



Impacts of a New Highway on Urban Development and Land Accessibility in Developing Countries: Case of Beirut Southern Entrance in Lebanon

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Abstract

This paper studies the impacts of the construction of a new highway on the built-up land use dynamics in the southern neighboring area of Beirut in Lebanon, whereas the impact of transport infrastructure on land use dynamics has been widely studied, few examples are found for developing countries where data are not widely available. Moreover, it is difficult to assess the impact of the infrastructure among several external and internal factors. Areas of built-up land use in Beirut Southern entrance in Lebanon were extracted from land use classification maps for years 1985 to 2019 using 30 m resolution satellite reflectance images in ArcGIS software. To compute an accessibility index to the population, average car travel speeds were determined for major local roads and population distributions were collected for years 2004 to 2019. Results revealed that after the completion of highway's construction, the development of built-up land use has increased by 13.9%, but also that the land use dynamics depends highly on the unexpected arrival of Syrian refugees between years 2011 and 2013. The results were analyzed with the help of several interviews of stakeholders.

Keywords Land use dynamics · Transport infrastructure · Urban land use · Accessibility · ArcGIS · Lebanon

1 Introduction

Many researches were conducted to investigate the transport and land use (LU) relationships. Indeed, a new transport infrastructure has necessarily some impact on land development. A classical concern generally evaluates the socio-economic benefits, partly linked to land use evolution and justifies the financial investment in the infrastructure. The review conducted by Acheampong and Silva [1] stated that many LU and transportation researches have been conducted with the help of models belonging to the field of classic microeconomic-urban models such as the models of Von-Thünen in 1826, Wingo in 1961, and Alonso in 1964. Other types of transportation and LU models were developed, for example, the gravity based model developed by Lowry in 1964 [1]. The authors indicated also that within the past sixty years, several aggregate and disaggregate transport and LU theories were developed. All the previous and currently operational models and theories focus mainly on the economic dimension within the transport and LU relationships in addition to other factors [1]. Moreover, recent studies that investigate the transport accessibility and LU interactions, also analyze this relationship of accessibility and LU from

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an economic viewpoint [2–4]. Also, Ismael [5] linked the spatial accessibility to urban economies by defining it as one of the determinant elements of economy.

For instance, a study conducted in turkey in 2020 [6] shows explicitly that previous investments in road infrastructures had positive effects on the national economic growth. However, this economic viewpoint is not totally suitable to explore all the spatial effects of a transport infrastructure, especially the spatial evolution of territories over time, as most approaches rely on equilibriums. Besides, they require data that are not available in many developing countries. Additionally, a study conducted by Bathrellos et al. [7] argued that the urban management and the human-made development, as the urban sprawl and the extension of infrastructural coverage suchlike road networks, must be managed and planned not only in economic and social perspectives. The authors indicated that the geographic, geologic and geomorphologic aspects of the studied areas in addition to the occurrence's probability of natural hazards must be taken further into account. From other viewpoints, several studies explored the impacts of implementing a highway on environment, landscape, traffic, population and LU. Urban sprawl, linked to the development of transport infrastructures, has become a major concern with the global climate change and the rarefaction of fossil energies. An investigation on the sprawl of urban development in the USA between years 1976 and 1992 indicated that the dependence of a city on car travel over transit service represents one of the important elements that encourages the urban sprawl [8]. Thus, implementing new highways could promote the urban expansion. A study in 2007 was conducted to find the impacts of building a new unprecedented highway on the evolution of central cities' population in the USA for the period from 1950 to 1990 [9]. The author deduced that the construction of new highways is contributing in declining the population density in central cities. Moreover, enhancing the transportation and improving the railroad and highway systems promote the suburbanization and increase the population growth in suburban areas in Spain [10, 11]. A study in Turkey by Mansuroglu et al. [12] indicated that the construction of Antalya-Alanya highway induced negative environmental and ecological direct impacts such as consumption of agriculture areas and removal of vegetation in favor of building the highway and other indirect impacts such as the increase in water, air and noise pollution, the accumulation toxic substances in the soil, the increase in erosion and deterioration of cultivated lands in addition to the conversion of agriculture lands to urban development in rural zones. Other studies show that the majority of built-up lands, respectively, in Switzerland and in China are located in the proximity of highways which promote the relocation of developed land uses to their proximity [13, 14]. In 2014, a study in Puli town in Taiwan showed that building new highways will result in

the fragmentation of neighboring lands into different LU and the conversion of farmlands and forests into built-up LU [15]. Similarly, the urban growth induced by the implementation of new highways and explained as the conversion of agriculture areas and farmlands to built-up LU was the key findings of the study conducted to investigate the LU changes in Hang-Jia-Hu plain in China between years 1990 and 2010 and the study conducted to find the LU impacts of implementing the program of the "Appalachian Highway System" which initiated in 1960s in southern Ohio in the USA [16, 17]. The study investigating the effects of expanding a highway network on population growth and distribution, conducted in the Netherlands in the 1960s, indicates that the new highways increased the growth of population in peripheral areas and depopulate the central zones of the cities [18]. Additionally, the results indicate that constructing new highways has no impact on suburban areas since the development in these areas was subject to development restrictions and restricted planning policies. However, the impacts of new highways on population distribution in suburban areas with no development restrictions were not identified. Similarly, Niu et al. [19] developed a new land use transport interaction model to examine the urban dynamics induced by land use policies in Beijing metropolitan area in China between the year 2009 and the year 2013. This model consists of four urban aspects: (i) real estate rent, (ii) employment location, (iii) residential location and (iv) transport infrastructure. The findings show that new urban development, induced by the increased accessibility of new transport infrastructure, will take place in the city's fringes within the pattern of different sub-centers around the city.

Furthermore, Yatoo et al. [20] indicated that the urban expansion in Ahmedabad city in India over the period 1976–2017 was driven mainly by the development of roads and highways network which induced an increased accessibility to resources and led to an accelerated commercial and industrial development.

From different perspectives, Bathrellos and Skilodimou [21] indicated that the human activities as the construction and extension of infrastructure, suchlike the construction of new road networks, in addition to the urban development accompanied with over population could potentially affect and change the natural landscape. In the same context, the authors reported that these activities would trigger the natural hazards in developing and developed countries as for instance by the acts of excessive land exploitation and the conversion of green areas into urban settlements which lead to the deforestation and land degradation. As a result, the increased possibility of natural hazards to occur would in contrast damage the human made and natural environments and negatively affect the sustainability of urban and infrastructural development [21].

This paper contributes to the emerging literature by investigating the impacts of a newly constructed highway on the spatial distribution of land uses and particularly on the built-up LU evolution in the adjacent and neighboring areas in developing countries. The transformation of bare soils and green zones into urban development is also investigated. Moreover, this study examines the correlation between the built-up LU dynamics and the accessibility of the newly constructed highway through a correlation analysis. Landsat satellite images of the study area for years 1985 to 2019 were used to detect the evolution of built-up LU before and after the completion of construction works of the highway. In Lebanon, the satellite images are the only available data for LU classification. An investigation of built-up LU dynamics from 1985 to 2003 and from 2004 to 2019 in the case study is carried out in this paper to differentiate between the built-up LU trend before the construction of the highway and the trend after the completion of construction. LU evolution is investigated through the LU classification process in ArcGIS software. LU classes used in the production of maps are defined as: built-up areas, bare soil and green areas (agriculture and forested zones). Then, accessibility indexes for the newly constructed highway were calculated for years 2004 to 2019 and a correlation analysis between the evolution of built-up LU and highway's accessibility was conducted.

The paper is structured as follows. Section 2 dictates the research methodology. Section 3 presents data collection techniques used in this study. Section 4 presents the results part depicting the dynamics of built-up LU over years 1985 to 2019. Section 5 presents the discussion part covering (i) the impact of construction a new highway on built-up LU dynamics and (ii) the correlation between built-up LU and the accessibility index of highway relatively to neighboring area. Section 6 summarizes the paper and proposes future research.

2 Methodology

The applied research methodology is discussed in this section.

2.1 Research Hypotheses

The first research hypotheses are that, classically, a newly constructed highway in a developing country such as Lebanon will increase the built-up development in neighboring areas, and that the boosted urban development will occur at the expense of both green areas and bare soils.

The second research hypothesis is that regular population growth, accompanied with the locative residential distribution, will significantly affect the accessibility level in the studied area, and thus, land use evolution depends on

both the internal factor of infrastructure development and the external factor of demography. It is to be noted that the factors affecting the locative distribution of new residents such as property prices and the competition for properties in addition to the attachment of land owners to their lands will not be discussed in a detailed way in this paper.

