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Principles of Infill Development Policy towards Sustainable Urban Containment in Residential Areas

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Abstract The Egyptian government has recently adopted a development of the National Urban policy (NUP) with the aim of increasing cities' ability in accommodating the growing population by making them more dense and compact. This comes through some policies and approaches which achieve the optimal use of different areas within cities to contain urban growth and its requirements. One of the most important of these policies (infill development policy) which exploit the land vacant, open areas and all possibilities, whether owned by the state or individuals to cover the development' needs. However, the application of this policy in cities faced a number of negative aspects such as the decreasing in the quality of life, reduction of open areas, selection of an inappropriate infill development' type and using unsuitable land plots for development process. Therefore, this paper aims to identify the necessary integrated principles for using infill development policy in developing residential areas and containing its urban requirements in sustainable way. To achieve this goal, the paper uses the descriptive analytical approach in reviewing the theoretical framework of infill development policy about its types and principles. In addition to testing the application of these principles in one selected area (Ezbet El Lemon) by using ArcGIS geographic information systems and statistical programs to find the degree of achievement urban containment through using infill policy and identify the main challenges which it faced. Also the paper polls the experts' opinions about the relative importance of infill' principles and how to face their challenges. Finally ,the results of theoretical and application framework help in suggesting the future infill principles for containing current and future urban needs in residential areas.

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1. Introduction

Population and urban growth has increased rapidly since the 1960s in many cities, at both local and international level [1]. Where the proportion of the population in cities increased to more than 60%, this led to more urban expansion, which was mostly horizontal expansion outside the city limits [2]. This Urban sprawl is more expensive in provision of facilities, infrastructure and transportation, in addition to its negative environmental, economic and social effects on the population and the place which are inconsistent with the various principles of sustainability [3]. These effects are represented in losing of green areas and agricultural lands, decreasing land economic' values of the land, and social segregation between different social classes within the cities [1, 2]

For long time periods, the potentials within cities for urban expansion and development were neglected and focus only on developing the periphery areas and cities 'outside in search of better environments for living [4]. Therefore, a number of policies had appeared since the sixties aimed at managing urban growth and trying to contain urban' components within cities by exploiting all capabilities within cities and reducing the previous negatives of urban sprawl [3,5]. These polices also minimize the travel distances between housing and work and between housing and services [6]. The infill development policy is one of these policies, which achieves the idea of compact cities with an acceptable high density and provides all necessary urban elements in one development unit for obtaining more livable and sustainable cities [7].

In the seventies this policy began with using available vacant land plots within the cities, and then developed into re-using of existing and dilapidated buildings [8, 9]. In

addition to exploited of the abandoned lands and buildings for revival and renewal regeneration of residential neighborhoods [8]. During the eighties and nineties, the concept of infill development was extended to include mixing of land uses in buildings and areas that have no horizontal possibilities for expansion [10]. This policy has been widely applied in the field of urban planning at many levels such as (land plot – urban block - part of the building - all building - a small area - neighborhood – urban sector - city) [11]. In each pervious level, the implementing' method of this policy differs according to the characteristics of each level, which appears in the used infill development type , density and the kind of allocated land uses [12]. Therefore, this policy played an important role in achieving sustainable and smart urban growth in the different cities with the other urban growth management policies such as transit-oriented development, zoning and urban boundary [13].

There have been many opinions recently about the feasibility of using infill development policy in managing urban growth. There are some studies that criticize this policy due to what it causes of high residential and population density, an increase in congestion and pollution rates, and a decrease in agricultural lands and open areas [14,15] on the other side, there are other studies that motivate the application of this policy to reduce random urban sprawl and meet the population' needs from housing, services and activities within their areas at the lowest level of costs and the highest possible profitability rates for residential and non-residential projects [16,17]. Besides the infill development policy is suitable with the limited financial expenditures of governments because it does not need new facilities and infrastructure [18], but rather uses what is available in cities with some renovations and reforms only to accommodate new development plans and achieve better efficiency in using land within cities [19]. In 2003, this policy helped to accommodate more than one million people in many cities around the world, and contributed in construction about 25% of required buildings for covering housing demand in these cities [20].

