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ORIGINAL PAPER

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Land use impacts of implementing a bus rapid transit system: case of Beirut southern corridor

Walid Al-Shaar^{1*} , Jocelyne Adjizian-Gérard², Olivier Bonin¹  and Nabil Nehme³

Abstract

This study investigates and forecasts the effects of implementing a newly proposed Bus Rapid Transit (BRT) system in Lebanon on the urban land use evolution between the years 2019 and 2049. It contributes to the emerging scientific literature by proposing a technique intended to identify the potential urban land use impacts of BRT. The identification of these impacts as part of the feasibility study for the BRT is considered important for policymakers, local officials, and urban planners. The impacts are identified by conducting the Analytical Hierarchy Process, based on data collected via survey and interviews with real estate experts. The outcomes show that implementing a BRT service complemented with bus feeder services will: (i) reshape the urban fabric, in proximity to BRT routes and particularly around the stations, by triggering the Transit-Oriented Development and increasing the attractiveness of urban development by 6 to 9% according to the distance from BRT route; and (ii) increase the attractiveness of urban development projects by 11% in areas distant from the highway if these areas are characterized by high coverage of bus feeder services, low possibility of an increase in estate prices, and medium to high public acceptance of the proposed BRT.

Keywords: Bus rapid transit, Land use, Housing Attractivity, Analytical hierarchy process, Transit-oriented development

1 Introduction

A fundamental question about identifying the induced land use (LU) impacts must always be associated with the planning phase of any proposed transport system. The induced changes in the LU distribution and development affect generally the social aspects and the economic equilibrium within the impact zones. This study examines the case of a zone located next to the highway section that represents the southern entrance to Beirut city in Lebanon.

The highway section in this area suffers from several traffic and congestion problems that led the Lebanese government to adopt the concept of a new proposed Bus

Rapid Transit (BRT) project and start the corresponding studies. The study investigates the effects of the newly proposed project on urban dynamics. The information to be identified in this paper would be highly considered as a guiding/supportive tool that provides a general outline about the land development and the feasibility of the proposed transport implementation. As a response to mobility problems, as the rapid deteriorating state of traffic congestions in addition to high costs of road construction and maintenance, the Public Transportation (PT) systems appear as an essential cost effective way to serve the needed transport demand (Levinson et al., 2003).

1.1 Proposed non-effective transport solutions

Flyvbjerg et al., (2003, 2004) stated that the rail-based transit systems have been the publicly favoured transport modes for many previous years. Additionally, the rail transit systems bring positive impacts on spatial accessibility and

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urban development. However, these systems are difficult and costly to implement and operate, time-consuming when establishing the infrastructure, and not well matched to suburban mobility markets (Flyvbjerg et al., 2003, 2004 and Levinson et al., 2003). Likewise, the conventional bus systems seem to be unreliable, slow, infrequent in service, difficult to use and generally not attractive. Conventional buses are considered poorly suited to markets, old fashioned systems, with little amenities at stops and little passenger information systems (Levinson et al., 2003).

1.2 New proposed solution: bus rapid transit

A new form of Public Transport services known as the Bus Rapid Transit (BRT) has emerged in the last decades as an economic, cost effective, reliable, comfortable, frequent and fast public passenger mobility service. Against other modes of mass transit, BRT is more flexible, more economic, more cost effective, easier to be built and much more popular (Demirtaş & Acar, 2020). Appropriate use of the proposed BRT is highly linked to the urban distribution, as the spatial development, and to the corresponding policies. Understanding and defining the whole effects of BRT systems becomes increasingly important with time since the BRT systems could affect the socio-economic, political, environmental and urban forms conditions of nations (Deng & Nelson, 2011). The state of the art showed that the whole effects of BRT systems remain generally unidentified. Polzin and Baltes (2002) indicated that the awareness of the ability of BRT systems to affect LU distribution and development is considered as the most important thing to be taken into consideration during the phase of assessing a BRT project proposal. The reduced travel time and cost, the increased capacity of transportation corridors and the corresponding accessibility induced by BRT systems tend to make the urban areas in proximity to BRT stations more attractive for new residential developments and economic activities as well as for redevelopment (Carrigan et al., 2013; Deng & Nelson, 2011). These impacts are similar to those of a newly constructed highway (Al-Shaar et al., 2021). With regard to land values, the authors indicated that areas in proximity to BRT stations showed a positive impact (increase) on land/properties' values (Al-Mosaind et al., 1993; Rodriguez & Targa, 2004; Wirasinghe et al., 2013). Generally, the areas in the surrounding of BRT stations tend to be more transit dependent and dense areas, providing a diversity of LU by combining residential, commercial and other types of LU into single development areas called "Transit Oriented Development (TOD)" (Wirasinghe et al., 2013). Additionally, the authors stated that BRT systems would emphasize the "Decentralization" in form of urban expansion since they connect affordable suburban dwellings to business central districts (BCD) where the high-density development is located. The TODs

could if inappropriately planned affect negatively different social, economic and environmental aspects of the region (Wirasinghe et al., 2013). In light of this, strong coordination among urban and transport planning and an essential integration with local policies are required to be realized.

1.3 Problematic

The needed coordination and integration must be based primarily on identifying and even on forecasting the LU impacts of the proposed BRT. However, the problematic is perceived as the difficulty in quantifying and in evaluating the LU impacts of BRT and particularly in a cost-benefit analysis (Carrigan et al., 2013). The effects of BRT on urban form and land development, are not yet fully examined by the literature review (Deng & Nelson, 2011). In addition, many other sides and effects of BRT are not well recognized and understood by official decision makers, ruling, political and institutional authorities when they adopt a strict economic point of view, which could generate in consequence suboptimal transportation development decisions (Wirasinghe et al., 2013).

The purpose of this study is to evaluate, quantify and identify the spatial extent of the LU impacts of the proposed BRT. In a more detailed way, the changes in urban development induced by the proposed BRT project will be investigated. Understanding and quantifying the LU impacts are requirements that need essentially to be performed prior to implement any planned PT service. Identifying these requirements would give a big picture for the governing bodies and other stakeholders about the potential change in the urban form that will be induced by the proposed BRT service. In order to attain these objectives, the analysis of the Analytical Hierarchy Process (AHP) will be performed. The Analytical Hierarchy Process (AHP) is employed since it has been widely used for locative comparison and making decisions for suitable spatial locations. The data used to carry out the AHP are collected through conducting face to face interviews with real estate experts, and by conducting a questionnaire survey. The data collected via the interviews will reflect the property prices, the ability of these prices to increase, the availability of public transport infrastructure, and the availability of the basic infrastructural utilities (Networks of potable water, sewerage and electricity). The data collected by the questionnaire are related to the proposed BRT, public acceptance and social aspects of the participants. This research will contribute to the developing literature by identifying how the BRT will affect the spatial distribution of urban development, which leads to changes in the urban form in Lebanon. It is hypothesized that BRT systems could have impacts of attracting more new urban development in areas nearer to the service' route and stations. The hypotheses are also extended to consider that the BRT will induce urban changes in areas

within two kilometers (km) distance from its stations, and will change the urban pattern in these areas to the Transit oriented Development form. This hypothesis is based on the fact that 82% of the survey's participants stated that they are willing to walk daily for a distance of less than 10 minutes which is equivalent to 0.66 km, taking into account that the walking speed is of 4 km/hour (Williams & Thompson, 2013). The distance of 2 km was selected since the LU effects are assumed to be radially extended from BRT stations to a spatial range equivalent to three times the preferred walking length. This assumption is in line with a consideration of the availability of feeder service. With regard to limitations, this paper inspects only the effects of BRT on the built up LU and the urban expansion. The interaction among other types of LU, which will be induced by the BRT, is not examined. Moreover, the spatial extent of the LU impacts is limited within the study area. This extent could be normally limited to this area; nonetheless, it could sometimes be extended outside the geographical limits of the study area. The paper is structured as follows. The second section addresses the selection of the study area and discusses its locational, population and travel patterns aspects. The third part highlights the used research methodology and the data collection method. Section four presents and discusses the identified LU impacts of the BRT. The conclusion section summarizes the main concluding observations of this study, the limitations; and presents the proposed topics for future research.

2 Study Area

The travel pattern in Lebanon suffers from different operational and reliability problems (Council for Development and Reconstruction (CDR) and ELARD Company, 2018). Within the context of travel mode split, the Lebanese people rely mostly on private vehicles and not on public transport (PT) services because of several factors. The mismanagement, the non-reliability, the inappropriate distribution over the market and the lack of service coverage are the main problems associated with the PT systems (BlomInvest Bank, 2017; Council for Development and Reconstruction (CDR) and ELARD Company, 2018). Furthermore, the travel safety in addition to personal security against harassment and discrimination is not ensured in the PT services (Danaf et al., 2014; Kaysi et al., 2010). The lifestyles and cultural habits associated to travel behavior, which define the PT as socially inferior services in comparison to private cars (Liu, 2007), represents an additional factor in the favor of high reliance on private vehicles in Lebanon (Aoun et al., 2013). As a solution, new projects of BRT services were proposed to be put in operation in Lebanon in order to serve the traffic by linking Southern, Eastern and Northern Lebanese zones to the capital Beirut (Council for Development and

Reconstruction (CDR), 2019). The environmental and social impacts assessment report and the feasibility inception report for this BRT project indicated the urgent need for these projects to be implemented in the coastal highway of Lebanon (Council for Development and Reconstruction (CDR) and ELARD Company, 2018; Council for Development and Reconstruction (CDR), 2019).

