance of the street network the least (Figure 4). The possible options would be S1S1', S1S2', S1S3', S1S4', S1S5', S1S6', S1S7', and then S2S1', S2S2'... and so on. For simplicity and feasibility, this exercise will be tested only on 4 streets with the highest scores (2 from each list).

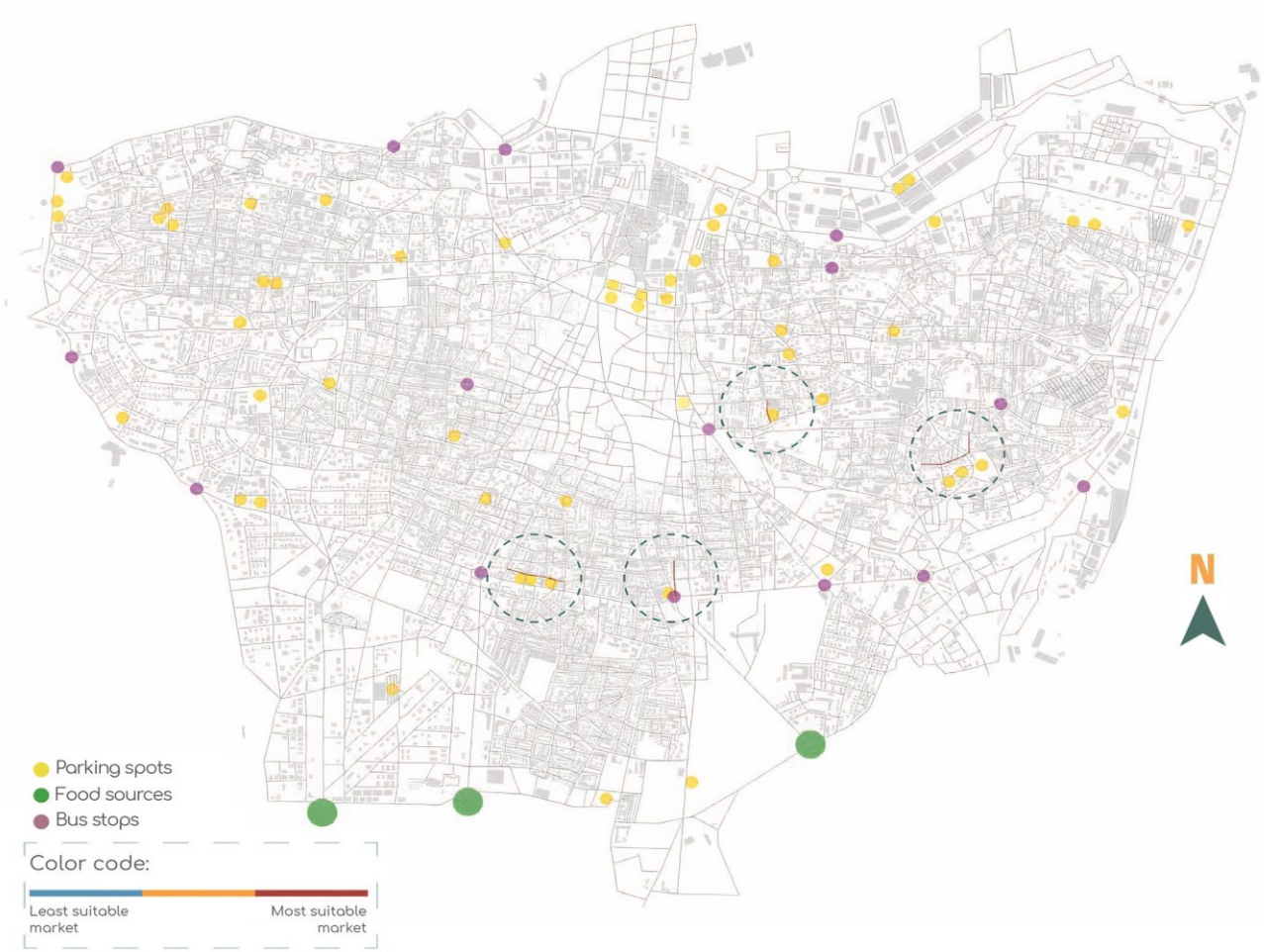

Figure 4. All Optimal Streets.