With the emergence of resilient city' idea in 2005, the importance of this policy has grown to face the environmental risks of urban expansion, benefit economically from the place and achieve efficient use from energy and resources within the city [21]. By reviewing the status of urban growth in the existing Egyptian cities, it was found an increasing in population size in Egypt, which is expected to increase from 100 million people to 160 million people by 2050 [22]. This urban growth was characterized by spreading outside urban areas, especially in suburban areas and cities 'outskirts of at the expense of the inner areas [23] . Also the population densities inside most of cities are less than what is proposed by planning law (150 people / acre) [23]. Despite the feeling of high density, this is the result of the high rates of crowding and irregular distribution of activities [24].Therefore, one of the national urban policy' recommendations in 2020 is to apply new appropriate approaches of urban development, to increase density by exploiting all potentials within cities, including vacant, unused lands or buildings and assets [23].These capabilities achieve economic efficiency and avoid unplanned urban expansions on agricultural lands in the cities. As well as it accommodate the population increase and save the huge investments for building new cities [23]

The policy of infill development was applied in Egyptian cities during the previous times by using only vacant lands, whether unexploited land plots or the land of removed deteriorated buildings which their percentage reached to more than 30% of the cities' areas according to statistics of 2016 [23,24]. Therefore, the rest of the policy forms were neglected, which can be used in increasing the ability of residential areas for future urban expansion [24]. Moreover, there is no specific methodology to implement this policy in Egyptian cities to determine what potentials can be used for development purpose and what should be kept without any development [24, 25]. These failures affected the appearance of unplanned urban intensification in some areas and wasting of development potentials in others as a result of lack of clear vision about how to deal with that policy in the development process [24, 25]. This is what the paper aims at defining the necessary principles of infill development policy to contain the current and future urban elements in a balanced way. The suggested principles also help decision makers to use this policy without any negatively affect the sustainability of the residential area.

2. Previous Studies

2.1 Definition of infill development policy

The different definitions of a policy have developed according to the development trends that have emerged since the second half of the twentieth century. The first definition was called *green infill development* which began by focusing on the environmental dimension during the fifties through using the available spaces for green areas' uses, especially in industrial areas, to reduce pollution rates to minimum levels [26]. With the importance of the economic development dimension in the cities during the

sixties and seventies, this policy was called *infill economic development* [26, 27]. This term defined as a mechanism to raise the economic values of land within cities by employing the available lands to localize compatible uses with the economic characteristics of the place, such as profitable economic activities [26,27]. In the late seventies, there was an increasing construction and development movements in existing cities around the world. Therefore the policy called *infill building construction* to build the available voids for development purposes [28].

Many studies have added also in the same time the functional definition by describing it as the process of adding a building or some buildings according to their characteristics from size, shape, height and construction which not have negatively affect the functional performance of the area [29].A group of other studies confirmed this concept and showed that it is a means to complete the urban, architectural, aesthetic and visual elements of the urban fabric and to link between the old and new buildings [29, 30]. Many cities have paid attention to the social *inclusion* through using the policy of *(infill social inclusion)* to apply the principle of the convergence between land uses and the integration of different social groups in cities [31, 32]. At the beginning of the eighties and the trend towards applying sustainability in cities, the policy became a main tool to achieve the principles of sustainability in different spatial levels [19, 20]. During that period, the policy was called *sustainable infill development* to preserve non-renewable resources, support social inclusion and maximize the economic values of the place [17, 18].

The previous terms focused on the exploitation of empty lands only those have not exploited yet or have been exploited before to meet environmental, economic and social needs in cities with low or medium densities.

However, with the increase in densities within residential areas and lack of available land for urban expansion, other terms for infill policy have emerged to add different forms of the policy [18]. The first term was *urban infill redevelopment* which appeared in the nineties and depended on using the land of dilapidated buildings or parts of buildings to cover the urgent uses in cities. Therefore, it was used to revive and develop areas and to improve the quality of life [33, 34].