Out of all zones adjacent to the BRT line, proposed for implementation in the coastal highway to link southern and northern Lebanese zones to the capital Beirut, the area located next to the highway of Beirut's southern entrance was selected to represent all areas to be served by the BRT. This selection seems to be random; however, some development aspects triggered it. This area represents a new potential urban development zone since it is geographically located next to the capital Beirut which is urbanely saturated. It is still under development and it was selected to forecast the induced urban development by the proposed BRT and compare it to the rate of development in the scenario of no BRT. This recent urban development is triggered by the construction of Khaldeh-Beirut highway section which was completed in the year 2003 (Al-Shaar et al., 2021).

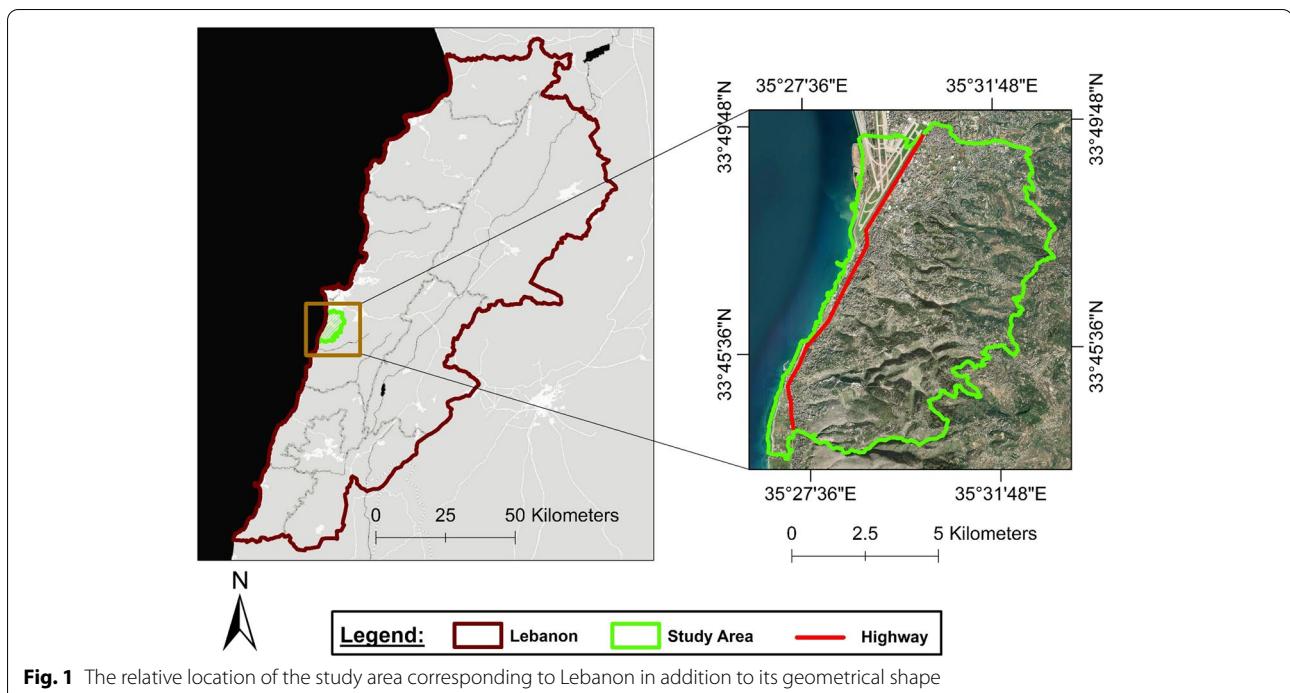
Additionally, a questionnaire survey was conducted in this area to determine and collect information related to BRT, preferences, effects and perceptiveness. Thus the survey is conducted based on the clustered sampling method. The area of the case study is extended within an almost rectangular shape with a length of 12 km and 7 km width. Figure 1 illustrates the relative location of the study area corresponding to Lebanon in addition to its geometrical shape. This area is characterized by high accessibility to the highway, representing one of the main BRT serviced zones to be affected by the proposed BRT. Moreover, the majority of its population commute daily to Beirut to achieve different social and economic activities located in the city (The World Bank Group, 2017 and IDAL, 2018).

3 Methodology and data collection

3.1 Research methodology

The adopted process of the methodology is based on three scientific pillars: (i) Prescreening the significance of the LU impacts of the proposed BRT, (ii) Quantifying, and (iii) Allocating the forecasted LU changes. First, a brief indication about the status of the proposed BRT in addition to the actual corresponding progress, in terms of required studies and design, is introduced. Some aspects of the design that are not yet defined will be proposed in this study. A preliminary screening of how significant the LU changes induced by the proposed transport implementation must be performed.

This indication provides decisive information about the feasibility and the need to assess and understand the LU impacts of the proposed BRT. If the prescreening



assessment indicates that significant LU impacts of BRT are to be expected, the processes of quantifying these changes and identifying their spatial distributions should be carried out. The general structure of the methodology is shown in Fig. 2.

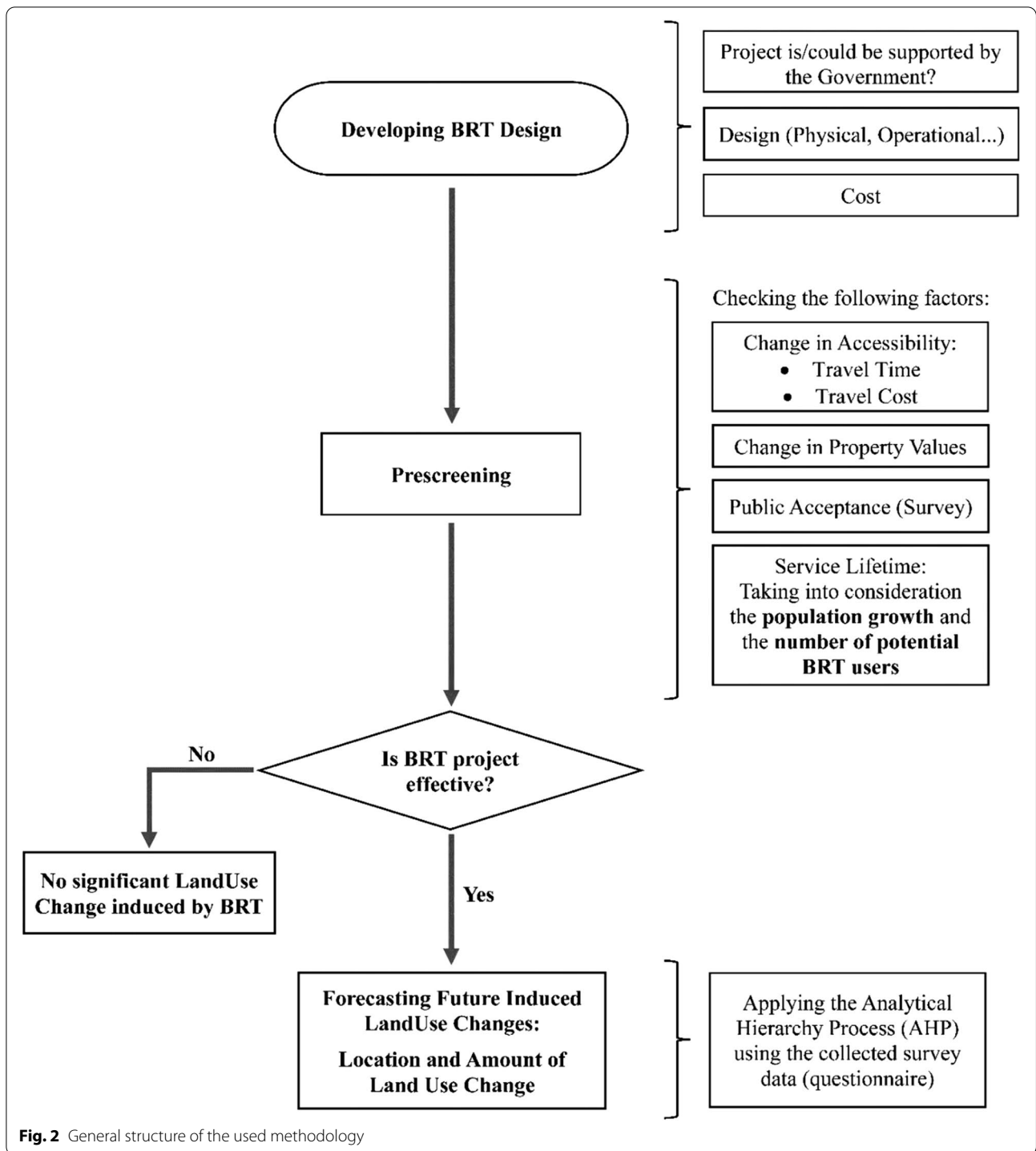
3.1.1 Proposed design

The Lebanese government has started the necessary studies for a proposed BRT project planned to link the areas along the southern Lebanese coast to Beirut city (Council for Development and Reconstruction (CDR) and ELARD Company, 2018). For instance, the proposed project was found through the feasibility study as an urgent necessity for national and infrastructural development (Council for Development and Reconstruction (CDR), 2019). Nevertheless, design studies are still in the processing phase.

Within this section, a detailed design of the proposed BRT will not be presented. However, the proposed route, lanes, running speed, stations, fare cost, service lifetime, and complementary services are discussed. The BRT route is to be implemented within the coastal highway as indicated within the feasibility study (Council for Development and Reconstruction (CDR), 2019); however, the cross-sectional geometry of the highway allows for the corresponding lanes to be separately dedicated by the form of one segregated lane per direction. In general, the BRT operating speed ranges between 60 and 80 km/hour (Siedler, 2014; Zhang, 2009). However, other references indicate that the operating speed of BRT systems could

reach 100 km/hour (Currie, 2006). Thus, the operating speed is assumed to be 80 km/hour in this study. Survey Data on the willingness to use the BRT service and to walk to reach stations were used to define the spacing between stations. Further details of this survey are presented in the succeeding data collection sub-sections. The survey revealed that 82% of potential BRT passengers are willing to walk daily to reach stations. 52% of these passengers indicate their willingness to walk for a distance of 5 to 10 minutes in each destination.