4.1.3 Comparing Closeness

When performing a centrality test using parametric tools such as the present case, a map showing colourful segments would be one of the outcomes. This map comes as a graphical representation of centrality values, the higher the difference between values the greater the colour contrast would be on the coloured map.

When comparing the four scenarios, it is not possible to rely only on the graphical representations since it is not an accurate, nor a scientific method, while sometimes the difference might not be visible to the naked eye. Hence, a more sensitive method is put in place. The four possible outcomes are compared as follows:

Each street value in the four scenarios is compared to the current street value, and the difference is kept as a variation value. Once all the variation values of all streets are collected, the values are added to reach one value. The same goes for the remaining three outputs and then the total variation values are compared to each other. The lowest value is the most suitable for this test if the aim is to not disturb the street network performance in terms of centrality as much as possible.

Around 6950 street segments were extracted, and each segment obtains a centrality value varying from 0 to 1, hence for each segment, the variation value is something between 0 and 1. The sum of all variation values for each scenario is the sum of all these variations defined as numerical values between 0 and 1. This is to give an impression of the importance and scale of the variation values in each scenario.

The combination of the two streets in red (Figures 5 & 6) has proven to affect least the current spatial centrality revealed by a global closeness centrality test. These two markets have quick access to bus stops and parking spaces while being long enough to host physically as many stalls as possible. They are also central in terms of food accessibility which will lead to an uninterrupted supply and waste exhaust. Therefore, theoretically, these two streets are the optimal location for setting up fixed markets.

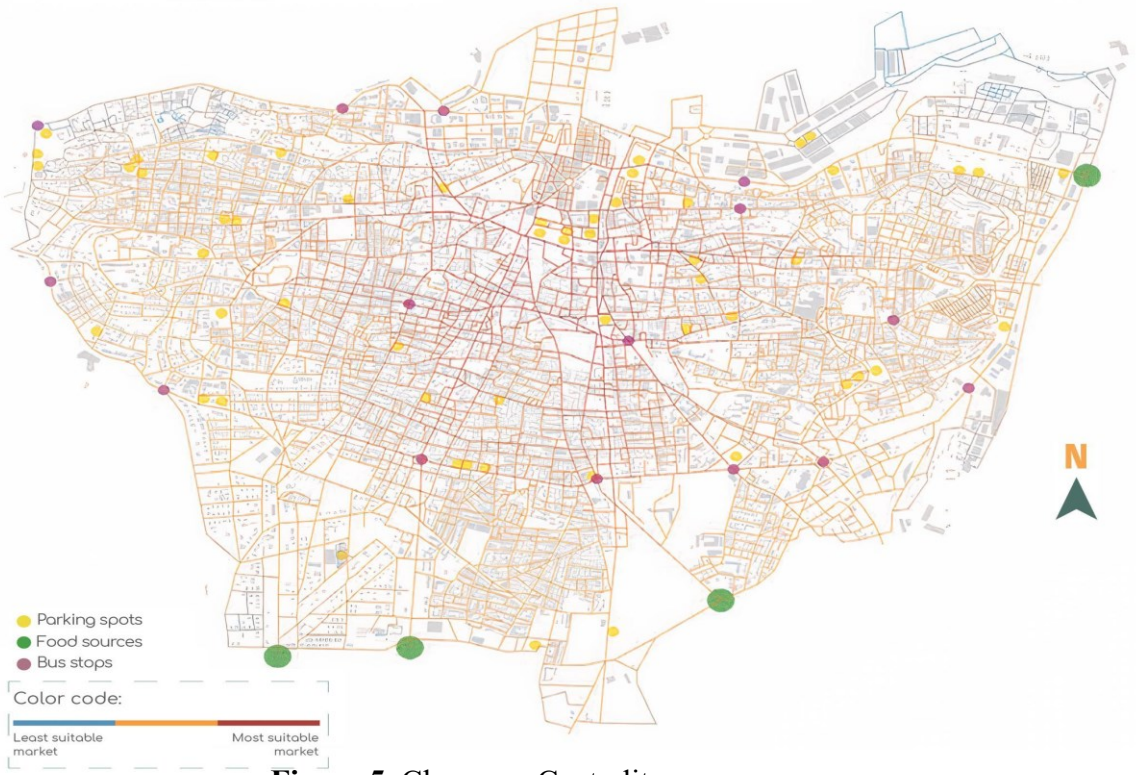

Figure 5. Closeness Centrality.