2.2 Research Methodology

The research methodology consists of defining the geographic boundary of the study area. Then, the satellite images of the study area for year 1985 to 2019 are collected to generate the supervised LU classification using ArcGIS software.

The trend of built-up LU is deduced from the LU classification to detect any changes after the date of completion of constructing the highway.

As detailed census data do not exist for Lebanon, the actual population data for year 2004 [22] were collected and the population distribution for each town of the study area for the period extended between year 2005 and year 2019 was estimated by projecting the data provided by “World Population Review” webpage [23] and the actual data of year 2004 [22]. The determination of major local roads was performed. In addition, the vehicle operating speeds in these local roads were investigated. The map of local roads and the average vehicle speeds were used, respectively, to generate an Euclidean distance map and to calculate the average travel time between the towns and the highway. The projected population data and the calculated travel times are used to calculate the highway's accessibility indexes over the period extended from year 2004 to year 2019.

A correlation analysis between the areas of built-up LU and the accessibility indexes and between the population and the accessibility indexes was conducted and discussed. Figure 1 illustrates the used research methodology via a flowchart.

3 Study Area: Beirut Southern Corridor

The case study is the area neighboring the Beirut southern entrance presented as the Khaldeh-Beirut section of Lebanon's south coastal highway. This area was selected since the construction Khaldeh-Beirut section was completed in year 2003 [24].

Figure 2 illustrates the geographical boundaries of the study area. From the West, the highway alignment since the highway is at the coastline. From the East, the administrative extent of “Aramoun” and “Bchamoun” towns. From the North, the administrative extent of “Chouaifat” and “Kfarchima” towns. From the South, the administrative boundary of Naamat town. Towns located in the study area

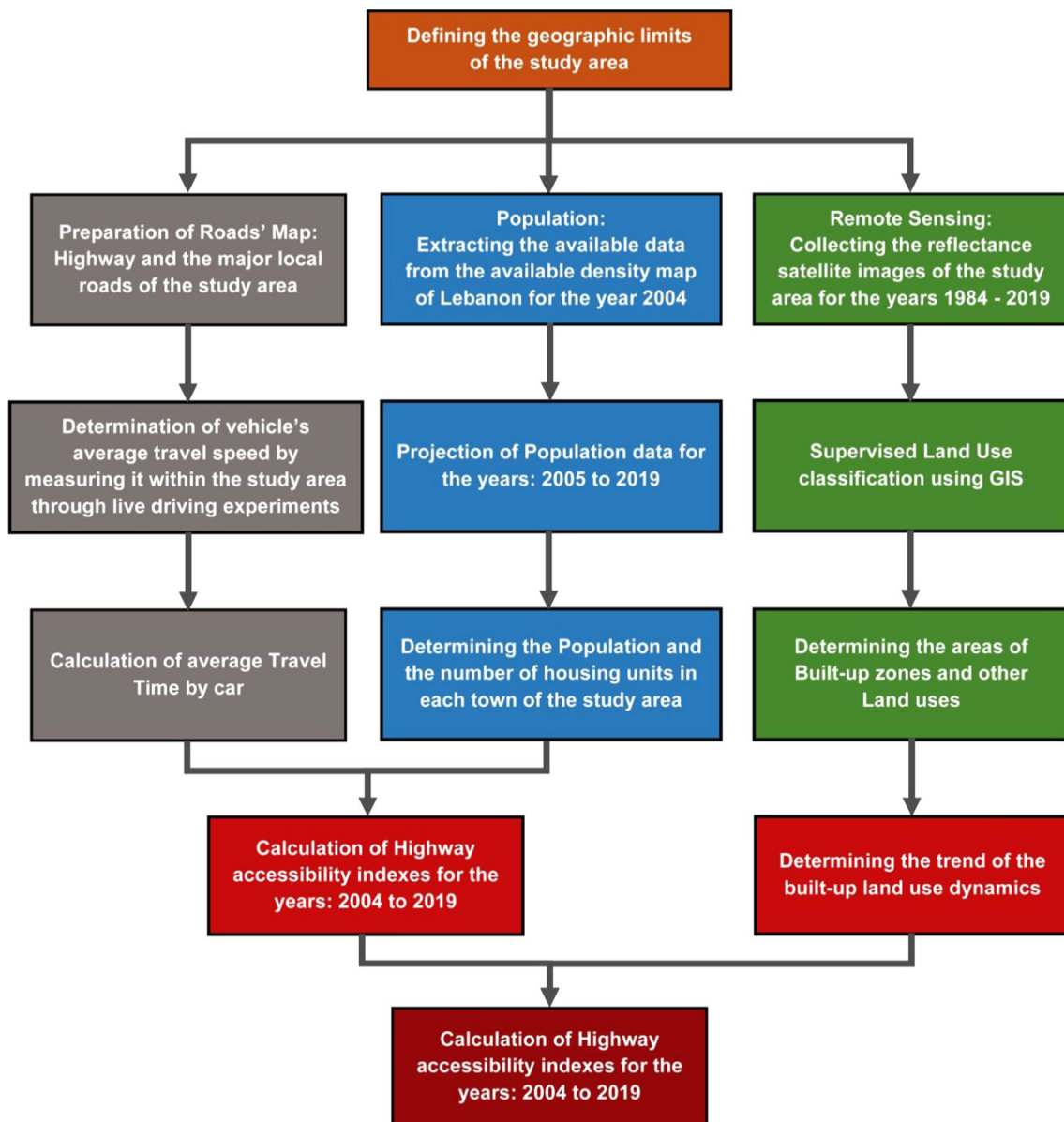


Fig. 1 Flowchart of the followed research methodology

are Aïn-Enoub, Aïn Drafile, Aramoun, Baouarta, Bchamoun, Bsaba Wadi Dlab, Chouaifat Amroussyat, Chouaifat Oumara, Chouaifat Qobbat, Deir-Koubel, Kfarchima, Naamat and Sarahmoul. The Governor of Mount Lebanon zone, known as the Mouhafaza of Mount Lebanon, Mohamad Mekkawi [25] indicated that in the proximity to Beirut southern entrance road high residential agglomerations are located in Aïn-Enoub, Aramoun, Bchamoun, Chouaifat, Deir-Koubel, Kfarchima and Naamat towns which represents the major analysis zones of the study area as illustrated in Fig. 2.

4 Data Collection

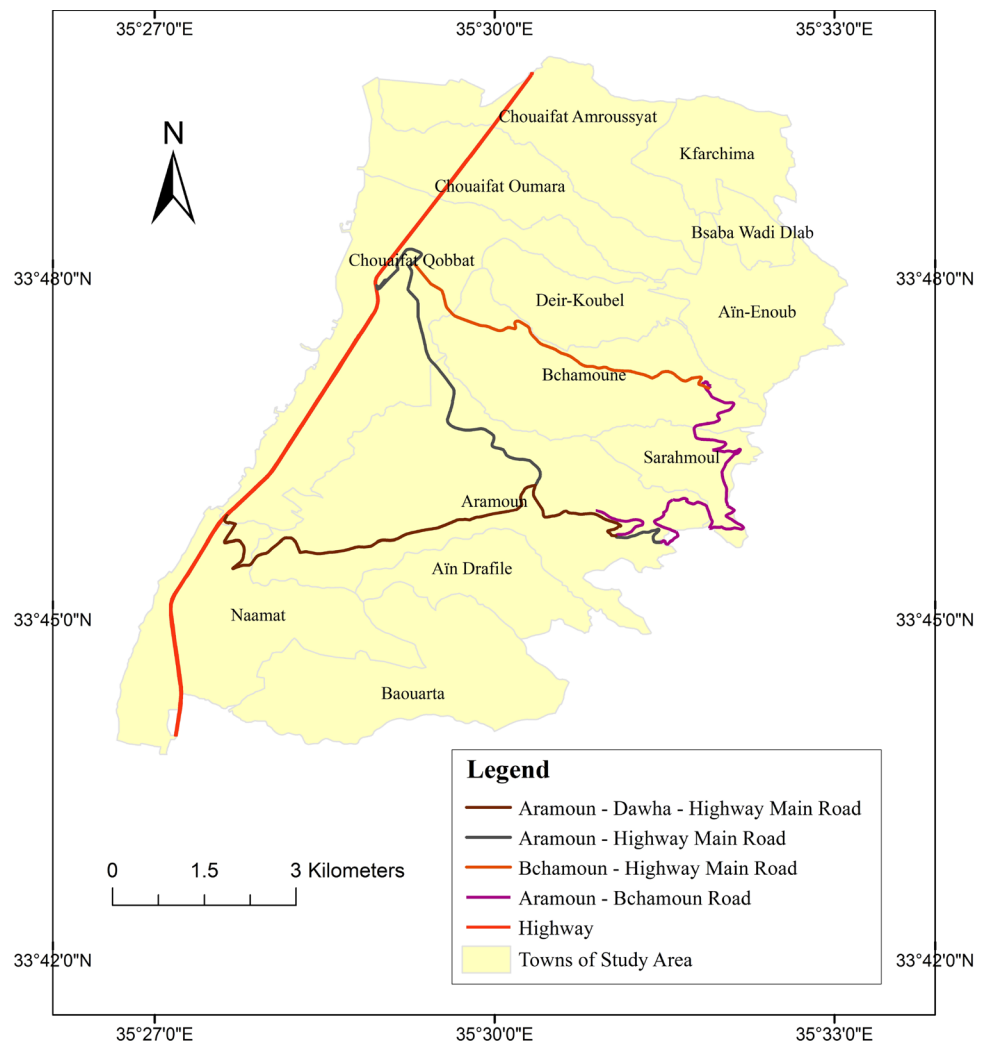
In this section, data collection methods used in this paper are designated via four elements: (1) population, (2) accessibility map, (3) satellite images, and (4) LU classifications.