At the end of the twentieth century, there was a technological development that had an impact on urban planning ideas such as smart cities, digital city, information city and knowledge city [13].. This led to the existence of a new term for the policy called *smart infill development* which refers to apply mixed land use and create a diversity of uses within the same development unit to reduce the distances between them and manage urban growth [35, 36]

In 2019, Monmouthshire Country Council developed a comprehensive concept for the policy by describing it as exploiting all Greenfield and brownfield sites within cities to accommodate their future urban growth internally [37]. And that the policy is not only adding uses, but extending to reuse current buildings or deleted other in favor of more demanding uses or more compatible with the cities' needs. Therefore, infill development has become an important policy in the areas of planning, redevelopment, regeneration, and upgrading and growth management [36, 37].

2.2. Definition of sustainable urban containment

The idea of urban containment is very old since the eighteenth century. Its basis was the desire for urban agglomeration in specific locations, especially with low population densities, the spread of urban and population on agricultural land. Therefore the first goal of urban containment was the preserving natural resources and agricultural lands in cities and different areas [38].

With the weak exploitation of land economic values within the cities during the sixties, the containment approach was used as an attempt to create investments in a way that increases the rate of profitability and reduces financial waste [38, 39]. Thus this approach has become an economic requirement that increases the economic values of places [35]. Furthermore the increasing of social segregation and divergence between social classes during the seventies, led to adopt some approaches that enhance social inclusion such as urban containment to reduce social disparities and cover different housing units' types within the same residential neighborhood [35, 40].

Also the decline in the quality of life, the increase in pollution rates, and the deterioration of urban characterizes, the term urban containment appeared to develop the city entity through replacing the old buildings with the new. Besides it provide sufficient green areas inside cities to maintain its urban quality [41, 42].

On the other side, many cities faced some challenges during the eighties and nineties such as the increasing of using cars and long distance between the uses of housing, services and activities [43]. Therefore urban containment adopted the idea of mixed land uses which depended on using pedestrian paths instead of mechanical movement to solve these problems and create integrated societies [44].
Nowadays the new ideas of sustainability, smart cities and resilient cities appear to deal with urban growth issue and

achieve development in all urban sectors. In which urban containment has become a main tool exploit the potential of the place from infrastructure, land plots and development areas in order to provide the current and future requirements of the population without the need to growth outside cities' boundaries [45]. Also this approach creates an optimal distribution of land uses in accordance with the social, environmental and economic characteristics at the lowest possible cost, risk, and highest returns [44, 45]. According to the foregoing, sustainable urban containment is defined as meeting all current and future needs within the city limits to cover environmental, social, economic and urban sustainability standards by exploiting everything available inside cities without the need to expand beyond its borders [45, 46].

In order to achieve the approach of urban containment,, a number of policies are used as shown in the following points [39]**:**

- Infill vacant land plots
- Reusing of buildings and land plots
- Urban redevelopment
- Mixed land use
- Density bonus
- Compact communities
- Walkable neighborhoods

2.3 Role of infill development policy in achieving urban containment

Many studies have indicated the importance of using infill development policy in managing urban growth and achieving urban containment within the cities. Its roles are represented in some environmental, social, economic and urban returns that can be illustrated in the following figure No. 1

2.4 The challenges of infill development

Despite the revenues of using infill development policy in the development of residential areas and meeting the residents' needs from services, activities and housing units, this policy have some challenges that impede its implementation, as shown in the following points [20]:

- The Natural obstructions in some site.
- The high cost of dealing with soil characteristics or topography.
- Existing of small and large land plots' areas which are not comply with development requirements.
- The lack of capacity for the infrastructure to accommodate urban expansion.
- Some residents refused to exploit their land plots.
- Legislative and regulatory' challenges that impede the use of some land plots.
- Existence of privately owned land plots that reduce the development opportunities.
- High land prices in some areas
- Variation in social characteristics
- Lack of development plan for the residential area.
- The implementation of infill development policy needs a long period of time.