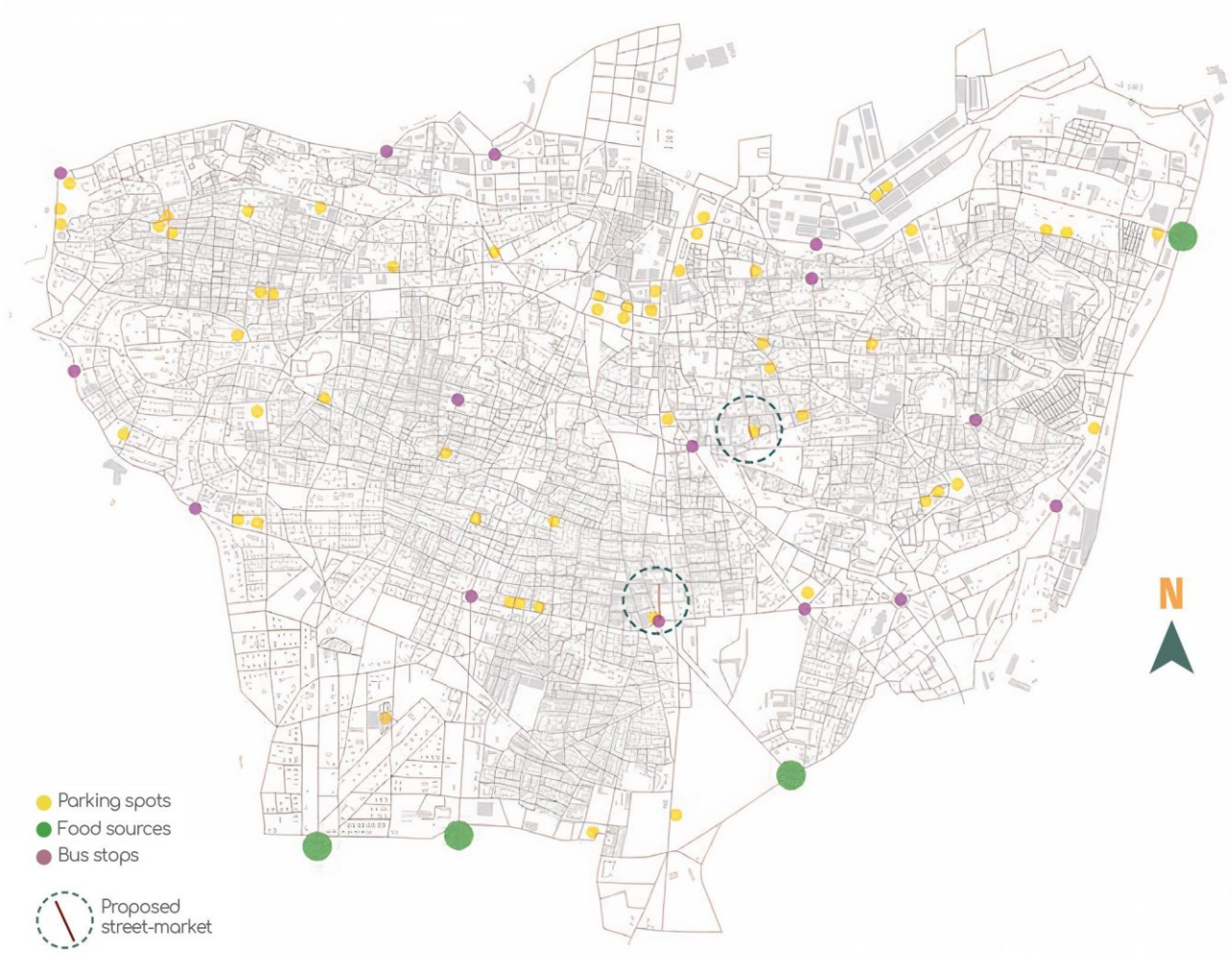

Figure 6. Most Optimal Combination.