4.1 Population

The population in the towns of the study area for the year 2004 was extracted from the Lebanese population density map [22]. Data of total population in Lebanon from year 2004 to 2019 that were extracted from “World Population



Fig. 2 Geographical boundary, towns and major Local Roads of the study area (Beirut Southern Entrance zone)



Review” webpage [23] and from “United Nations DESA / Population Division” webpage [26] were used to project by extrapolation the population of the study area towns since these data were not available. The population growth rate is assumed to be uniformly distributed over all Lebanese towns. The evolution of population of the towns over the years 2004 to 2019 is indicated in “Appendix 1.”

4.2 Accessibility

The analysis of accessibility is considered as an important factor to be measured as a means of evaluating the transportation plans and assessing the distribution of urban land use [27].

4.2.1 Definition of Accessibility and Dependent Factors

In general, accessibility is defined as the ability for an individual to travel from a defined zone, mainly home town, to another zone/s to reach the desired attractive activities using

a defined transport mode taking into consideration the travel time or the travel cost [28, 29].

The population of a metropolitan area could be divided into smaller areas where each area has its own attractiveness which is based on the opportunities for interaction it could provide [29]. The accessibility could be measured on the basis of the intensity of the possibility of interaction which reflects the spatial distribution of activities about a location such as the number of job opportunities [29]. High accessibility index reflects the ability for a traveler to reach a specific destination with less travel time or travel cost with the same transport modes [30].

4.2.2 Travel Time

The ability to move in the case study area is mainly dependent on personal vehicle mobility due to (i) large spatial area of 45 km² and (ii) lack of appropriate and reliable public transport services [31]. The main local roads connecting the major towns of the study area: Aramoun, Bchamoun

and Dawha are shown in Fig. 2. The average vehicle travel speeds extracted from Google traffic maps are estimated to be 30 km/hour in all local roads in both directions and at all times. Average vehicle travel speeds were further checked through live driving experiments and by using the “Speed-Tracker” mobile application (downloaded from AppAnnex.com). The experiments were conducted in the main local roads during peak times as indicated in Table 1.

Instead of collecting detailed vector data (for instance from OpenStreetMap) and implementing itinerary computations, which would have been time-consuming given the size of the area and the number of origin / destination couples to take into account, a simplified approach is adopted with raster computation.

This simplified approach gives accurate enough travel time that has been checked afterward. The raster map of vehicle travel time from all towns to highway through the local roads is generated using the ArcGIS 10.6.1 software based on the “Euclidean Distance” module and on the raster calculator module by dividing these distances to the running speed of vehicles (30 km/hour).

The average travel time in minutes between the highway and each town is determined as follows. For Aïn-Enoub, it is 11.7; for Aïn Drafile, it is 8.7; for Aramoun, it is 6; for Baouarta, it is 10.4; for Bchamoun, it is 6.4; for Chouaifat Amroussyat, it is 6.3; for Chouaifat Oumara, it is 4.3; for Chouaifat Qobbat, it is 2; for Deir-Koubel, it is 5.3; for Sarahmoul, it is 11; for Bsaba Wadi Dlab, it is 12; for Kfarchima, it is 11.4; and for Naamat, it is 4.2. Figure 3 shows the vehicle travel time between the highway and each town of the study area. It worth noting that the travel times in far towns from highway are almost double of directly nearer neighboring towns. This is justified by the existence of more tertiary roads in nearer towns and by the fact that the accessibility of roads in nearer towns is higher due to short distance to the highway.

4.2.3 Accessibility Indexes

An accessibility index is determined relatively to a given quantity of interest, generally jobs or certain kinds of amenities. In a commuting perspective, accessibility to employment is interesting. The correlation between housing and its affordability on one hand and the growth of employment opportunities on the other hand was explored and validated within a study conducted by Zhang and Chakrabarti [32].

However, employment data are not available for the area, and it is worth noting that the majority of job opportunities in the study area are characterized by their retail, commercial and social amenities patterns since the area of study is not considered as a city center or industrial/agricultural zone.

In line with this, the growth of job opportunities is proportional to the housing represented by residential agglomeration.

Therefore, the mass attractiveness of each town of the study area represented by the number of employment opportunities is replaced by the number of households in the calculation of accessibility indexes.

An average household size of 4.25 is assumed to be applicable for the whole period between 2004 and 2019 [33, 34, 34–36]. The below equation [30] shows the process to calculate the Accessibility index for a specific zone “ A_i ”:

$$A_i = \sum_1^n B_j e^{-t_{ij}} \quad (1)$$

where A_i : the accessibility of highway, B_j is the attractive mass such as the number of employment/number of retail shops/number of housing residences (in this study the number of residences was used) and t_{ij} is the travel time from zone i to zone j , in this study, zone i represents the highway and zones j are all the towns of the study area and their number is n .

Table 1 The date schedule of driving experiments

Experiment number	Direction	Date	Starting time	Average speed (km/hr)
1A	Aramoun town to Highway	Monday October 7, 2019	7:30 AM	30
1B	Highway to Aramoun town	Monday October 7, 2019	7:00 PM	32
2A	Aramoun town to Dawhah intersection	Tuesday October 8, 2019	7:30 AM	33
2B	Dawhah intersection to Aramoun town	Tuesday October 8, 2019	7:00 PM	32
3A	Bchamoun town to Highway	Wednesday October 9, 2019	7:30 AM	30
3B	Highway to Bchamoun town	Wednesday October 9, 2019	7:00 PM	33
4A	Bchamoun to Aramoun town	Thursday October 10, 2019	7:30 AM	27
4B	Aramoun town to Bchamoun	Thursday October 10, 2019	7:00 PM	31