The fact that 10 minutes walking distance is equivalent to 0.66 km (Williams & Thompson, 2013) would give a preliminary indication about the selection of stations' spacing to be 1.3 km. Within the frame of fare cost, the case of Bogota's BRT was adopted. Currently, the Bogota BRT service in Colombia is extended along a network of around 200 km. Cervero (2013) stated that the daily BRT fares adopted in Bogota are equivalent to one United States Dollar (USD). Basing on these information, this study considers that a daily fare of 1 USD, which is equivalent to 8000 Lebanese Pounds in September 2020 (Lebaneslira, 2020), is fair to compensate the costs of operations and maintenance of the proposed BRT extended along 84 km routes. Moreover, this daily BRT fare of 1 USD corresponding, to 2 trips over this 84 km road section is more cost effective compared to other transport modes. For instance, the BRT fare which corresponds to 0.006 \$/km is considerably less than the average cost of transportation using: (a) private cars (0.143



\$/km (Ministry of Environment in Lebanon – United Nations Development Programme (MoE/UNDP), 2015)), (b) Jitneys (0.07\$/km), and (c) Buses and Minivans (0.044 \$/ km) as stated by many operators of Jitneys, Buses and minivans in September 2020. Additionally, the BRT feeder services are supposed to be provided, as complementary services within the study area, to facilitate the mobility of

potential BRT users between the locations of daily activities and stations.

3.1.2 BRT Service lifetime

The service lifetime based on the capacity and the ability to serve future passengers will be determined by the following factors: (i) Daily traffic counts, (ii) vehicle

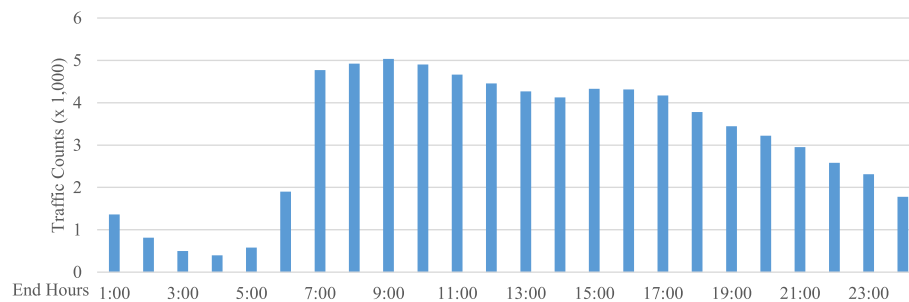


Fig. 3 Average Daily Traffic Count - North Bound (Entering Beirut)

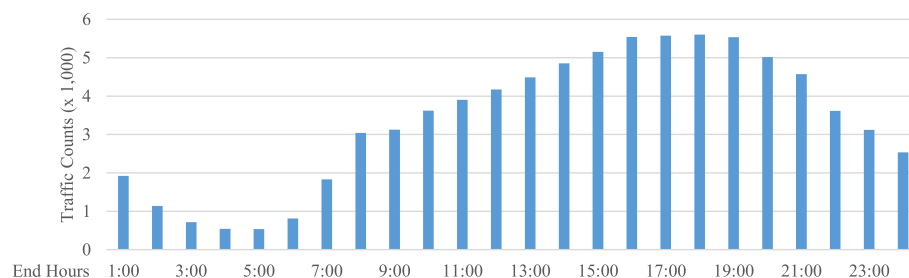


Fig. 4 Average Daily Traffic Count - South Bound (Departing from Beirut)

occupancy rate, (iii) BRT's public acceptance rate, and (iv) Expected population growth. The first three factors would indicate the total number of daily commuting passengers in both directions of the highway. The daily traffic counts were obtained from the database of the Council for Development and Reconstruction (Council for Development and Reconstruction (CDR), 2019). Figures 3 and 4 illustrate the daily traffic volume by hours for both directions of the highway road section in the study area. These traffic counts show the non-existence of traffic peak hours since a significant increase of traffic volume is observed by 6:00 AM, and since this amount of traffic remains to midnight.

The maximum hourly traffic volume was determined as 5036 and 5601 vehicles respectively for north (within the direction to Beirut) and south (for traffic departing from Beirut) bounds. The vehicle occupancy rate in Lebanon in the year 2019 was estimated as 1.2 (Saroufim & Otayek, 2019).

Taking into consideration that the counted vehicles are all private cars, the maximum number of commuting passengers is 6043 and 6721 respectively for north and south bounds. The data collection section of this study discusses in details the questionnaire survey conducted to determine the public acceptance rate and the number of potential users of the BRT service. The results indicate that 36% of respondents show their willingness to use the service. At the present time, the maximal number of hourly potential BRT users is estimated as 2175 and 2420 respectively for north and south bounds. Starting

by the year 2020, the population of Lebanon is expected to evolve in a declining trend as indicated by Lebanon Population (2019). It is assumed that the forecasted population growth is uniform over all the Lebanese towns. Hence, the maximum number of potential BRT users will potentially not exceed the total number of daily commuting passengers corresponding to 42 buses per hour taking into consideration that the maximum capacity of one BRT bus is 160 passengers (Deng & Nelson, 2011). Within the framework of accessibility provided by the BRT, specifically in terms of capacity and ability to serve passengers, and based on all aforesaid data, the proposed service lifetime would easily exceed 50 years where at the end of this period, a new study on the service reliability should be performed.

3.1.3 Prescreening

Taking this initial evaluation into account will lead to a general indication of the amount of potential LU changes the proposed BRT will generate. For instance, high probabilities of significant LU change, within the study area, are expected to occur if: (1) the induced changes in travel time ranges between 5 and 10 minutes, or exceeds 10 minutes, and if (2) significant changes in the property values will be induced by the BRT (Avin et al., 2007; ECONorthwest and Portland State University, 2001). Moreover, the authors indicated that (3) high service coverage and high public acceptance would also lead to strong LU changes. It was assumed in this research also

that (4) long service lifetimes of transport implementations will have the potential to change the urban pattern of the actual LU distribution. The results of the pre-screening assessment are presented in this subsection. Within the context of the induced change in accessibility, the calculated travel time of the BRT over this 12 km road section including acceleration, deceleration, and waiting times at stations is 14.25 minutes. The minimal differences in travel times between BRT and the general traffic (private cars) are 9.75 minutes in the morning and 3.75 minutes in the evening (Council for Development and Reconstruction (CDR), 2019). These values lead to indicate that high probabilities of significant LU change are expected to take place (Avin et al., 2007). Besides, the full proposed BRT project is designed to link the southern Lebanese coastal areas to the capital Beirut. This BRT will be implemented with high service coverage over a highway section of 84 km length. The public support and acceptability of the proposed BRT are investigated through a questionnaire survey which reveals that 86% of participants support this project and 36% of them are willing to use it as the preferred transport mode. Further details of this survey are presented in the succeeding data collection sub-sections. With respect to the service lifetime, this was predefined in the previous section as 50 years. These factors: (a) High service coverage, (b) significant transport modal share of BRT, and (c) long service lifetime, point out that considerable LU change is expected to happen (ECONorthwest and Portland State University, 2001). With regard to the induced changes in property values, several interviews with real estate developers and real estate brokers were conducted to anticipate and assess the potential variations. Detailed information on these interviews are reported in the data collection sub-section. Interviewees indicated that the implementation of a BRT service associated with bus feeder services would moderately increase the property values of areas within 2 km of stations since these areas are almost saturated in terms of urban development and since the values are elevated at present. However, they indicated that the significant increase of values is likely to occur in the next neighbouring areas which are extended within the next 2 km of radius.

3.1.4 The land use impacts of BRT: application of the analytical hierarchy process

In order to start the process of identifying the LU impacts induced by the BRT, the spatiotemporal dimensions of the studied impacts must be defined. The lifespan of the investigated impacts is considered to be over 30 years (to the year 2049). The lifespan does not exceed the lifetime of the proposed BRT (50 years); however, the spatial extent of these effects will be examined over the study

area divided into 7 adjacent clusters, with 1 km width each, distributed gradually from the highway.

Many socio-economic and infrastructural factors could affect the dynamics of the LU pattern. For instance, Avin et al., (2007) indicated that the dynamics of LU are generally affected by the actual property values and the corresponding potential changes, the accessibility to transport services in addition to the availability of water and electrical infrastructures. By integrating these factors as comparison criteria, the alternatives represented by the clusters of the study areas could be compared through the analysis of the AHP. In other words, the impacts of BRT on future built up LU distribution will be identified via the practice of the Analytical Hierarchy Process (AHP) which is a multi-criteria decision process. This process consists of scaling the criteria and the compared alternatives in addition to many calculation sequences in order to generate a final decision matrix showing the priorities/scores of the alternatives. The methodology of assessing the effects of BRT could be explained by calculating and comparing two decision matrices, differentiated by their selection criteria, where the BRT service is considered in the first matrix's criteria and not in the second one. The decision matrix that takes the BRT services into account will be used to forecast the distribution of future urban development. Figures 5 and 6 present respectively the clusters of the study area and the used analysis process to identify the urban LU impacts of the BRT, depicted within a flowchart.