4.2 Temporary Markets

C1- Streets with minimum length

Flea markets on street markets will preferably be installed in a linear layout, therefore streets above 80 meters should offer enough stalls. However, 100 meters and above is preferable and would be more spacious and give more space for people to showcase their goods leading to higher chances of success for the market.

C2- Proximity to parking lots

A market with a walkable distance from a parking space would give a success boost to the market. The distance does not have to be short, yet it should be easily walkable.

C3- Integrated public transportation network

A distance of 750 meters, which is equivalent to a 10-minute walk, is the furthest distance a person would have to walk from the bus stop to a market or public space. This ratio makes the market more attractive and stimulates the activation of public spaces as well.

C4- Distance from existing public spaces

Since Beirut suffers from a lack of public spaces, it is essential to allocate public spaces at a fair distance from the existing ones. This would ensure spatial justice in the city, where the accessibility to public spaces should be granted to as many people as possible. The proposed public spaces are set in a way to be at least 300 meters far from existing ones, and preferably 500 meters and above.

C5- Proximity to sub-centres

All potential markets are preferred to be within a distance not exceeding 600 meters from attractive spots in the city. Public spaces should be close to attractive places, considering the initial area is more or less active.

4.2.1 Overlaying Results

Using the fuzzy logic concept to overlap and summarize all values streets have gained in previous parameters, a new set of values is generated as represented in the map below (Figure 7). However, similar to the fixed food market process, this representation offers results while treating all parameters equally and not prioritizing one parameter on the other. Although the red dark streets are located only in two main areas, other streets in lighter colours, are streets holding smaller values that could also be considered valid candidates since they fulfill all previous criteria. Any choice from this street list is theoretically a good choice for a temporary market and public space given the available data and selected parameters.