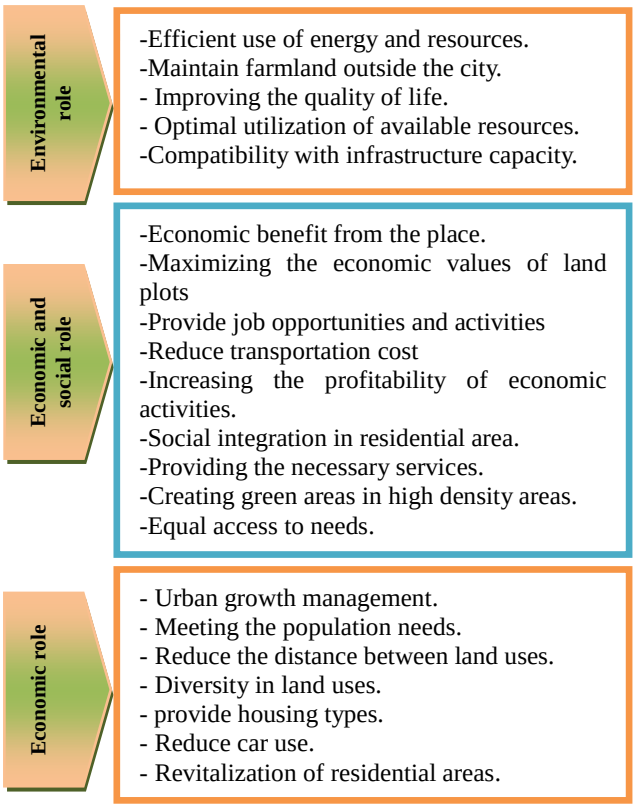
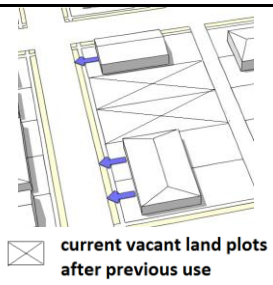
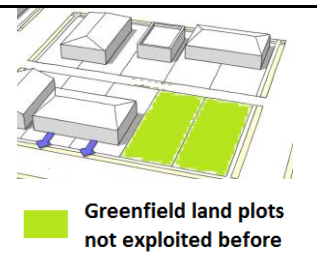
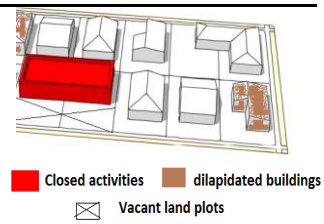
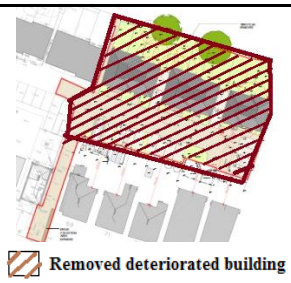
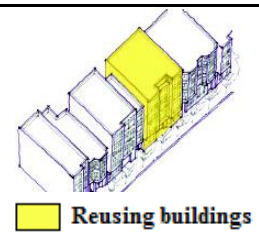
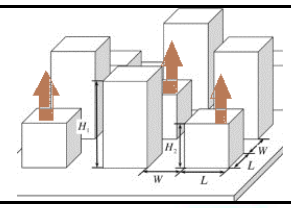
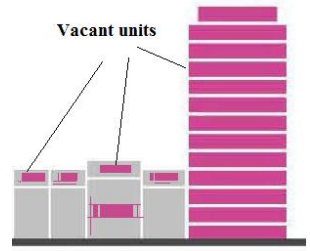


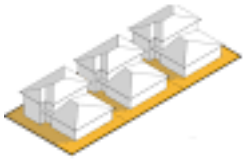
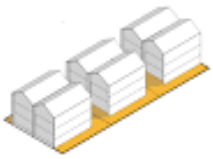
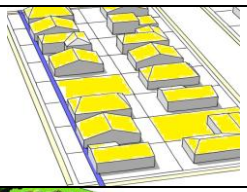
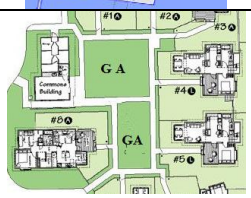
Fig. 1 Role of infill development policy in urban containment (Author accordion to [39, 45]