Fig. 3 Vehicle travel time (minutes) between towns and highway

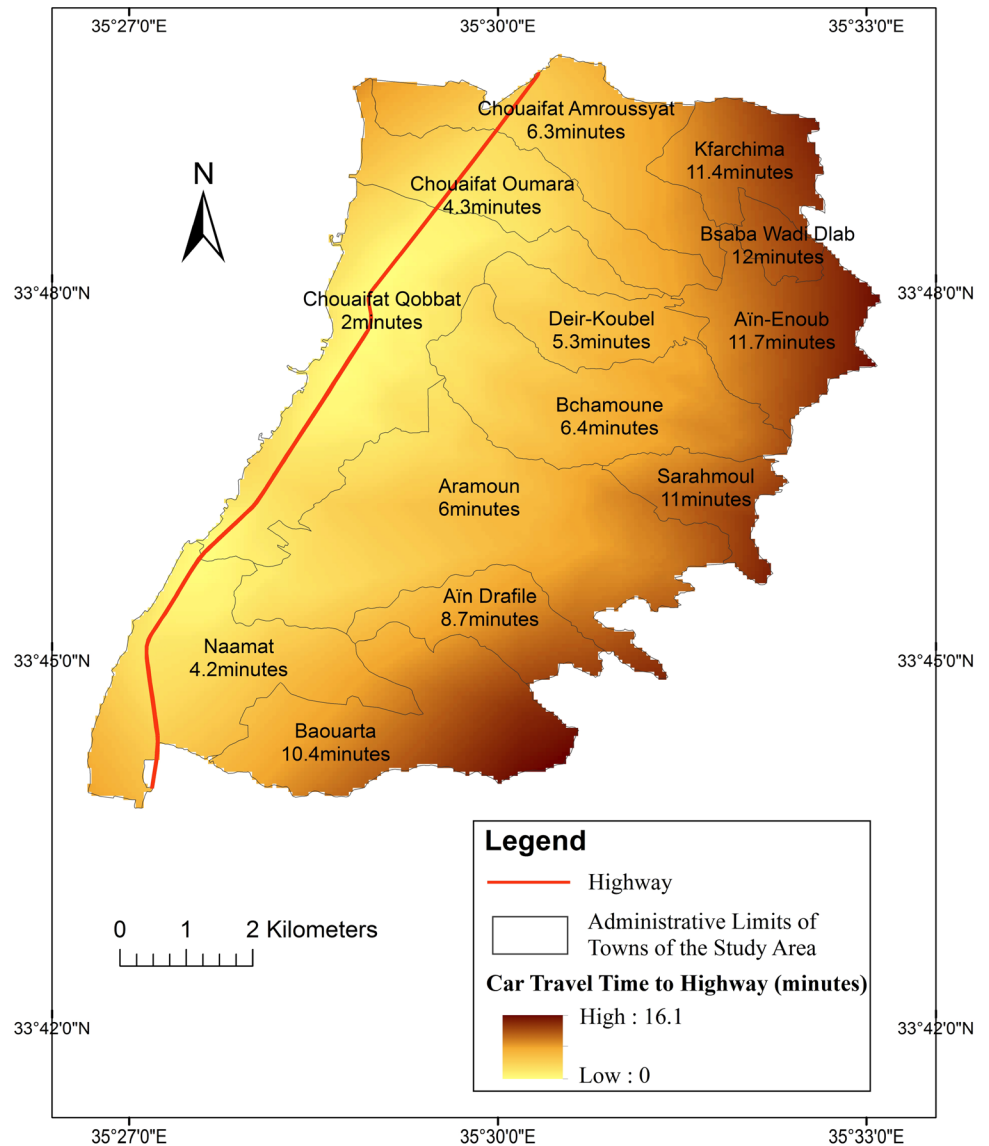


Figure 4 illustrates evolution of highway accessibility over the period from 2004 to 2019. The values of accessibility over this period are indicated in “Appendix 2.”

4.2.4 Satellite Images, Land use Classification and the Classification Accuracy

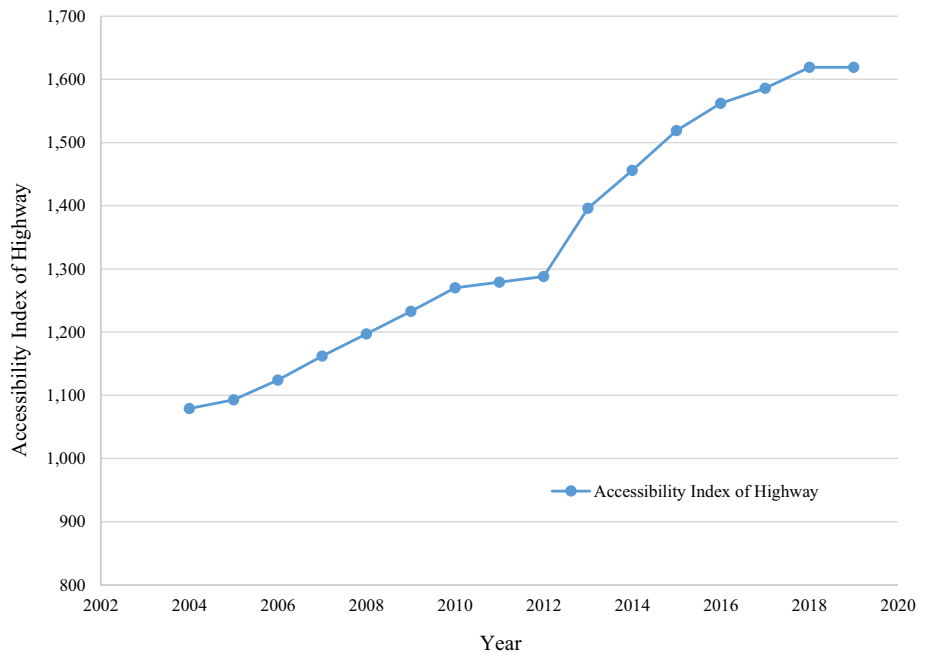
34 Landsat satellite images of the case study for years 1985 to 2019 were collected from “EarthExplorer” webpage [37]. The resolution of these multispectral band images is 30 m. The sources of Landsat images for years 1985 to 2011 are the Landsat 4 and 5 and the source of Landsat images for years 2013 to 2019 is the Landsat 8. Landsat images for years 1985 to 2019, except for year 2012 due to technical damage, were inserted in ArcGIS 10.6.1 to generate the supervised classification within three LU classes: built-up areas, agriculture and forested areas that includes all forest

fields and agricultural lands, and bare soil areas including all non-built-up areas without any significant vegetation. LU classification processes were checked for validity using the accuracy assessment test in ArcGIS software. Accuracy percentages for all years are above 85%, and all test’s Kappa values are above 0.77. The literature indicated that LU classification maps with accuracy for more than 85% are considered as the result of good LU classifications [38]. Similarly, kappa values over 0.77 refer to substantial agreement/accuracy [39].

5 Results

In this section, the actual built-up land use’ dynamics between year 1985 and year 2019 is presented.

Fig. 4 Evolution of highway accessibility through years



5.1 Dynamics of Built-Up Land Use Over Years 1985 to 2019

The built-up LU change between year 1985 and year 2019 was extracted from the generated LU maps for these years. Figure 5 illustrates the trend of this dynamics. The LU dynamics shows that the increase in built-up LU area between year 1985 and year 2019 is occurring at the expense of bare soil LU areas that decrease significantly for the same period while the total area of green zones (forests and farmlands) stay unaltered. Figure 6 shows the areas of

LU classes: built up, bare soil and green areas (forests and agriculture lands) in year 1985 and year 2019. The total area of green zones did not considerably change from year 1985 to 2019 it changes from 23,959,800 m² to 21,881,700 m². However, the built-up LU has significantly increased from 11,885,400 m² in 1985 to 35,824,500 m² in 2019 and the total bare soil area has considerably decreased from 29,283,300 m² to 7,422,300 m² for the same period. The values of these land use over the period 1985 – 2019 are indicated in “Appendix 2.”

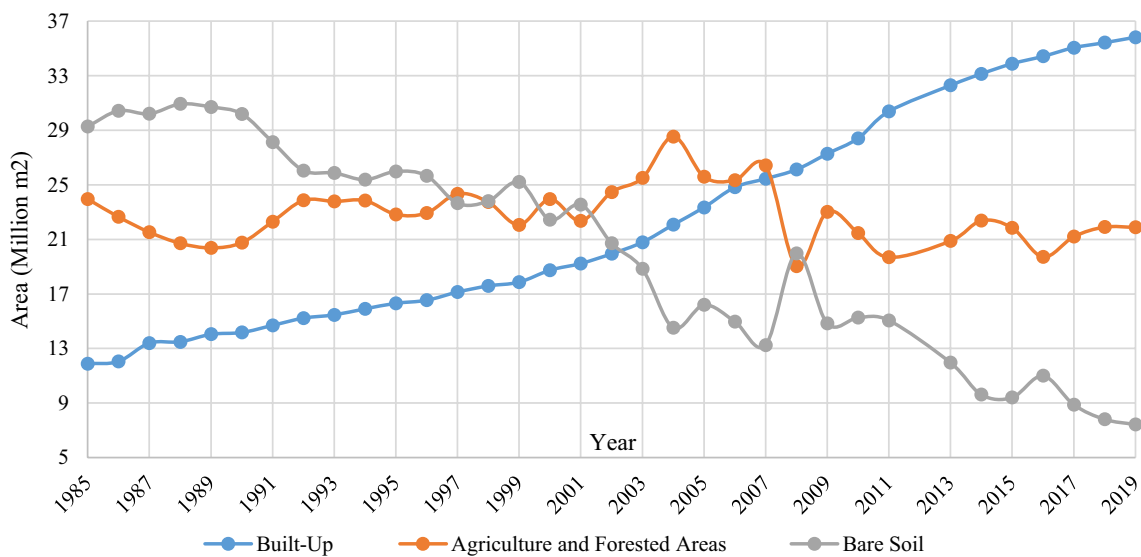
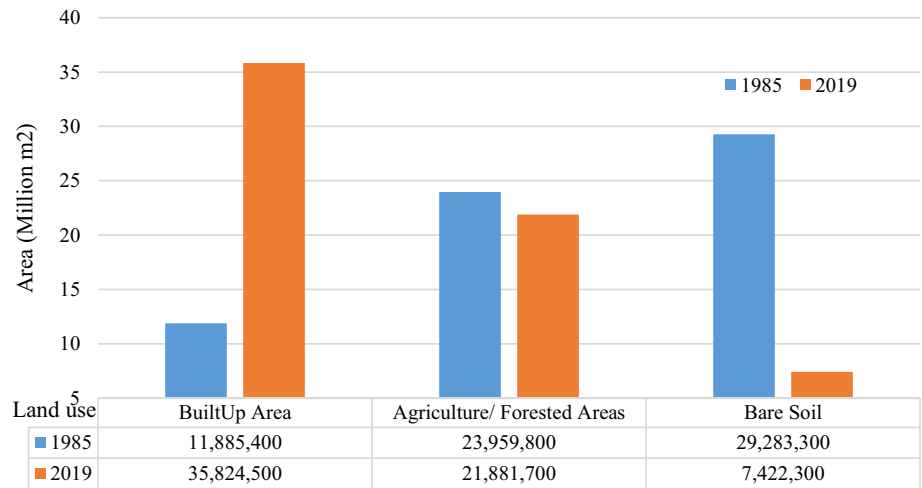