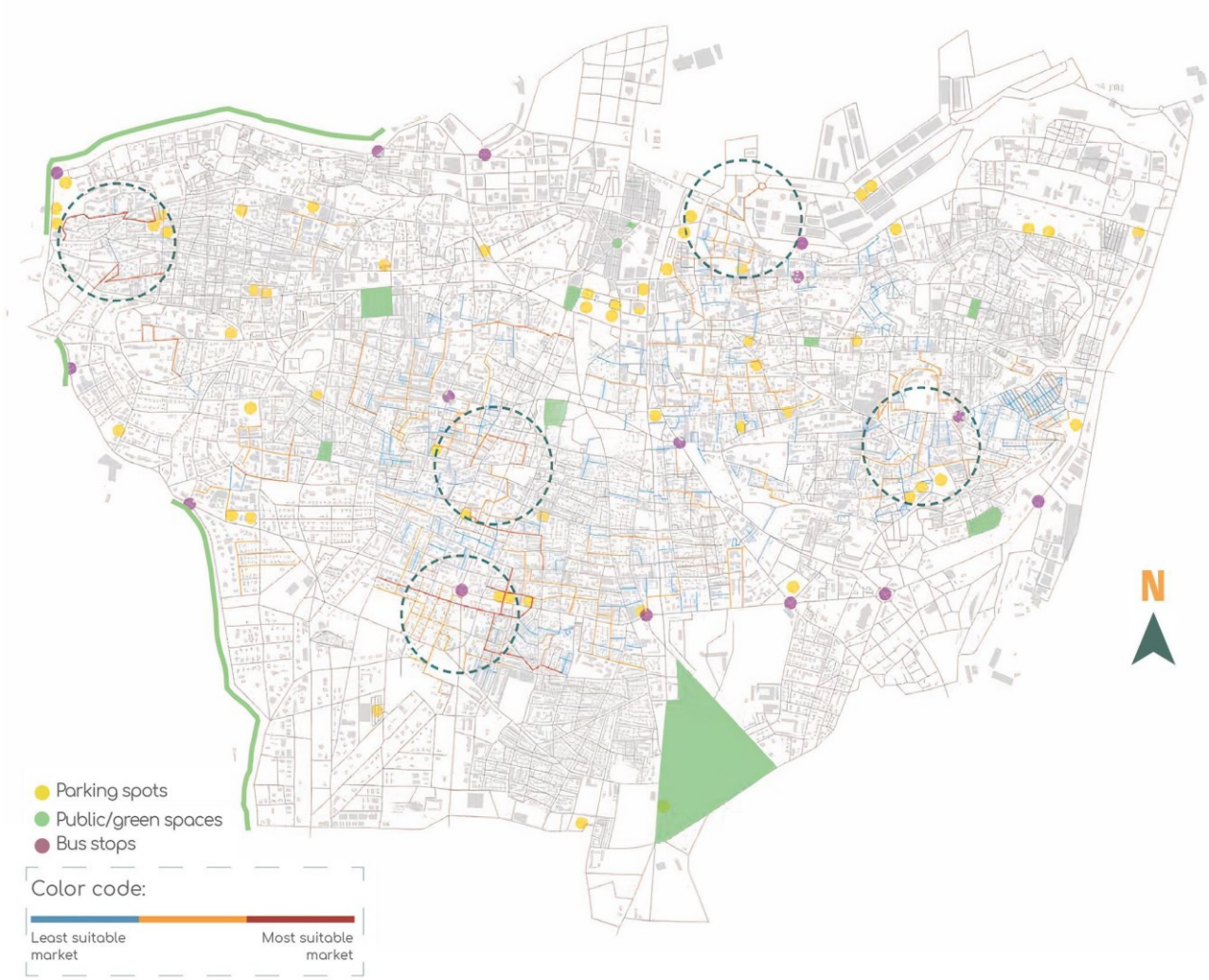

Figure 7. Most Suitable Streets for Conversion.

4.2.2 Street Observation

These temporary markets will mostly hold light and dismountable structures which allow them to adapt to any existing street layout. However, since these markets are public spaces, the convenient way to describe these spaces would be pedestrian areas which could function as temporary markets. In the chosen street, parked cars on public domain streets should be relocated to the nearest parking area, while keeping cars in privately owned parking spaces as they do not interfere with the street performance.

The plinth here is significant since most buildings have plinths, these plinths will become more attractive once these areas are turned into proper public spaces, which will increase their revenues as well as property value. The streets will also be a great use for the residents, kids can safely play and use the streets, while people can enjoy walks and exercise recreational activities when markets are inactive. In a way, this network of temporary streets could act as a series of pocket public green spaces (Figure 8).