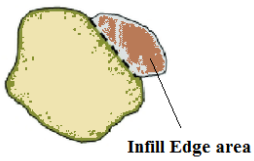
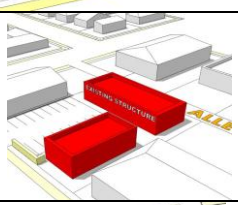
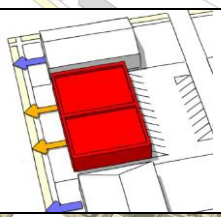
2.5 Classification of infill development types

There are many types of infill development policy according to a number of factors such as (the kind of available possibilities – infill land uses' types- the degree of development' density - the spatial level that is dealt with -the size of land plots). These types can be clarified through the following table 1 [34, 35 36, 37, 46, 47].

Table 1 The properties of infill development policy' types

Classification standard	Infill development type	Description	Cases of application	Illustrative example
2.5.1 Available possibilities	2.5.1.1 Infill current vacant land plots	It is the use of land plots that have no current use. And the selection of its appropriate use shall be in accordance with the needs of population, its pervious use and the characteristics of the surrounding uses.	This type used in sparsely populated areas and when Land plots are suitable for development	
	2.5.1.2 Infill greenfield areas	It is the use of vacant lands that have not been exploited before and have no current use. Their exploitation' type is affected by the suggested development plan and the kind of existing uses.	This type is used in areas that have unexploited vacant lands and have an urban assimilation to intensify more uses.	
	2.5.1.3 Infill brownfield and greyfield areas	This type refers to the use of all potentials within the city that have previously been exploited but currently neglected or exploited insufficiently.	This type is applied in areas that own lands, buildings, or activities which are not exploited or need development to achieve a better development vision.	
	2.5.1.4 Infill removed deteriorated building sites	It is the use of dilapidated building sites that are removed to construct new buildings with the same or different use.	This type is suitable for degraded areas that are removed for development purposes.	
	2.5.1.5 Infill reusing building	It is the re-use of the entire building or part of it without any removal in order to redistribute the land uses in a more compatible manner.	This type is used in areas where inconsistent uses appear and need to change their use to meet urgent needs and avoid misdistribution of land uses.	
	2.5.1.6 Infill building heights	This type refers to raising buildings with one or more floors according to the structural characteristics and planning and building requirements.	This type appears in areas with lower building heights than permitted, in addition to their good structural condition and structural system.	
	2.5.1.7 Infill vacant units	Using the vacant units in buildings to cover the demand of housing, services or activities according to the characteristics and location of the buildings.	This type is suitable for new areas in which not all their residential or non-residential units have been occupied, so that the vacant units are used to meet future needs.	

2.5.2 The degree of densities	2.5.2.1Infill low development density	This type expresses the exploitation of expansion possibilities, but with less intensity due to some of special environmental or social characteristics of these areas.	This type is used in tourist areas, distinguished housing, or protected areas, which do not need more increasing urban densification.	
	2.5.2.2 Infill medium development density	It is an application of medium development intensity according to the capacity of the infrastructure, besides the social and environmental characteristics of these areas.	This type is suitable in medium housing projects and in urban structures that are not subject to vertical expansion.	
	2.5.2.3 Infill high development density	This type means the increasing of urban densification in a way that does not contradict the building and planning requirements.	It is used in low-income housing projects or areas with high economic value to achieve the highest rate of profitability.	
2.5.3 The kind of land uses	2.5.3.1 Residential infill development	It is the provision of residential uses with the available capabilities to provide future housing units for the population of various social groups.	The application is valid in residential areas to cover the needs of different social groups	
	2.5.3.2 Commercial infill development	This type is intended to establish commercial activities with different densities and locations according to the size and kind of demand.	It is used in commercial centers and in residential areas that suffer from a lack of commercial uses.	
	2.5.3.3 Infill industrial uses	It is the addition of industrial uses in new or existing industrial zones with the aim of achieving integration or benefiting from the economies of place.	This type is used in industrial areas located in new or existing cities, which can accommodate more industrial activities without any negative effects.	
	2.5.3.4 Infill service uses	It is the establishment of educational, health and social services according to the kind and size of the deficit in services.	It is used in residential areas or service centers to cover the future needs.	
	2.5.3.5 Infill green and open areas	It refer to provide green areas within different areas by exploiting the available capabilities, whether vacant lands or dilapidated buildings.	It is used in high-density areas, the most polluted areas, and within industrial areas.	
	2.5.3.6 Infill mixed uses	It is the combination of more than one use in one building or block to reduce travel distance and increase the benefit from land economic value.	It is used in areas with high economic values and in cases where there is no vacant land for expansion or provision of the necessary services and activities.	