In this analysis, the main objective was defined as the identification of the attractiveness of built up development. The adopted criteria comprise the factors of: Property values, their Potential to increase, the Availability of amenities and infrastructure, and the Coverage of transport feeder service. The alternatives to be compared are represented by the clusters of the study area (from 1 to 7). The hierarchical structure of the adopted AHP is illustrated in Fig. 7.

The calculation process followed during the application of the AHP is depicted by the flowchart illustrated in Fig. 12 in Appendix 7. Readers interested more in AHP could refer to Alonso and Lamata (2006).

3.2 Data collection

This sub-section presents the collected data comprising stated preferences.

3.2.1 Survey

A questionnaire survey was conducted in this study to check the public acceptance of the proposed BRT service. The adopted survey method is a combination of clustered and random sampling. The study area was selected as the listing unit for the clustered survey to represent the target population of the country (Lebanon) since the listing units of clustered surveys could be

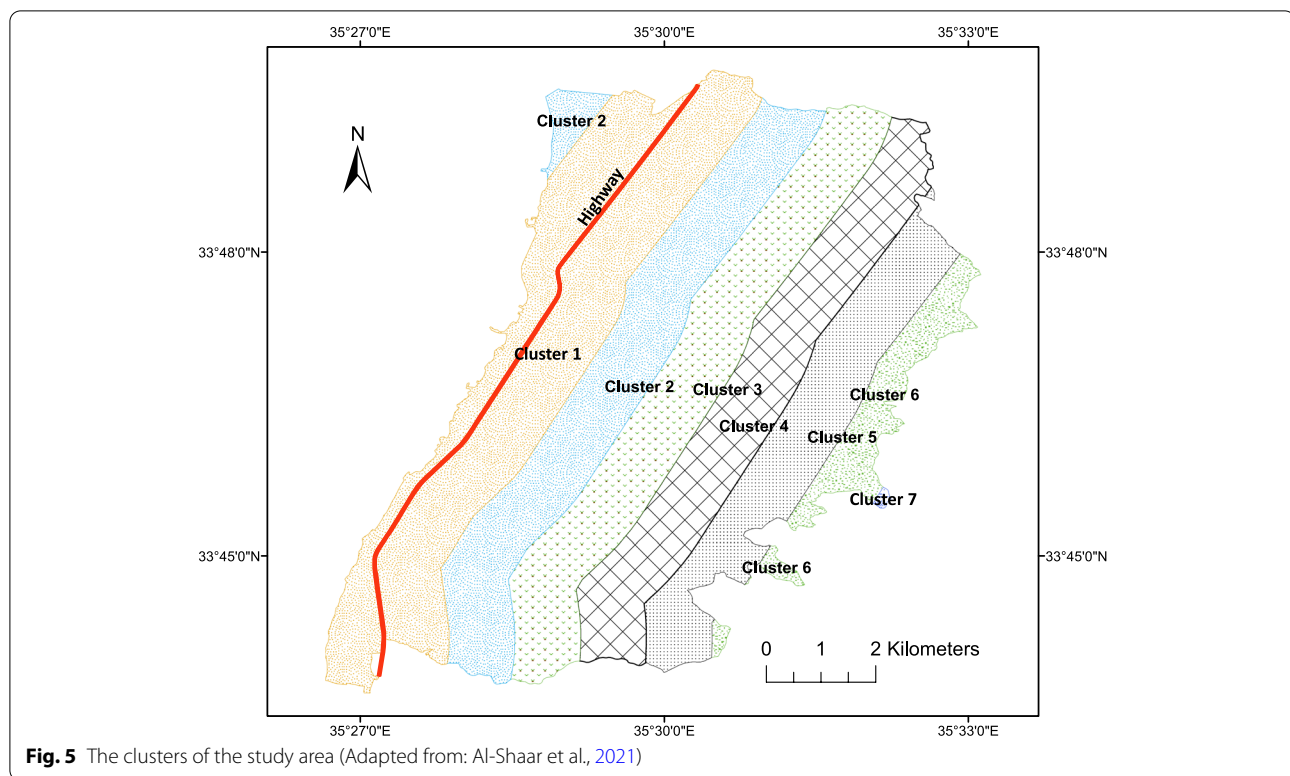


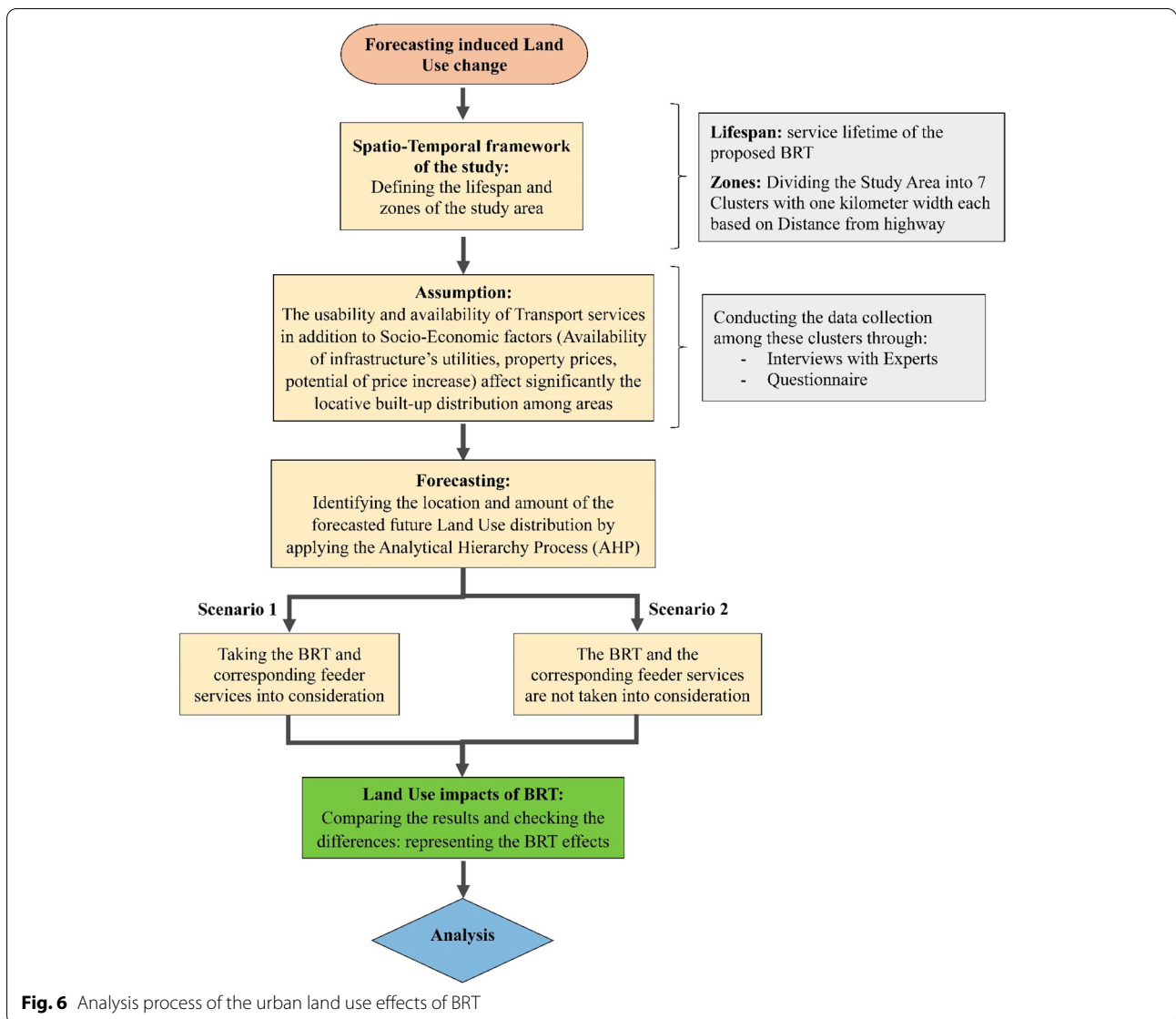
Fig. 5 The clusters of the study area (Adapted from: Al-Shaar et al., 2021)

represented by spatial units (Levy & Lemeshow, 1999). An online Google form was used to distribute the questionnaire randomly to the population of the study area towns from June 16th, 2020 to August 4th, 2020. The website link of the online survey was sent to different aldermen, municipalities' council members and residents, in each of the study area towns, after contacting them and explaining the aim of this study. Moreover, a brief description of the objectives of this survey in addition to its link was posted in social media groups of the residents in the aforesaid area. A total number of 200 valid survey responses were used to assess the public acceptance of the proposed BRT complemented with feeder bus services. With regard to the population size of the study area: 144,611 in the year 2019, a confidence level of 90% and an error margin of 5% indicate that the sample size must be 270 participants. However, due to the low participation, the total number of collected responses is 257. A response validation process was used to remove the non-significant records, among the total 257 collected responses, in order to exclude them from the analysis. Data were reviewed and validated in order to remove the following responses: (1) non-serious responses, for example the respondents who stated that they make daily trips for working or studying and at the same time stating they are retired; and (2) respondents living outside the area of study.

A confidence level of 90% and an error margin of 5.81% are associated with the 200 retained valid responses. The survey's participants represent only the study area's residents.

Other stakeholders as local officials, transport operators, business and shop owners were not involved in the survey, which is acknowledged by the authors as the main limitation of the study. Notwithstanding the foregoing, the survey's results are considered a coherent outcome since the size of the survey sampling is in compliance with the criteria of a 5.81% margin of error and a 90% level of confidence. With respect to the male-female distribution, a marginal calibration method was not applied to the survey data. The male-female ratio of respondents is 104%. This value is close enough to that indicated by the Lebanese Central Administration of Statistics: 93.7% for the year 2018 and year 2019 (Lebanese Republic Central Administration of Statistics (CAS), 2020). The survey data indicate that: (i) 81% of respondents belong to the age profile of 18 to 64 years (12% for respondents with ages between 18 and 24 years and 69% for respondents with ages between 24 and 64 years); and (ii) 77% of respondents make daily study (16%) and work trips (61%). The survey data indicates also that the proposed BRT would potentially have a significant share (36%) of the modal split against private cars, PT, and Jitneys as indicated in Fig. 8.