Fig. 5 Dynamics of land use from year 1985 to year 2019

Fig. 6 Change in areas of land use between years 1985 and 2019



6 Discussion

This section is divided into two subsections. The first subsection discusses the actual effect of constructing the new highway on this trend and it compares the trend of built-up LU before and after the construction of the highway. In the second subsection, the correlation between the evolution of built-up LU and the accessibility indexes of the newly constructed highway is investigated.

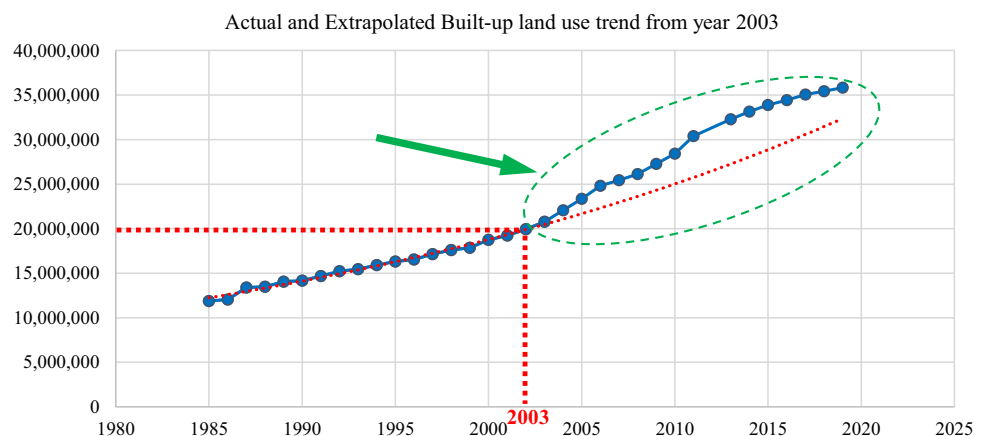
6.1 The impact of Construction a New Highway on Built-Up Land Use Dynamics

Figure 7 highlights an inflection point in the evolution trend of the areas of built-up LU from year 1985 to year 2019. This point refers to year 2003 where the construction of highway was completed [24]. An extrapolation of the built-up LU trend before 2003 was made to estimate the evolution for the period between years 2004 and 2019 as indicted in Fig. 7.

The difference between actual and estimated built-up LU for the period between year 2004 and year 2019 shows that the impact of highway led to an increase in built-up areas’ growth rate by 13.9% more than the rate of the precedent trend. The first hypothesis proposed in the study is partially validated. The impacts of a newly constructed highway on built-up LU, observed as a boost in the urban development in adjacent areas, assert the first part of the hypothesis. However, this accelerated increase in urban development occurred mainly at the expense of bare soil but the green areas are globally preserved. Several interviews with policy makers [40, 41], officials [25, 42, 43], economists [44], real estate developers [45] and brokers [46–48] and historians [49] were carried out to identify factors steering this variation in LU evolution.

Based on these interviews, it was concluded that the Lebanese government indirectly revitalized the urban development in the study area, previously considered as rural area, by constructing the said highway road and the essential infrastructure utilities as the water, sewer and electrical networks within four kilometers from the highway. Moreover,

Fig. 7 Inflection point and change in built-up land use trend in year 2003



housing loans were subsidized by the government and supported the Lebanese banking sector. The trigger factor for this LU variation is the construction of highway and the complementary infrastructural utilities which led to increase the accessibility and enhance social and economic activities of the study zone.

In order to understand LU distribution and transitions relatively to the distance from the highway, the study area was divided into seven uniform clusters with one-kilometer width per cluster. It is worth noting that no previous studies have determined the impact zone of the highway [17]. However, two studies indicated that the LU change induced by the new highway took place in a buffer zone of one kilometer apart from the mentioned highway [50, 51]. The study conducted by Song et al. [17] considered that the impact zone of a highway is extended to two kilometers apart from it due to rapid urbanization in the study area. The authors divided the impact area into ten intervals to better study the dynamics of built-up land use. In this paper, the impact zone of highway is assumed to be extended to seven kilometers away from highway since the study area represents one of the suburban

areas located directly around the Lebanon's capital "Beirut." Figure 8 illustrates the seven clusters of the study area.

The evolution of built-up areas of clusters over the period 1984–2019 is depicted in Table 6 in "Appendix 3."

Figure 9 highlights the evolution of the built-up LU areas within these cluster over the period extended from year 1984 to year 2019.

The figure shows that the cluster 1 had witnessed an acceleration in the pace of built-up LU evolution for the period extending from year 1999 to year 2004 and witnessed different variations over the next periods. However, the evolution of built-up LU in clusters 2,3,4,5 and 6 witnessed slight accelerations starting by year 2004.

The pace of built-up development in cluster 1 has accelerated in the period extended from year 1999 to year 2004 during the period of the construction works in Beirut southern entrance. This increase in urban development in cluster 1 from year 1999 to year 2004 could be referred to two main reasons. First, the knowledge of real estate developers by the intention of the government to build essential infrastructure in the study area such as the highway and all related