2.5.4 The spatial level	2.5.4.1 Inside city infill development	It is intended to exploit the capabilities within the city to meet the requirements of urban expansion without the need for expansion outside the city limits.	It is used in different cities that have possibilities for expansion within them for the purposes of housing, services and activities projects.	 Infill inner city
	2.5.4.2 Edge city infill development	This type is about placing some land uses that restrict urban growth on the city's borders to avoid informal extensions on its outskirts.	It is used in cities with increasing urban growth, which include extension areas that are not designated for specific land uses.	 Infill Edge area
	2.5.4.3 Neighborhood infill development	This type is concerned with planning residential neighborhoods and exploiting all available land to meet the residents ' needs from of housing units, services.	It is used at the level of the residential neighborhood with its different housing 'types to provide its basic needs which requires the least walking distance to reach them.	
	2.5.4.4 Block infill development	It is the exploitation of the available land plots in the block to suggest some uses that are compatible with the prevailing uses in the block.	It is used at the level of residential, industrial, service or commercial blocks, which includes sufficient areas for exploitation in a manner that does not conflict with the block characteristics.	
	2.5.4.5 Infill land plot development	This type suggests an appropriate use for land plot according to its location, area, and the uses of the surrounding land plots.	It is used at the level of land plot to put suitable use, building ratio, building height and setbacks.... in accordance with planning and building requirements.	
2.5.6 The size of land plots	2.5.5.1 Infill small separate land plots	This type focuses on using of small land plots between residential buildings	It is usually used in high-income housing projects with, low-density to provide small villas	
	2.5.5.2 Infill small connected land plots	This type refers to the use of small land plots between residential, services, commercial or industrial buildings.	It is used in the case of existing small land plots between buildings in favor of roads, spaces, pedestrian paths according to the buildings length of the connected buildings.	
	2.5.5.3 Infill large separate land plots	This type refers to the exploitation of large plots of land separated by pedestrian roads or paths from the surrounding plots of land.	It is usually used in industrial areas that need large land plots for achieving the requirements of production process.	
	2.5.5.4 Infill large connected land plots	The type expresses the exploitation of large land plots between connected buildings.	It is used inside industrial, residential or service areas in favor of open areas.	

2.6 Main steps for application infill development policy

The Infill policy depends on a set of steps to ensure its success in containing urban elements in residential areas. These steps were concluded by studying and analyzing international previous experiences in this field, such as some residential areas in the cities (El Paso- Chilliwack- Edmonton- Atlanta). Figure 2 shows the most important steps of infill development process. [48, 49, 50, 51, 52, 53, 54].