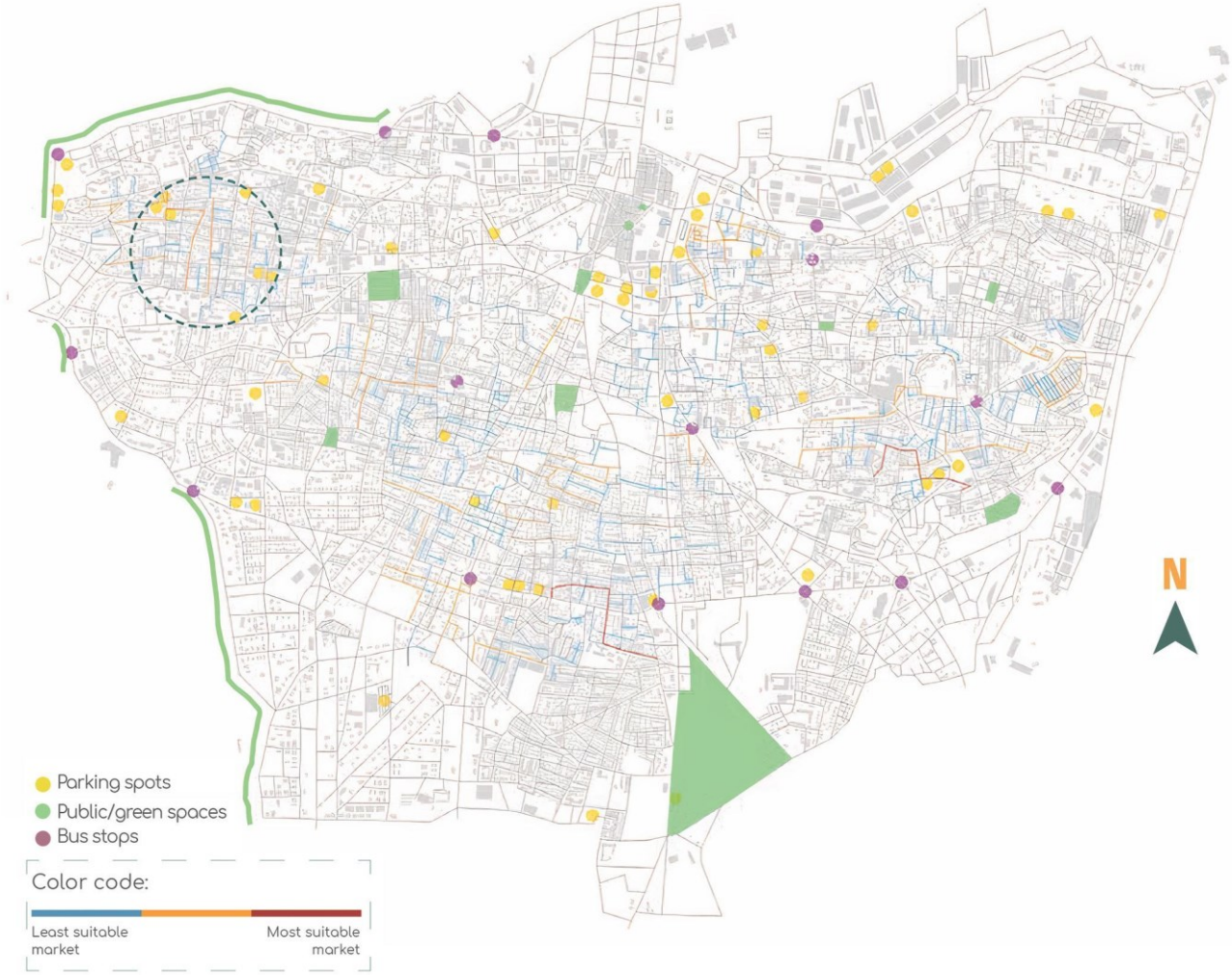

Figure 8. Changing Ratios.

5. Discussion & Outlook

When searching for a city or any area via Google Maps, if users have the default settings, the application reveals informative content beyond its basic purpose, a navigation tool. Google Maps highlights areas that attract people and cars and has to some extent a vibrant impression. How Google

Maps acquires this kind of information is not the main point in this research rather just seeing where people go in Beirut city regularly, and what areas are considered attractive. In the map below (Figure 9), Google Maps highlights vibrant areas in light yellow while regular areas are left light grey, and dark pink is for hospitals.