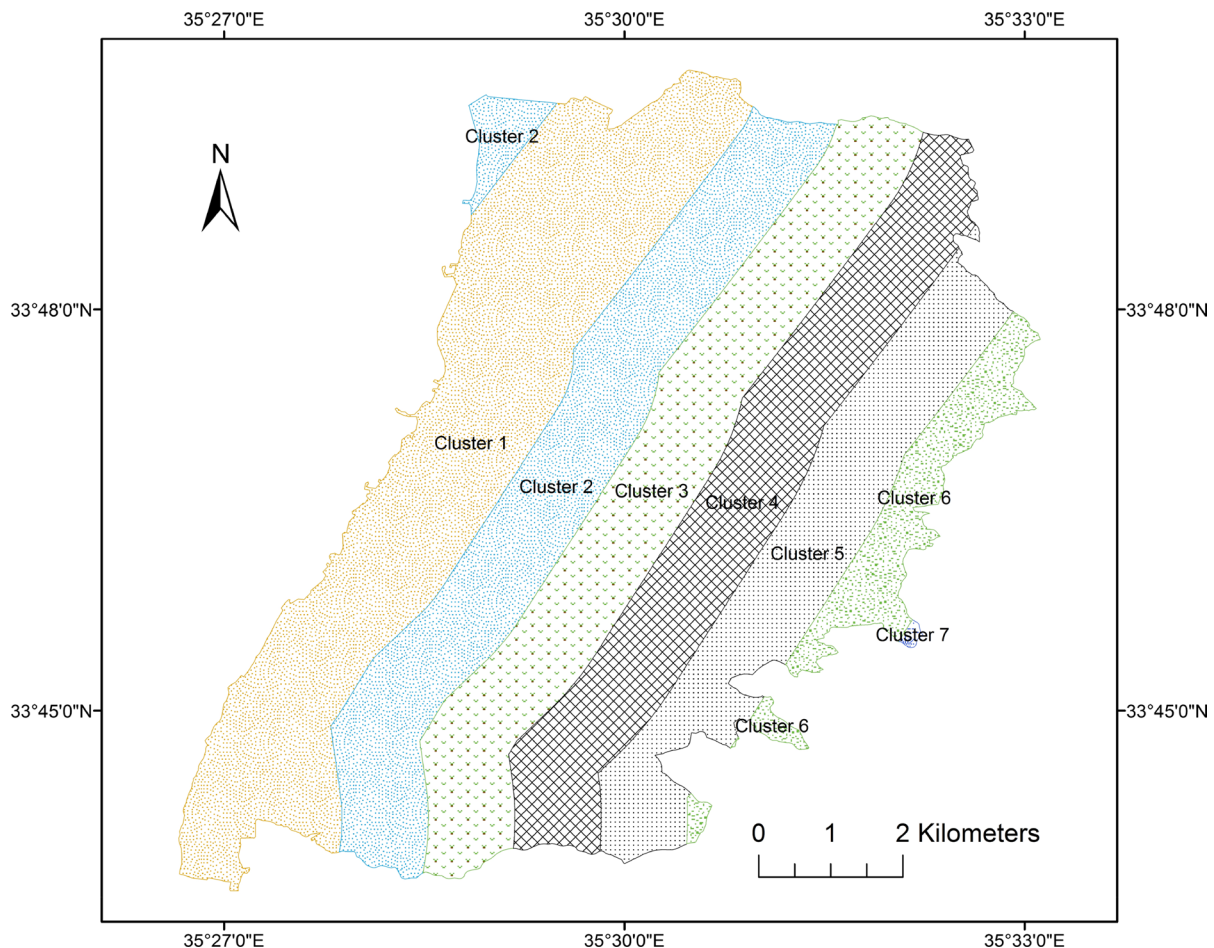
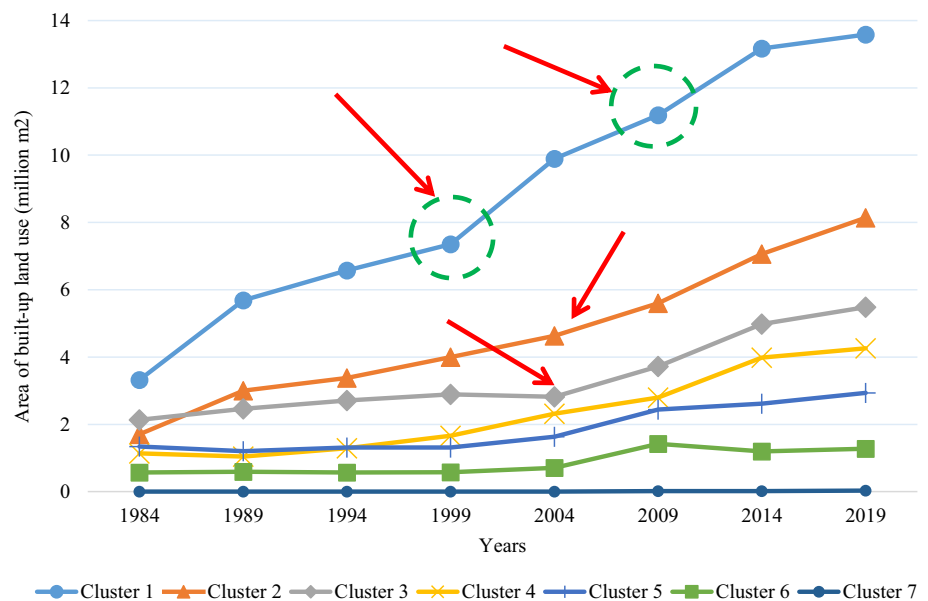


Fig. 8 The clusters of the study area

Fig. 9 Built-up land use distribution within clusters (1984–2019)



infrastructure utilities since the framework of different constructions and reconstruction projects was declared within the Project Law No. 246 dated July 17, 1993 [24]. Second, the high level of accessibility characterizing this cluster due to its proximity to highway. All interviewees pointed out that the real estate developers anticipated that the construction of the highway will increase the housing demand in this area, so they started investing in real estate development immediately after the start of highway's construction works and extensively by year 1999.

For the next period which is extended between year 2004 and year 2009, the pace of the increase in built-up areas in cluster 1 has diminished significantly. This decrease is due primarily to the instability of internal and external security conditions starting by the assassination of the prime minister Rafic Hariri in 2005 followed by the Lebanese-Israeli war in 2006 and the internal security turbulences that occurred over a period extended from the summer of year 2006 until May 2008 where the election of a new president of the Lebanese Republic occurred.

Nevertheless, some interviewees argued that these security situations (2004–2009) have slowed down the urban development in cluster 1 but conversely have increased the development in clusters 2,3,4,5 and 6 especially after the Lebanese-Israeli war in 2006 since the built-up blocks in these clusters represent affordable and temporary substitute residences for the displaced people because of war.

The period extended from year 2009 and 2014 was characterized by a recovery and a revitalization in the estate development sector in cluster 1. All interviewees reported that the increased governmental support of housing loans and the good financial, economic and political situation in addition to stable internal and external security conditions

after the election a new president of Lebanon in 2008 has subsidized the estate sector in cluster 1 as well as in the other clusters. Besides, the growth in gross domestic product (GDP) in Lebanon reached its peak value of 10.05% in year 2009 over the period 1996 to 2018 [52].

This increase in the GDP reflects a strong economic, banking and financial sector which created an attractive investment environment in Lebanon. Moreover, the arrival of Syrian refugees due to the Syrian war that started in 2011 [53] has increased the housing demand starting from year 2011 and promoted real estate market. Some interviewees indicated that the international economic crisis that occurred in year 2008 did not affect the economic situations in Lebanon which was characterized by a growth in banking sector, and inversely it pushed and encouraged many Arabic gulf investors to make short term investments in Lebanon in the form of real estate trades or financial deposits. They indicated also that the increased expatriate's financial transfers and the increased foreign deposits in Lebanon have emphasized the estate sector during this period.

Contrariwise, the period extended from year 2014 to year 2019 witnessed a dramatic decrease in the pace of the increasing evolution of the investment in real estate sector in clusters 1, 2, 3 and 4. All interviewees who pointed out that during this period the extensive built real estate supply was surpassing significantly the demand, and that a reduction in the number of provided housing loan was recorded. Furthermore, some interviewees indicated that the decrease in petroleum price between years 2014 and 2015 [54] has prevented the sovereign wealth funds of the Arabic petroleum-producing countries especially the Arabic gulf countries to invest in Lebanon and to transfer financial deposits to Lebanon. Moreover, the Syrian war that started in year

2011 [53] and the terroristic menaces from the Islamic State of Iraq and the Levant (ISIS) in years 2015 and 2016 have negatively affected the Lebanese economy and security conditions after the year 2015.

6.2 Correlation Between Built-Up Land Use and Accessibility Indexes

Figure 10 illustrates the correlation between the areas of built-up LU and the accessibility indexes of the highway. The curve shows two steady linear correlation states separated by significant change phase. This changing state that occurred between year 2011 and year 2013 is explained by an accelerated increase in built-up areas overpassing the increase in accessibility and coupled by the increasing number of Syrian refugees [33, 53]. Many studies indicated that the ongoing Syrian war that started in 2011 has resulted in forced displacement and migration of millions of Syrians [55–57]. For instance, in the year 2017, Lebanon has hosted more than one million Syrian refugees during this period in addition to its 4.5 million inhabitants [55]. Similarly, and by year 2019 Lebanon has hosted approximately 1.5 million Syrian refugees [57].

The “High Commissioner for Refugees” of the United Nations [53] indicated that the number of registered Syrian refugees was around 800,000 persons by end of year 2013.

The increased housing demand caused mainly by the sudden arrival of Syrian refugees was fulfilled by constructing new residences that are not highly accessible to the highway in the study area, which explains the correlation changing phase.

Figure 11 highlights the evolution of population and highway accessibility index over the period extended from year 2004 to year 2019.

The figure indicates that the values of highway accessibility index are exceeding those of population ($\times 100$ person). This distance between the two curves saved a constant value over the period extended from year 2004 to year 2011.

However, from year 2011 to year 2013, the distance’s value has decreased and this is mostly explained by the increasing number of Syrian refugees.