In a more detailed way, the public acceptance of the BRT was investigated among the towns and clusters of the study area. The public acceptance rate in each town



of the study area in addition to the percentage of town's area relatively to the clusters were used to calculate the BRT acceptance rates and priorities among clusters. These data are indicated in Tables 8 and 9 in Appendix 5.. The priorities of BRT public acceptance by cluster are depicted in Table 1.

It is worth noting that the public acceptance in cluster 7 is 0% as it is located in the fringe of the study area. Since the inhabitants of this cluster are located far from the highway, it is assumed that they perceive the BRT as reducing the roadway capacity of the highway.

While the proximity to BRT stations is perceived as advantages, low public acceptance in clusters 1 and 2 could be explained by the perception of inhabitants who see the high traffic congestion and the high levels of noise as induced by the proposed BRT in comparison to the previous situation.

3.2.2 Interviews

The LU impacts of the proposed BRT service are identified in the framework of the AHP used to compare the priorities of the key determinant drivers that could change the LU pattern within a specific area. These factors were predefined as: amenities and infrastructure, availability of BRT feeder services, potential increase of price, and property values. Two pairwise matrices of criteria were calculated based on the collected data. The difference between these two approaches is explained as the insertion of BRT feeder service in one matrix, as a selection criterion, in order to take the effects of BRT on the urban LU into account. The difference between the scores of alternatives among the two decision matrices would present the urban LU impacts of the proposed BRT. The data of the following Pair Wise Comparison Matrices as shown in Tables 2 and 3 are collected through many interviews

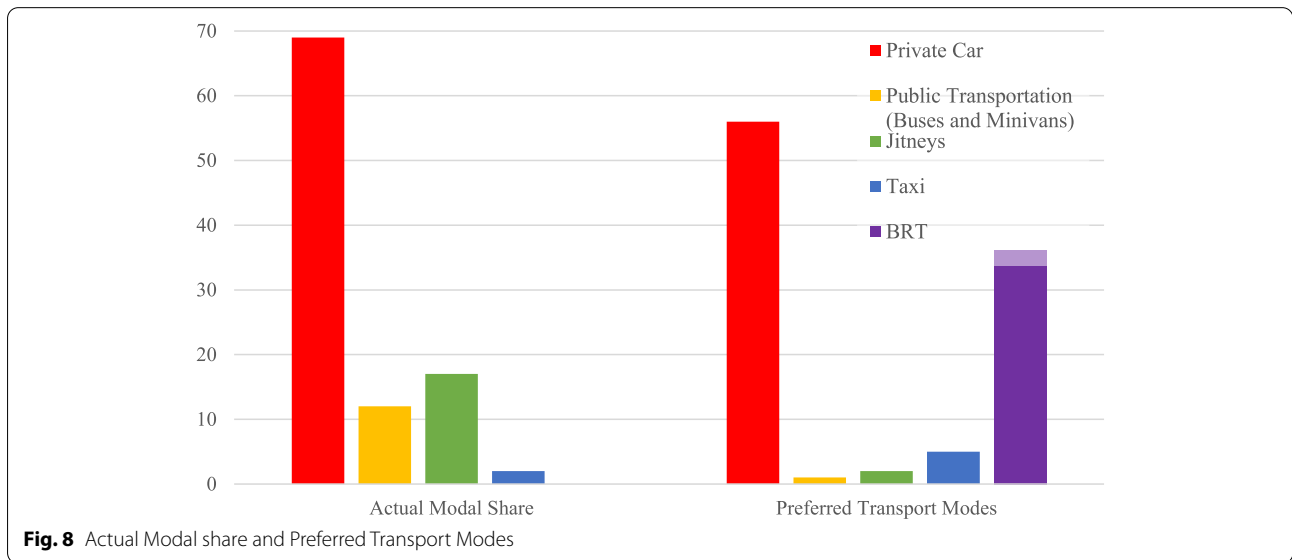
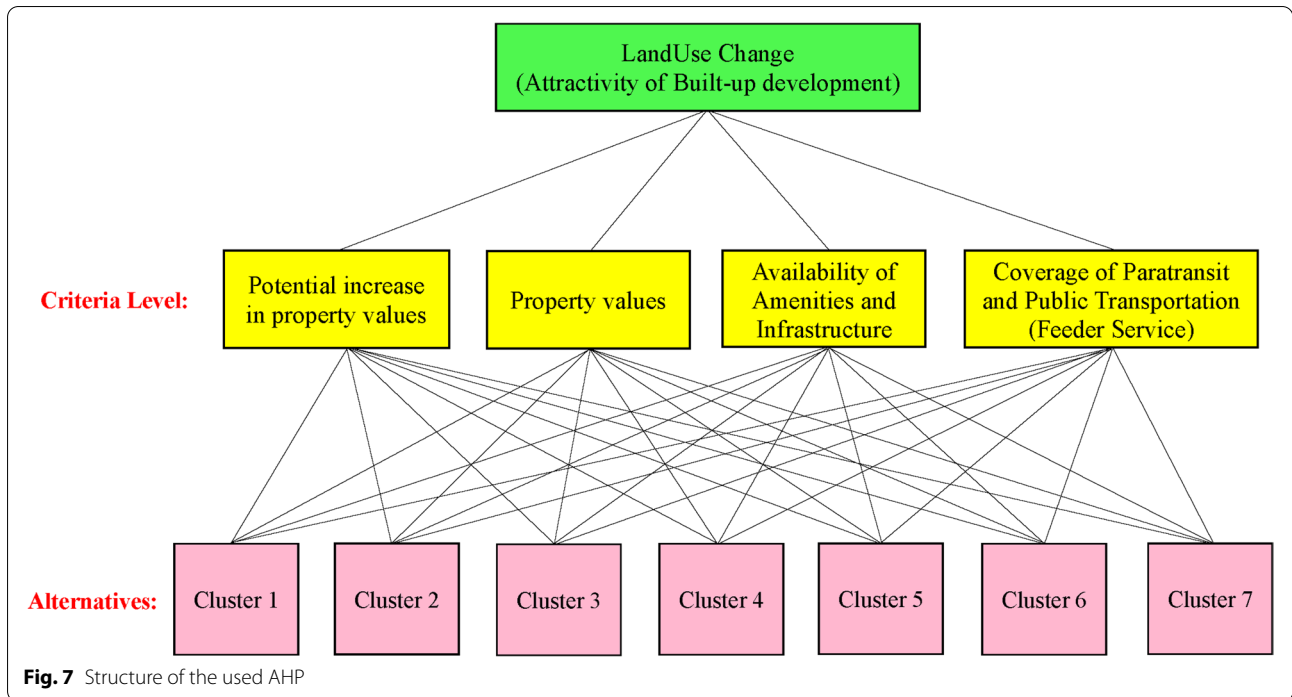


Table 1 Priorities of BRT public acceptance by cluster

| Cluster | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|----------|------|------|------|------|------|------|------|
| Priority | 0.15 | 0.16 | 0.19 | 0.18 | 0.16 | 0.16 | 0.00 |

with real estate developers (Lawand, 2020; Soubra, 2020; Wazzan, 2020; Yamout, 2020) and real estate brokers (Adada, 2020; Anouti, 2020; Mneimneh, 2020). By considering the effects of BRT, the criteria’s pairwise matrix shows that the potential increase of property prices and

the property values represent the most important criteria that determine the residential attractiveness of a specific zone within the study area; their effects’ percentages were respectively estimated by 37% and 30% using the AHP. Besides, the BRT feeder service and the availability of

Table 2 Pairwise Comparison Matrix of the used criteria (taking the BRT into consideration)

| Criteria | Amenities and Infrastructure | BRT Feeder Services | Potential increase of Price | Property Values | Priority |
|------------------------------|------------------------------|---------------------|-----------------------------|-----------------|----------|
| Amenities and Infrastructure | 1.00 | 1.00 | 0.50 | 0.50 | 0.1659 |
| Transport Feeder Services | 1.00 | 1.00 | 0.50 | 0.50 | 0.1659 |
| Potential increase of Price | 2.00 | 2.00 | 1.00 | 1.50 | 0.3674 |
| Property Values | 2.00 | 2.00 | 0.67 | 1.00 | 0.3008 |
| Total | 6.00 | 6.00 | 2.67 | 3.50 | – |
| Consistency Ratio: 0.0082 | | | | | |

Table 3 Pairwise Comparison Matrix of the used criteria (without taking the BRT into consideration)

| Criteria | Amenities and Infrastructure | Potential increase of Price | Property Values | Priority |
|------------------------------|------------------------------|-----------------------------|-----------------|----------|
| Amenities and Infrastructure | 1.00 | 0.50 | 0.50 | 0.1990 |
| Potential increase of Price | 2.00 | 1.00 | 1.50 | 0.4536 |
| Property Values | 2.00 | 0.67 | 1.00 | 0.3474 |
| Total | 5.00 | 2.17 | 3.00 | – |
| Consistency Ratio: 0.0188 | | | | |

infrastructure and amenities could affect the selection of a specific residential zone by 16.5%.

On the other side, the criteria's pairwise matrix not considering the effects of the proposed BRT shows that the potential increase of property prices represents the most important criteria that determine the residential attractiveness, of a specific zone within the study area, with a percentage of 45%. Also, the property values represent the second important selection criteria, where they could affect the selection by 35%. The availability of amenities and infrastructure is the criteria with the least effects on the selection with a percentage of 20%.