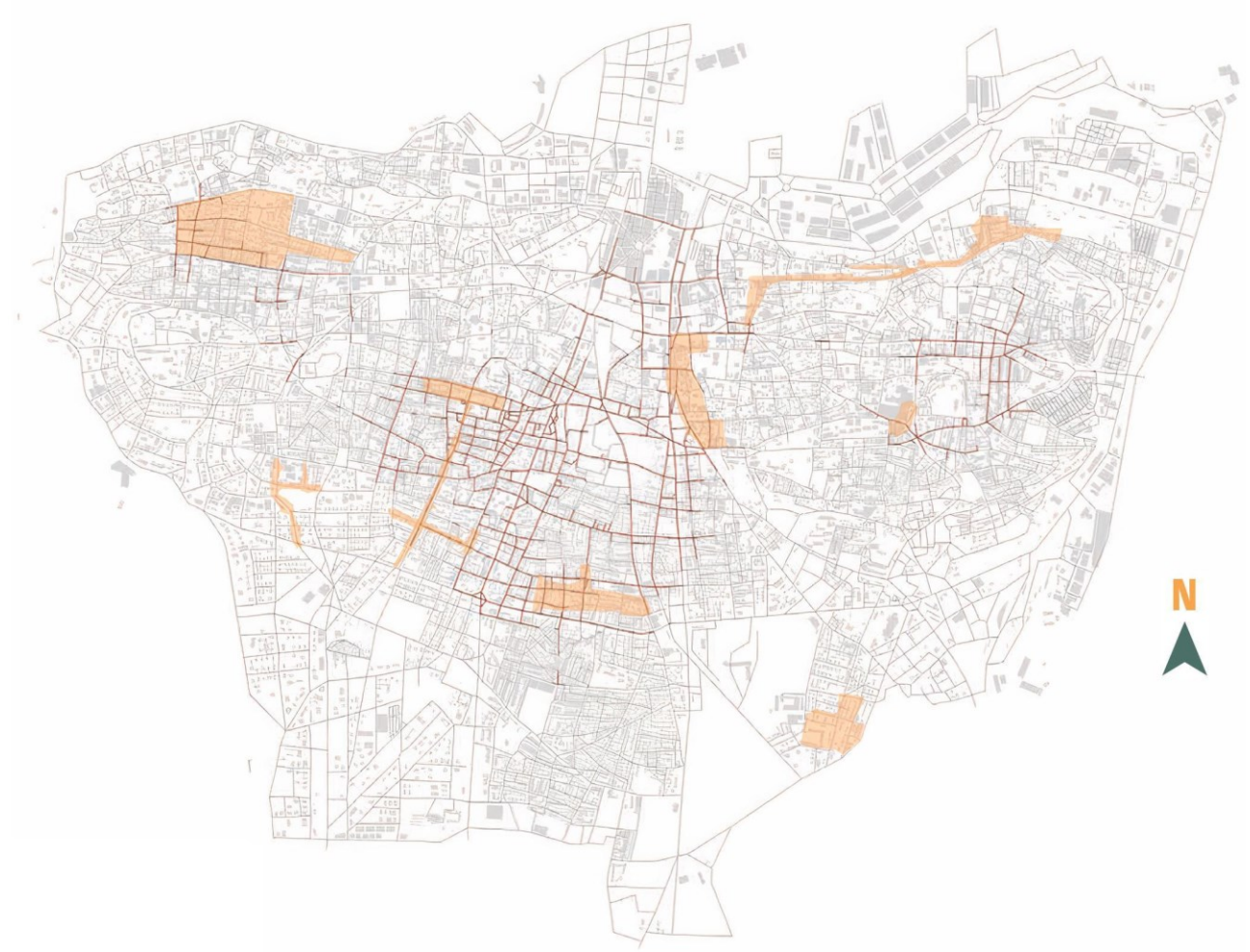

Figure 9. Layer of Centrality.

As a second step, it is essential to overlay these areas with the sub-centres that were found in the local closeness centrality test with a radius of 800 meters. The idea behind this exercise is to observe if the spatial central areas are used and if they match with the current attractive spots in the city. Following this observation, one can have an estimation of whether the used method aligns with reality, and if more sub-centres will emerge in the future of the city. Having more answers and a better understanding of the city can encourage decision-makers and stakeholders to rethink the future structure, its mobility plan, and its overall density potential.

The map shows in dark red the central street, as was previously illustrated in the local closeness centrality map, and the light orange patches highlight the current captivating spots in the city. At first sight, it is interesting to see that most of the orange patches align with the centrality test, while the three patches that do not overlap might have several reasons concerning the studied area during the simulation or the area could simply be vibrant while not being geometrically central. While most of the orange patches overlay with central streets, a lot of central streets are not considered interesting spots according to Google Maps, meaning that these streets have geometrically unattained potential.

Furthermore, this potential tackles many aspects of the city's performance, whether it is stations for public markets, future bus stops, or new green pocket areas.

5.1 Tool Optimization

After generating all kinds of informative and analytical maps in the different simulations, observing the results physically from a street scale, and finally drawing appropriate conclusions, it is vital to propose suggestions for future simulations to have a more optimized tool, hence optimized results. Since all simulation-based tools rely on data; the more available data is, the more accurate and correct the results will be.

Fixed Food Markets:

1) Data included are land use, architecture typology, and plinth availability. A good idea would be underground parking which does not appear on satellite maps and therefore could greatly change all results once integrated into the database.

2) Introducing street width as a parameter, and integrating a new simulation of the two street markets to be distant from each other.