Starting by year 2014, this distance between the two curves restitutes its value till year 2016 where the accessibility started to increase. Starting by year 2017, this distance increased due to the increase in accessibility generated from an enhancement in the level of service of

Fig. 10 Correlation of built-up land use and accessibility of the study area

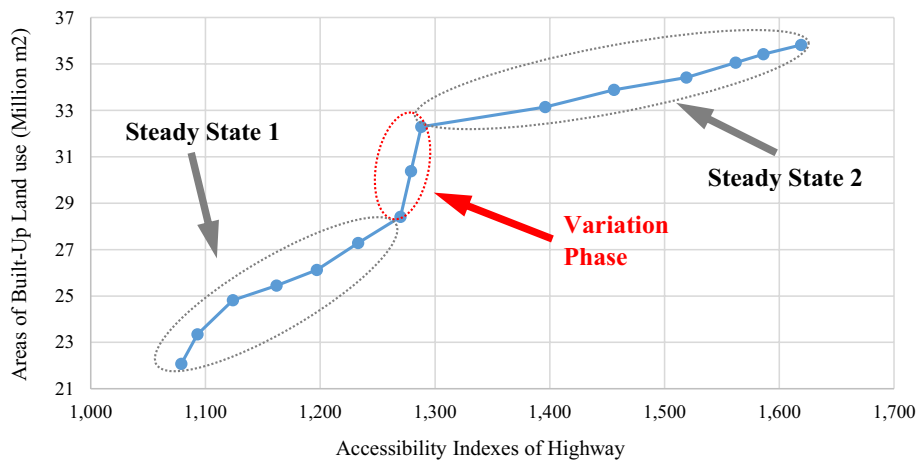
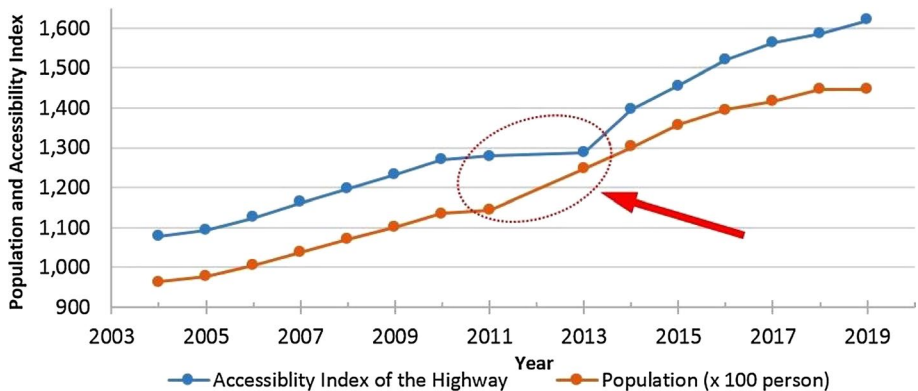


Fig. 11 Evolution of population and highway accessibility index (2004–2019)



transport infrastructure and the decelerated pace of urban development.

The steady phase 2 reflecting the accessibility index over the period extended between 2014 and 2019 is illustrated in Fig. 12. The figure shows that the accessibility index has increased at higher rate compared to the increase in the area of built-up LU from the value 1288 in year 2013 to the value of 1,369 in year 2014 (Phase A).

This indicates that the distribution of residents is centered in regions characterized by high accessibility and in proximity to the highway.

Figure 13 asserts the accelerated accessibility increase within phase A, shown in Fig. 12. The percentages of

built-up areas in the two first clusters (1 and 2) are strongly increasing especially between years 2013 and 2014. In year 2014, these percentages reached high values of 70% in cluster 1 and 55% in cluster 2.

Figure 13 shows that during the last five years, from 2014 to year 2019, the percentage of development areas relatively to the total area of clusters 1 and 2 did not change significantly. Thus, the urban development in these clusters became more condensed leading to a significant elevation in property prices. These high land-occupancy rates in clusters 1 and 2, which reached values more than 70% and 60%, respectively, directed the urban development, starting by year 2014, to occur in clusters 3, 4, 5,6 and 7 that are more distant from the

Fig. 12 Correlation of built-up ;and use and accessibility between 2013 and 2019

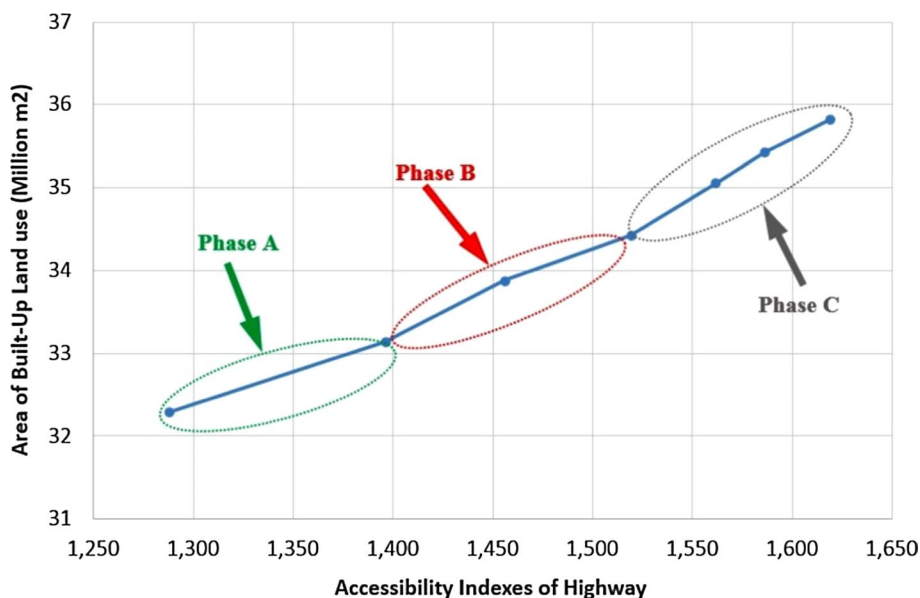
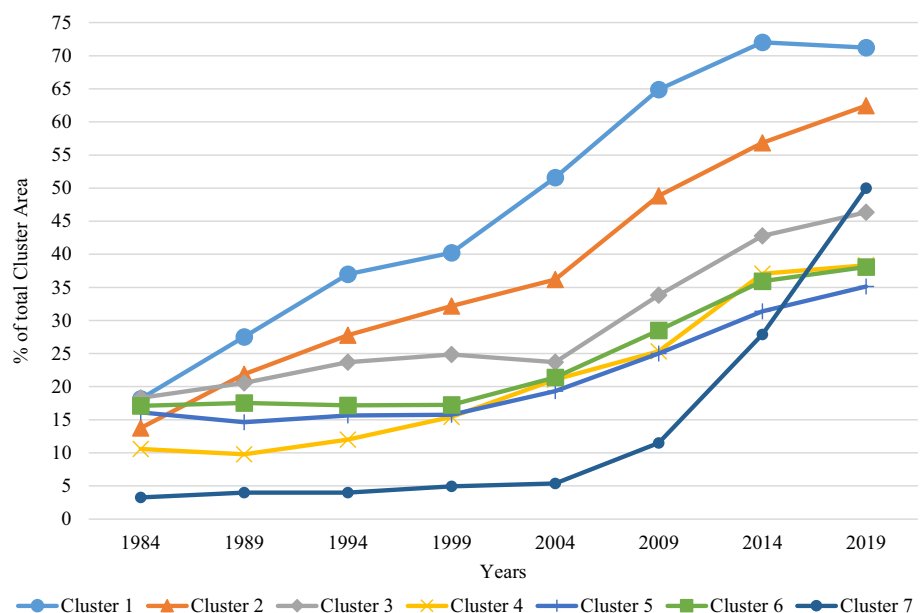


Fig. 13 Percentage of built-up areas in each cluster



highway and characterized by less accessibility rates. This locative steering of urban development toward more vacant lands that are distant from the highway justifies the constant phase (phase B) and the decelerated phase (phase C) trends of accessibility increase corresponding to two temporal periods between years 2014–2016 and 2016–2019, respectively. The second hypothesis of the study was validated since the population growth in addition to their locative distribution has significantly affected the accessibility level.

7 Conclusion and Future Research

This paper investigates the effects of constructing a new highway on the LU dynamics in the southern area adjacent to Beirut, Lebanon. The study investigated the evolution of land uses in the study area located in a neighboring zone adjacent to the highway's alignment and geographically limited by an average width of six kilometers. The land use evolution from year 1985 to year 2019 was observed through the LU maps generated from satellite Landsat images with a resolution of 30 m using the maximum likelihood image classification process in ArcGIS 10.6.1 software. The LU type used in the classification process was the built-up areas, the green areas which comprises the forests and the agriculture lands and the bare soil zones. The evolution trend of these land uses reveals an increase in built-up areas occurring simultaneously with a decrease in bare soil areas with the same rates of changes. However, the total area of green lands had some minor changes during this period. It was remarkably noted that directly after the construction of a new adjacent highway was completed, the trends of built-up LU and bare soil areas changed slopes and showed inflection points.