All interviewers indicated that the mentality of buying houses is the prevailing housing approach in Lebanon. Based on this, the prices of apartments in the study area were taken into consideration. The property (apartments) prices within each cluster of the study area over the year 2019 were calculated as the averages of prices indicated by all interviewees. Table 4 shows these average prices.

Based on the price's data, we assumed that the scaling ratio of relative importance will increase by a value of 1 when the price difference increases by 100 USD. Following this assumption, the pairwise comparison matrix of clusters with respect to the property prices is illustrated in Table 10 in Appendix 6. The real estate experts pointed out through the interviews that amenities as the water and electric utilities are fully provided within 2 km

from the highway, and that the services coverage starts lessening with more distance from the highway.

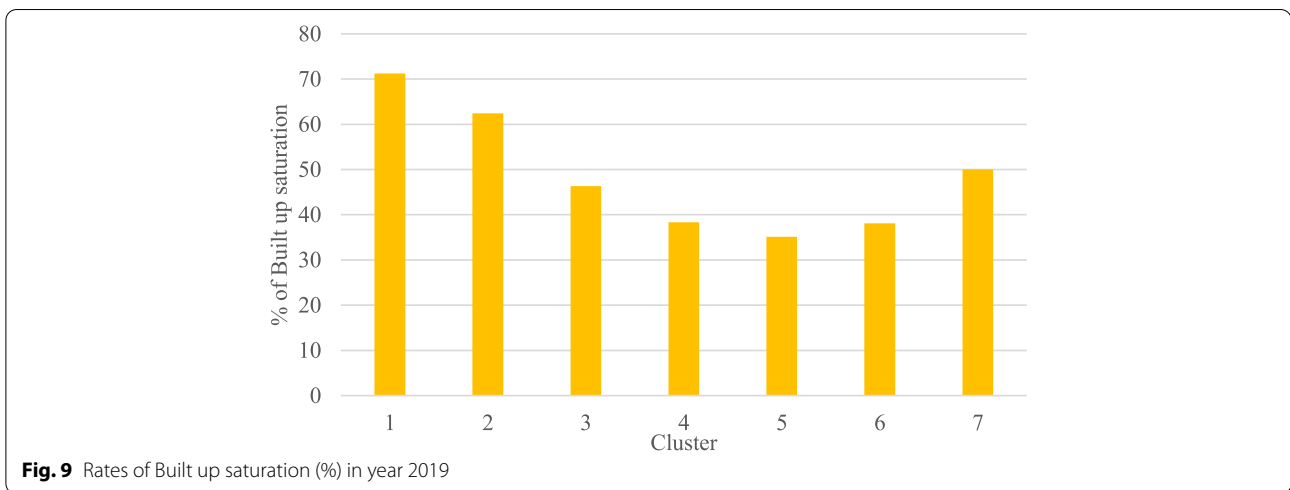
The estimated pairwise comparison matrix of clusters with respect to the availability of amenities and infrastructure is depicted in Table 11 in Appendix 6. With regard to the potential increase in property prices, the interviewees indicated that high and moderate probabilities are expected to take place respectively in clusters 4 and 5, and in cluster 3. However, low probabilities of future price increase are potentially corresponding to clusters 1, 2, 6 and 7. The real estate experts (interviewees) indicate that the urban saturation in clusters 1 and 2, and the distant location, away from the highway, of clusters 6 and 7 are the main reasons behind the foregoing low probability. Additionally, the medium and low saturation rates respectively of cluster 3, and clusters 4 and 5 in addition to the corresponding high accessibility to highway represent the main rationales behind the moderate and high potential growths of property values. These stated information are in conformity with the saturation rates for the 7 clusters. The estimated pairwise comparison matrix of clusters with respect to the potential increase in property values is depicted in Table 12 in Appendix 6. Figure 9 illustrates the urban saturation rates.

4 Land use impacts of BRT: analysis and discussion

The urban LU impacts of the proposed BRT will be identified by comparing the values of two decision matrices within the first the BRT is included as a selection criterion and not

Table 4 Property prices within the clusters of the study area for the year 2019

| Cluster | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 | Cluster 6 | Cluster 7 |
|--|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Property Values in the year 2019 (USD/m ²) | 1380 | 1200 | 1050 | 910 | 890 | 890 | 720 |



considered in the second one. The weighted decision matrix shown in Table 5 was calculated based on the data of pairwise matrices of criteria and alternatives by taking the effect of BRT on urban LU. This decision matrix shows that clusters 4 and 5 respectively ranked 1st and 2nd are the most attractive residential zones for the future period extended between the years 2019 and 2049. Cluster 4 is characterized by a high public acceptance of BRT (37.4%); however, cluster 5 is characterized by an average level of BRT’s public acceptance of 32%. Moreover, attractive residence prices in addition to a high possibility of an increase in property price represent the main aspects of these clusters. The amenities and infrastructure in these clusters are marked by their medium to low coverage. The clusters 7 and 3 ranked respectively 3rd and 4th, represent the potential future residential areas with an average level of living attractiveness.

Cluster 7 is marked by its low coverage of infrastructure, low possibility of an increase in estate prices, and no public acceptance of BRT service. Even though, the low property values in this cluster are considered attractive housing prices. As indicated in Table 5, cluster 3 is characterized by medium values of all the adopted criteria, except the BRT’s public acceptance, relatively to other clusters. The

least ranked clusters 5th, 6th, and 7th are respectively the clusters 2, 6, and 1. Despite their high coverage and availability of infrastructure and amenities services, clusters 1 and 2 are marked with their low attractiveness as residential areas. Their high property values complemented with a low potential increase of prices in addition to their medium-sized public acceptance of BRT service, prevent clusters 1 and 2 from becoming attractive future residential areas. Similarly, and notwithstanding the fact of attractive property values, the low possibility of an increase in property prices and the average public acceptance level of BRT service in addition to low service coverage of amenities and infrastructure, determine the low attractiveness of cluster 6 as a future residential area.

Similarly and in comparison to the first decision matrix, the new matrix (Table 6) which does not take the effects of BRT on urban LU into consideration indicates that the clusters keep the same decision ranks as reflected in Table 5.

A comparison of the two matrices shows a slight difference in decision scores of clusters as shown in Fig. 10. This means that the implementation of the BRT project would have little effect on the urban LU compared to other criteria. The impacts of BRT are also explained as

Table 5 Weighted Decision Matrix (BRT effects are taken into consideration)

| | Criteria | Amenities and Infrastructure | Potential increase in price | Property Values | Public Acceptance of BRT | Score | Rank |
|---------------------|-----------|------------------------------|-----------------------------|-----------------|--------------------------|--------------|----------|
| Alternatives | Cluster 1 | 0.041 | 0.030 | 0.009 | 0.025 | 0.106 | 7 |
| | Cluster 2 | 0.041 | 0.030 | 0.015 | 0.028 | 0.113 | 5 |
| | Cluster 3 | 0.027 | 0.056 | 0.029 | 0.031 | 0.143 | 4 |
| | Cluster 4 | 0.025 | 0.095 | 0.046 | 0.030 | 0.196 | 1 |
| | Cluster 5 | 0.016 | 0.095 | 0.046 | 0.027 | 0.184 | 2 |
| | Cluster 6 | 0.007 | 0.030 | 0.046 | 0.025 | 0.111 | 6 |
| | Cluster 7 | 0.007 | 0.030 | 0.109 | 0.000 | 0.147 | 3 |

Table 6 Weighted Decision Matrix (without taking into consideration the effects of BRT)

| Criteria | Amenities and Infrastructure | Potential increase in price | Property Values | Score | Rank | |
|--------------|------------------------------|-----------------------------|-----------------|-------|--------------|----------|
| Alternatives | Cluster 1 | 0.050 | 0.037 | 0.010 | 0.097 | 7 |
| | Cluster 2 | 0.050 | 0.037 | 0.017 | 0.104 | 5 |
| | Cluster 3 | 0.033 | 0.069 | 0.033 | 0.135 | 4 |
| | Cluster 4 | 0.030 | 0.117 | 0.054 | 0.201 | 1 |
| | Cluster 5 | 0.019 | 0.117 | 0.054 | 0.190 | 2 |
| | Cluster 6 | 0.009 | 0.037 | 0.054 | 0.100 | 6 |
| | Cluster 7 | 0.009 | 0.037 | 0.126 | 0.172 | 3 |

the differences in the selection scores ranging from 2% to 15% relatively to the location of the cluster and its distance from the highway. Figure 11 demonstrates that the BRT implementation would generally increase the housing attractiveness of clusters close to the highway (clusters: 1, 2, and 3), and decrease it in the distant clusters (clusters: 4, 5, and 7). This primary conclusion is in conformity with the literature indicating that the implementation of BRT projects subsidizes the residential and retail agglomerations around the BRT stations, and the Transit-Oriented Development (Wirasinghe et al., 2013). An exception in the distant cluster: 6 was remarked. In order to analyze this, a comparison, among the decision matrices, of scales corresponding to cluster 6 is carried out and highlighted in Table 7. The comparison shows that the previous scale of the BRT (0.027) was mainly restituted, in the No-BRT scenario, by a considerable increase in the scales of the property values and the potential increase in price.