3) Introducing closeness centrality in earlier phases to be able to locate how many markets are needed based on a certain walkable radius, in a city like Beirut maybe 3 or 4 are needed, and not just two.

Temporary Markets:

1) Integrate plinth land use here as well. This would be optimal for the local economy with a coherent combination of product-oriented flea markets and existing retail activity.

2) Integrate building typology to ensure a certain amount of people flow, allowing the public space to be active most times of the day.

3) Integrate street typologies (shared streets, pedestrian areas, scheduled service roads.) when the tool is taking a further step in placing the temporary markets.

Public space can be categorized into local use and regional use. The local might be integrated into the bigger proposed public spaces network and could perform as a whole in terms of biodiversity, green layer, and urban gardening. Regional public spaces can be combined for a bigger plan where Beirut has enough greenery and enough parks.

6. Conclusion

Markets have always been a significant element in the urban realm, yet when put in the Lebanese context they become one of the only possible solutions to the country’s current crisis. A sustainable action plan is urgently needed, whether it is food markets that can deliver affordable and fresh food from farmers directly to consumers without passing by very few wholesale traders who are making major profits just by being an intermediate channel, whereas when adopting markets, farmers could make more profits which can be reinvested in their business to improve it and enlarge it in terms of quality and quantity. Or, through flea markets that give a second life to previously imported unused products which will no longer be available in Lebanese communities in the future.

The challenge remains in strategically positioning these markets. For the fixed markets, two are needed, one supplying from Bekaa and the north, while the other from the south and Bekaa. Moreover, following the final generated gradient map of market suitability, having fulfilled all required criteria with different values, two streets that can hold fixed food markets are found, and then an open space network is established, a network that can hold temporary markets on weekly basis, each week located in a different area.

Meanwhile, the Central and North-Western part of the city has to be reconsidered when establishing markets and public spaces. At the moment, people living there head to the seaside boulevard since it’s the available public space there but it is not the ideal local public space as it is used more as a national/tourist destination. Whereas they should have public spaces around their neighbourhoods to

create communal connections and meet neighbours. These residents have only expensive stores and supermarkets to shop from, whereas markets could now be a great escape for them.
Going back to the main research question about how can underused mobility infrastructure host vibrant spaces of social cohesion and security, the answer relies on understanding how the street network performs, defining all the necessary and related elements of the urban realm, from logistics to accessibility, to attraction motivators, to people's behaviour and security, introducing them all to a rational functioning processing system, and then rethink the outputs for further optimization.
Markets have proven their role in cities all over the world, yet when introduced in the Lebanese context it is useful to customize such intervention. As a result, generating a list of streets is the main focus of this research. However, missing and unavailable data proved to be a great obstacle to a similar project. Therefore, one important key to success for any future intervention in the urban context would be the data collection/availability. In addition to the data-driven process, and the spatial dimension of similar projects, one must work on a social point of view for good integration of such spaces.
This is quite significant for a functioning market as it needs to be socially acceptable for people to go to and purchase used items. At the moment, this means purchasing is limited to only the poor and the low social class, yet for a better inclusive market, flea markets should be able to target all kinds of social classes. This can only be done after some awareness campaign and cultural acceptance.

Acknowledgements
This research was made possible by the support of the College of Architecture and Urban Planning (CAUP) at Tongji University in Shanghai.

Funding
This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Conflicts of Interest
The authors declare no conflicts of interest.

Data availability statement
The authors confirm that the data supporting the findings of this study are available upon request.

CRediT author statement:
Conceptualization: Y.A. & T.A., Formal Analysis: Y.A., Investigation: Y.A. & T.A., Methodology: Y.A., Resources: Y.A., Software: Y.A., Supervision: T.A., Visualization: Y.A. & T.A., Writing original draft: Y.A. & T.A., Writing, reviewing, and editing: T.A. All Authors have reviewed and approved the final version of the manuscript.

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How to cite this article:
Askar, Y., & Abdel-Ghani, T. (2024). Adapting Mobility Infrastructure to the Needs of a Liveable City: the Case of Beirut Street Markets. *Journal of Contemporary Urban Affairs*, 8(2), 364–384. https://doi.org/10.25034/ijcua.2024.v8n2-5