This is mainly referred to the newly constructed highway where the construction of this highway is considered as the main triggering factor that encourages and accelerates the growth of the urban development in this zone. The effect of highway construction was investigated specifically on the pace of dynamics of built-up areas where the actual trend before the highway, from year 1985 to year 2003, was extrapolated from year 2003 to year 2019 and compared to the current trend. This comparison revealed that the new

highway has accelerated the increase in built-up areas by 12% over the period between years 2003 and 2019.

This additional accessibility was explained as the increase in the highway's accessibility index which is based on the travel time between the highway and the local towns of the studied area, and the number of attractive masses considered in this study as the number of households/residences.

A correlation curve linking the values of highway accessibility indexes and the total area of built-up LU for years 2004 to 2019 showed that this correlation is highly affected by the growth and any sudden change of population in addition to the built-up saturation level in nearer towns.

Findings of this study show that the construction of a new highway in developing countries will increase the accessibility to adjacent and neighboring areas. The increased accessibility will in turn accelerate significantly the increase in the built-up development. Similar studies but in developed countries as the study conducted by Lein and Day [16] in the USA and the study conducted by Song et al. [17] in China show that the impacts of newly constructed highway on LU were observed as the conversion of farmlands into built-up areas. The similarity in the findings of this study and the previous relevant studies is presented as an accelerated increase in the areas of built-up developments in both developed and developing countries. However, the difference is seen as the type of LU conversions. For instance, while in developed countries the built-up areas are taking place at the expense of farmlands and green zones, the built-up development in the study area of this paper takes place in bare soil lands. Further studies could identify the types of LU over which the evolution of urban development in developing countries is taking place. Also, future studies are needed to investigate the LU impacts of highway on adjacent zones in function of time. Moreover, while urban development is mainly taking place in bare soil lands, it would be useful to study more carefully the evolution of built-up LU in interaction with agricultural and forested areas.

Appendix 1

See Tables 2 and 3.

Table 2 Population of towns for years: 2004 to 2011

Town	2004	2005	2006	2007	2008	2009	2010	2011
Ain-Enoub	3065	3105	3193	3303	3402	3504	3609	3634
Ain Drafile	403	409	420	435	448	461	475	478
Aramoun	4518	4576	4705	4868	5014	5164	5319	5356
Baouarta	1049	1062	1092	1130	1164	1199	1235	1243
Bchamoun	3791	3840	3949	4085	4208	4334	4464	4495
Chouaifat Amroussyat	17,663	17,891	18,398	19,032	19,603	20,191	20,797	20,941
Chouaifat Oumara	20,651	20,917	21,511	22,252	22,919	23,607	24,315	24,483
Chouaifat Qobbat	30,728	31,123	32,006	33,109	34,102	35,125	36,179	36,429
Deir-Koubel	1855	1879	1933	1999	2059	2121	2185	2200
Sarahmoul	242	245	252	261	269	277	285	287
Bsaba Wadi Dlab	565	572	588	608	627	645	665	669
Kfarchima	6050	6128	6302	6519	6715	6916	7124	7173
Naamat	5808	5883	6050	6258	6446	6639	6839	6886

Table 3 Population of towns for years: 2012 to 2019

Town	2012	2013	2014	2015	2016	2017	2018	2019
Ain-Enoub	3659	3967	4137	4317	4437	4506	4602	4599
Ain Drafile	481	522	544	568	584	593	605	605
Aramoun	5393	5846	6097	6362	6538	6641	6781	6778
Baouarta	1252	1357	1415	1477	1518	1542	1574	1573
Bchamoun	4526	4906	5117	5339	5488	5573	5691	5688
Chouaifat Amroussyat	21,085	22,856	23,839	24,873	25,565	25,965	26,514	26,500
Chouaifat Oumara	24,652	26,723	27,872	29,081	29,890	30,358	31,000	30,983
Chouaifat Qobbat	36,679	39,761	41,471	43,270	44,473	45,169	46,125	46,100
Deir-Koubel	2215	2401	2504	2613	2685	2727	2785	2784
Sarahmoul	289	313	327	341	350	356	363	363
Bsaba Wadi Dlab	674	731	762	795	817	830	848	847
Kfarchima	7222	7829	8166	8520	8757	8894	9082	9077
Naamat	6933	7516	7839	8179	8406	8538	8719	8714



Appendix 2

See Tables 4 and 5.

Table 4 Population, density and areas of built-up land use in the study area and the accessibility index of Highway for years 2004 to 2019

Year	Built-up area (m ²)	Accessibility index of highway	Total population of the study area	Density (person/km ²)
2004	22,076,100	1079	96,388	1480
2005	23,344,200	1093	97,630	1499
2006	24,819,300	1124	100,399	1541
2007	25,447,500	1162	103,859	1595
2008	26,119,800	1197	106,976	1642
2009	27,279,900	1233	110,183	1692
2010	28,407,600	1270	113,491	1742
2011	30,384,000	1279	114,274	1755
2013	32,294,700	1288	124,728	1915
2014	33,141,600	1396	130,090	1997
2015	33,883,200	1456	135,735	2084
2016	34,421,400	1519	139,508	2142
2017	35,054,100	1562	141,692	2175
2018	35,424,000	1586	144,689	2221
2019	35,824,500	1619	144,611	2220

Table 5 Evolution of land use in study area over years 1984 to 2019

Year	Land use area (m ²)		
	Built-up area	Agriculture/forested areas	Bare soil
1984	10,260,000	19,494,900	35,373,600
1985	11,885,400	23,959,800	29,283,300
1986	12,049,200	22,647,600	30,431,700
1987	13,395,600	21,527,100	30,205,800
1988	13,485,600	20,714,400	30,928,500
1989	14,042,700	20,375,100	30,710,700
1990	14,169,600	20,758,500	30,200,400
1991	14,696,100	22,302,000	28,130,400
1992	15,223,500	23,859,000	26,046,000
1993	15,466,500	23,787,000	25,875,000
1994	15,907,500	23,846,400	25,374,600
1995	16,312,500	22,831,200	25,984,800
1996	16,535,700	22,932,000	25,660,800
1997	17,136,900	24,345,000	23,646,600
1998	17,587,800	23,737,500	23,803,200
1999	17,863,200	22,062,600	25,202,700
2000	18,740,700	23,944,500	22,443,300
2001	19,229,400	22,350,600	23,548,500
2002	19,944,000	24,468,300	20,716,200
2003	20,787,300	25,500,600	18,840,600
2004	22,076,100	28,538,100	14,514,300
2005	23,344,200	25,592,400	16,191,900
2006	24,819,300	25,336,800	14,972,400
2007	25,447,500	26,428,500	13,252,500
2008	26,119,800	19,030,500	19,978,200
2009	27,279,900	23,018,400	14,830,200
2010	28,407,600	21,462,300	15,258,600
2011	30,384,000	19,684,800	15,059,700
2013	32,294,700	20,878,200	11,955,600
2014	33,141,600	22,371,300	9,615,600
2015	33,883,200	21,844,800	9,400,500
2016	34,421,400	19,710,900	10,996,200
2017	35,054,100	21,197,700	8,876,700
2018	35,424,000	21,900,600	7,803,900
2019	35,824,500	21,881,700	7,422,300

Appendix 3

See Table 6.



Table 6 Evolution of Built-up areas of clusters over the period 1984–2019

Year	Cluster							Total area (m ²)
	1	2	3	4	5	6	7	
1984	3,321,000	1,709,100	2,132,100	1,138,500	1,343,700	613,800	1800	10,260,000
1989	5,425,497	2,918,607	2,559,700	1,142,200	1,343,800	650,700	2196	14,042,700
1994	6,561,332	3,351,735	2,702,937	1,294,200	1,344,000	651,100	2196	15,907,500
1999	7,304,200	3,996,900	2,895,300	1,659,600	1,344,900	659,600	2700	17,863,200
2004	9,831,401	4,694,533	2,828,325	2,319,300	1,634,400	765,200	2941	22,076,100
2009	11,666,023	6,045,648	3,724,200	2,799,900	2,086,200	951,615	6314	27,279,900
2014	13,281,300	7,060,500	4,982,400	3,985,200	2,617,200	1,199,700	15,300	33,141,600
2019	13,280,306	8,064,889	5,650,100	4,383,300	3,092,200	1,325,955	27,750	35,824,500

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