Based on this, a comparison of decision scales for the “property values” and the “potential increase in price”

among cluster 6 and the preceding zone: cluster 5 is undertaken. The comparison shows the same scales of property values but considerably different scales of the “potential increase in price” ranging from 0.26 to 0.08 respectively in clusters 5 and 6 (as indicated in Appendix 6.). This comparison was carried out to identify why the BRT is expected to reduce the housing attractiveness in cluster 5 and increase it in cluster 6. The concluding remarks of this comparison are depicted as the significant effect of the potential increase in property prices in combination with the BRT impacts. In other words, the impacts of BRT could reconstitute the housing attractiveness of a specific zone in case of: (i) low possibility of prices’ increase, and (ii) significant (average to high levels) BRT public acceptance as the case of cluster 6. The same change as of cluster 6 could be predicted for cluster 7 in case the BRT had significant public acceptance. This final conclusion for the impacts of BRT on urban LU is in line with the literature pointing out that the employment of BRT services supports the Transit Oriented Development (TOD) and subsidizes

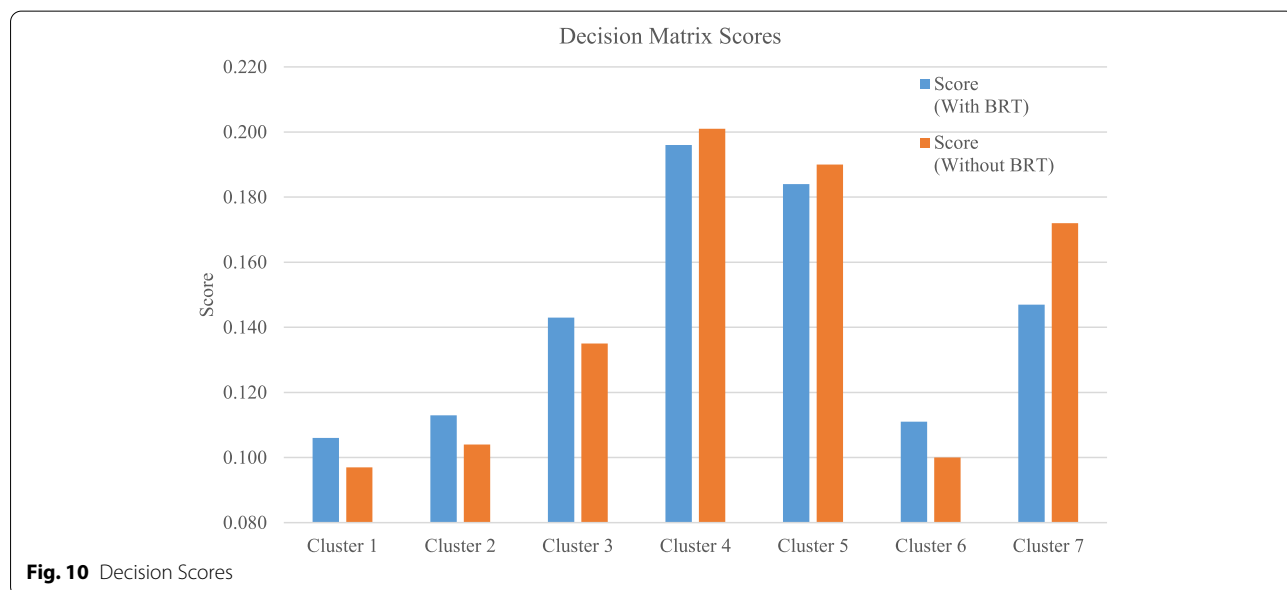


Fig. 10 Decision Scores

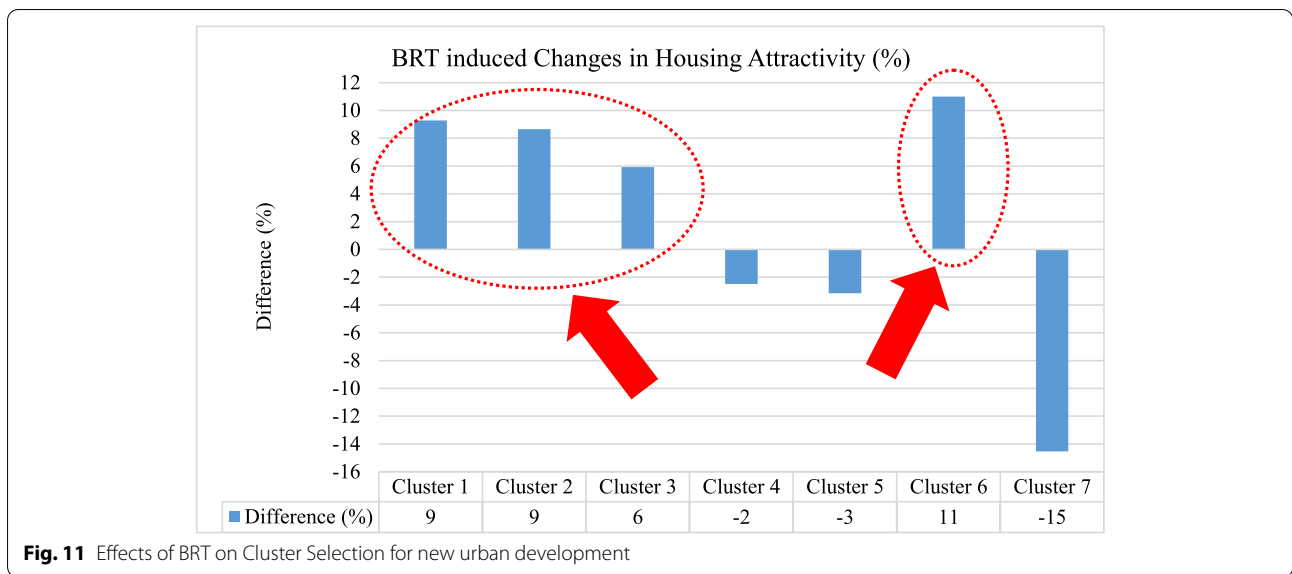


Fig. 11 Effects of BRT on Cluster Selection for new urban development

the residential and retail agglomerations around the BRT routes and particularly the stations. However, new aspects of the BRT were explored. These aspects are explained as the increase of housing attractivity of distant zones, currently characterized by low possibilities of increase in estate prices, by medium to high level of public acceptance of BRT, and good coverage of BRT feeder services.

5 Concluding remarks and future researches

This paper examines the impacts of a proposed BRT project on the urban LU and particularly the urban development between the years 2019 and 2049. The importance of this study could be depicted by the necessity to identify and assess the induced LU changes and impacts prior to start the design and the physical implementation of any transportation project and particularly the transit projects as the BRT. The conducted prescreening process indicates that the implementation of the proposed BRT service (complemented with feeder service) will potentially have a considerable amount of the induced urban LU change. The urban LU impacts are estimated by performing the Analytical hierarchy process based on survey and interview data.

These estimations are identified in terms of the amount, location and timeframe of LU changes. The study area was divided into seven clusters, of 1 km width each, distributed consecutively aside from the highway in order to track the locations of potential LU changes. The AHP indicates that implementing a new BRT service will increase the urban development in the first three clusters by 6 to 9%. The proposed service will potentially support the agglomerations of residential and retail LU in proximity to the BRT routes and particularly around the stations. This could be explained in a different way by the subsidization of the Transit Oriented Development (TOD) where the residents/workers of these areas are highly encouraged to use the rapid transit services. Moreover, the proposed BRT was identified to potentially increase the housing attractivity (by 11%) in distant areas characterized by: (a) medium to high BRT public acceptance, (b) high coverage of feeder services, and (c) low potential of increase in estate prices. Future researches are needed to examine the interrelationships of different socio-economic and legislative factors (as the property prices, amenities, transport and policies) with the urban development within the context of the structural analysis form.

Table 7 Comparing the weighting values corresponding to cluster 6 with and without BRT

| Criteria | Amenities and Infrastructure | Potential increase in price | Property Values | Public Acceptance of BRT |
|-------------------------|------------------------------|-----------------------------|-----------------|--------------------------|
| Cluster 6 (with BRT) | 0.007 | 0.030 | 0.046 | 0.027 |
| Cluster 6 (without BRT) | 0.009 | 0.037 | 0.054 | - |
| Difference | 0.002 | 0.007 | 0.008 | - |
| Difference (%) | 11.765 | 41.176 | 47.059 | - |

Appendix A

Table 8 Public acceptance rate of the BRT and town surface distribution over Clusters (% of Total Cluster’s Area)

| Public Acceptance by Town (%) | Town | % of Total Cluster’s Area | | | | | | |
|-------------------------------|-----------------|---------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| | | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 | Cluster 6 | Cluster 7 |
| 50 | Ain-Enoub | 0 | 0 | 0 | 7 | 23 | 39 | 0 |
| 25 | Ain Drafile | 0 | 0 | 7 | 11 | 9 | 0 | 0 |
| 37 | Aramoun | 6 | 30 | 20 | 17 | 23 | 22 | 0 |
| 25 | Baouarta | 1 | 10 | 15 | 18 | 15 | 4 | 0 |
| 35 | Bchamoun | 0 | 12 | 13 | 17 | 14 | 9 | 0 |
| 35 | Chouaifat | 68 | 31 | 16 | 5 | 0 | 0 | 0 |
| 44 | Deir-Koubel | 0 | 6 | 10 | 7 | 0 | 0 | 0 |
| 0 | Sarahmoul | 0 | 0 | 0 | 1 | 11 | 26 | 100 |
| 22 | Bsaba Wadi Dlab | 0 | 0 | 0 | 5 | 5 | 0 | 0 |
| 75 | Kfarchima | 0 | 0 | 13 | 11 | 0 | 0 | 0 |
| 20 | Naamat | 25 | 11 | 6 | 1 | 0 | 0 | 0 |
| Total | | 100 | 100 | 100 | 100 | 100 | 100 | 100 |

It is worth noting that the public acceptance in Sarahmoul town is 0% since it is the located in the fringe of the study area. Since the inhabitants of this town are located far from the highway, it is assumed that they perceive the BRT will reduce the roadway capacity of the highway.

The BRT public acceptance rate for each cluster = (% of total cluster’s area) x (% Public acceptance by town). These values are indicated in Table 9. In addition, the priority factor for each cluster, with regards to BRT’s public acceptance, is estimated as the ratio of “cluster’s acceptance rate” over the “sum of all acceptance rates”.

Table 9 Public acceptance rate of the BRT

| Town | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 | Cluster 6 | Cluster 7 |
|--------------------------------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Ain-Enoub | 0 | 0 | 0 | 350 | 1150 | 1950 | 0 |
| Ain Drafile | 0 | 0 | 175 | 275 | 225 | 0 | 0 |
| Aramoun | 222 | 1110 | 740 | 629 | 851 | 814 | 0 |
| Baouarta | 25 | 250 | 375 | 450 | 375 | 100 | 0 |
| Bchamoun | 0 | 420 | 455 | 595 | 490 | 315 | 0 |
| Chouaifat | 2380 | 1085 | 560 | 175 | 0 | 0 | 0 |
| Deir-Koubel | 0 | 264 | 440 | 308 | 0 | 0 | 0 |
| Sarahmoul | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bsaba Wadi Dlab | 0 | 0 | 0 | 110 | 110 | 0 | 0 |
| Kfarchima | 0 | 0 | 975 | 825 | 0 | 0 | 0 |
| Naamat | 500 | 220 | 120 | 20 | 0 | 0 | 0 |
| BRT Public Acceptance by Cluster (%) | 31.27 | 33.49 | 38.40 | 37.37 | 32.01 | 31.79 | 0.00 |
| Priority | 0.15 | 0.16 | 0.19 | 0.18 | 0.16 | 0.16 | 0.00 |

Appendix B

Table 10 Pair Wise Comparison Matrix of Alternatives with respect to Property values

| Property Values | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 | Cluster 6 | Cluster 7 | Priority |
|-----------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| Cluster 1 | 1.00 | 0.33 | 0.25 | 0.20 | 0.20 | 0.20 | 0.14 | 0.0301 |
| Cluster 2 | 3.00 | 1.00 | 0.33 | 0.25 | 0.25 | 0.25 | 0.17 | 0.0497 |
| Cluster 3 | 4.00 | 3.00 | 1.00 | 0.50 | 0.50 | 0.50 | 0.25 | 0.0954 |
| Cluster 4 | 5.00 | 4.00 | 2.00 | 1.00 | 1.00 | 1.00 | 0.33 | 0.1542 |
| Cluster 5 | 5.00 | 4.00 | 2.00 | 1.00 | 1.00 | 1.00 | 0.33 | 0.1542 |
| Cluster 6 | 5.00 | 4.00 | 2.00 | 1.00 | 1.00 | 1.00 | 0.33 | 0.1542 |
| Cluster 7 | 7.00 | 6.00 | 4.00 | 3.00 | 3.00 | 3.00 | 1.00 | 0.3621 |

Consistency Ratio: 0.0253

Table 11 Pair Wise Comparison Matrix of Alternatives with respect to the Availability of Amenities and Infrastructure

| Amenities and Infrastructure | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 | Cluster 6 | Cluster 7 | Priority |
|------------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| Cluster 1 | 1.00 | 1.00 | 1.50 | 2.00 | 3.00 | 5.00 | 5.00 | 0.2498 |
| Cluster 2 | 1.00 | 1.00 | 1.50 | 2.00 | 3.00 | 5.00 | 5.00 | 0.2498 |
| Cluster 3 | 0.67 | 0.67 | 1.00 | 1.50 | 2.00 | 3.00 | 3.00 | 0.1656 |
| Cluster 4 | 0.50 | 0.50 | 0.67 | 1.00 | 2.00 | 4.00 | 4.00 | 0.1485 |
| Cluster 5 | 0.33 | 0.33 | 0.50 | 0.50 | 1.00 | 3.00 | 3.00 | 0.0972 |
| Cluster 6 | 0.20 | 0.20 | 0.33 | 0.25 | 0.33 | 1.00 | 1.00 | 0.0445 |
| Cluster 7 | 0.20 | 0.20 | 0.33 | 0.25 | 0.33 | 1.00 | 1.00 | 0.0445 |

Consistency Ratio: 0.0118

Table 12 Pair Wise Comparison Matrix of Alternatives with respect to the Potential increase in property prices

| Potential increase in price | Cluster 1 | Cluster 2 | Cluster 3 | Cluster 4 | Cluster 5 | Cluster 6 | Cluster 7 | Priority |
|-----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|----------|
| Cluster 1 | 1.00 | 1.00 | 0.50 | 0.33 | 0.33 | 1.00 | 1.00 | 0.0825 |
| Cluster 2 | 1.00 | 1.00 | 0.50 | 0.33 | 0.33 | 1.00 | 1.00 | 0.0825 |
| Cluster 3 | 2.00 | 2.00 | 1.00 | 0.50 | 0.50 | 2.00 | 2.00 | 0.1530 |
| Cluster 4 | 3.00 | 3.00 | 2.00 | 1.00 | 1.00 | 3.00 | 3.00 | 0.2585 |
| Cluster 5 | 3.00 | 3.00 | 2.00 | 1.00 | 1.00 | 3.00 | 3.00 | 0.2585 |
| Cluster 6 | 1.00 | 1.00 | 0.50 | 0.33 | 0.33 | 1.00 | 1.00 | 0.0825 |
| Cluster 7 | 1.00 | 1.00 | 0.50 | 0.33 | 0.33 | 1.00 | 1.00 | 0.0825 |

Consistency Ratio: 0.0002

Appendix C

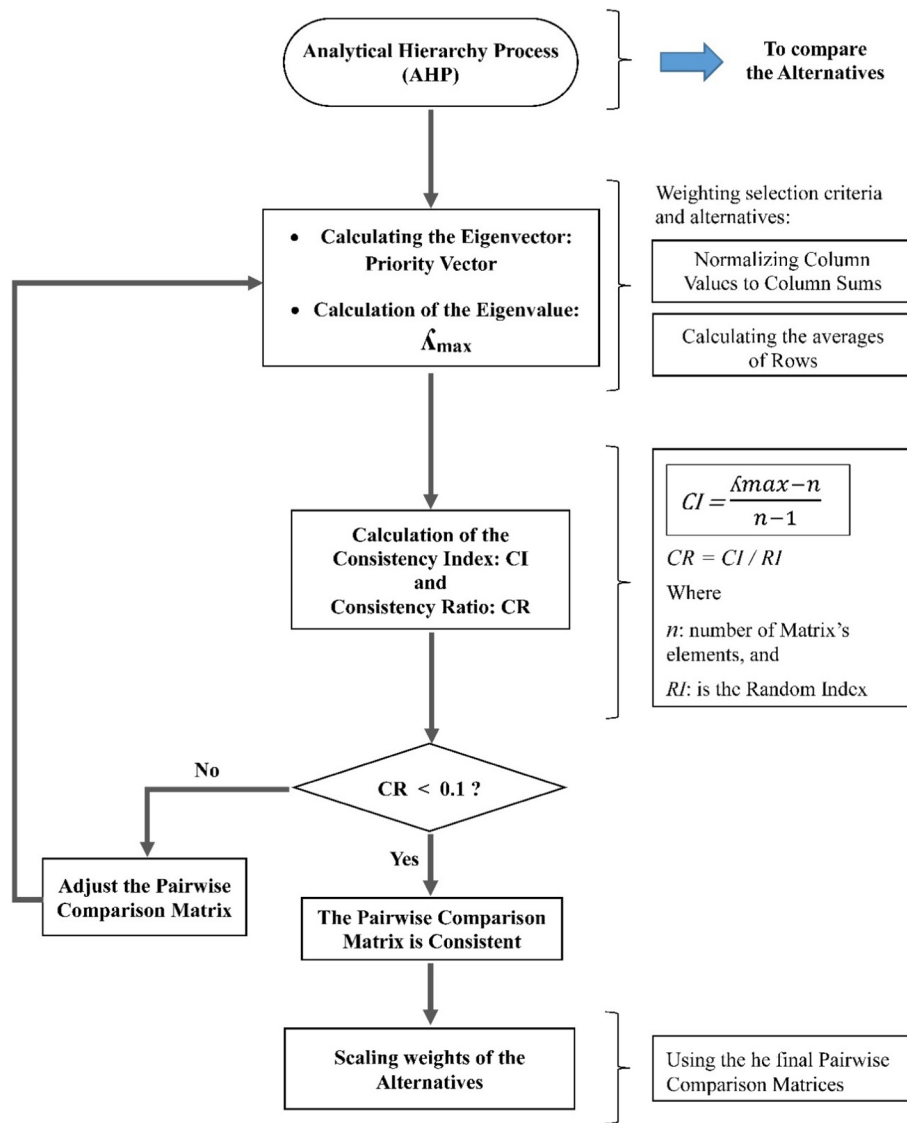


Fig. 12 The steps followed in the AHP. (Random Indexes (RI) are obtained from Alonso & Lamata, 2006)

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Authors' contributions

CRedit taxonomy: Walid Al-Shaar, Nabil Nehme, Olivier Bonin, Jocelyne Adjizian Gérard: Conceptualization, Methodology, Analysis and Validation. Walid Al-Shaar: Resources, Data curation, Software, Writing - Original draft preparation. Olivier Bonin, Nabil Nehme, Jocelyne Adjizian Gérard: Supervision, Writing - Review and Editing. The author(s) read and approved the final manuscript.

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The authors declare that they have no conflict of interest.

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