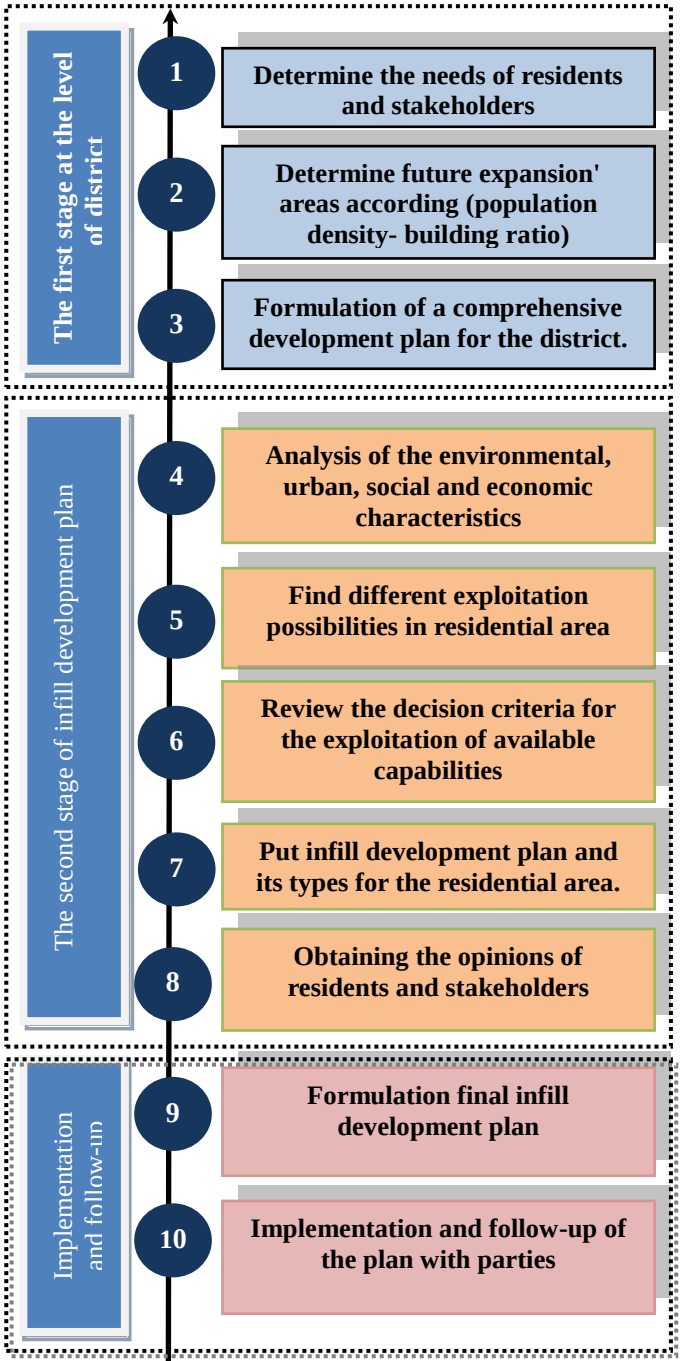


Fig. 2 Main stages for application infill development policy in residential area (Author according to 48, 49, 50, 51, 52, 53, 54)

2.7 Principles of infill development policy and their measuring for urban containment in residential areas

This part depends on some of international reports and experiences that dealt with the important infill development principles for the success sustainable residential areas. Among these studies (report of managing Maryland's Growth models and guidelines for Infill development in 2001 [49] - the report of single plot and other types of residential infill development by Supplementary Planning Guidance Environment Committee in September 2003 [37] - City of El Paso report in 2017 to give a guide to planners and decision-makers for effectively implementing infill policy [50] - City of Chilliwack report in 2020 on how to prepare a good infill development [51] - Richmond Hill report on residential infill development compiled in October 2021 by Gladki planning associates [52] - MRSC report in 2023 for empowering local Governments to encourage friendly neighborhoods [47] - Edmonton City report in 2022 on developing a guidance report on how to prepare a complementary infill Plan for residential areas [53] - the City of Greater Atlanta Home Builders report in 2023 on criteria of using right infill policy in cities). [54].

2.7.1 Principles of district development plan

Choosing infill development policy for the development of residential areas depends on a set of requirements at the level of the broader scale (for example, the district), which are represented in the following points:

2.7.1.1 Estimating the development needs at the district level

This step is focused on calculating the needs of the population and the various stakeholders in terms of housing, services and activities. Thus, the total areas required for these uses are determined in district [49, 51].

2.7.1.2 Finding the potential areas within the district

This stage is intended to identify areas that include capabilities for urban expansion and development, and this is based on the criteria of population density and building ratio that are lower than legally permitted [52].

2.7.1.3 Putting suitable district development plan

One of the most important factors for the success of the district development plan is that it is compatible with the environmental, urban, social and economic characteristics of the residential areas within it so that it can be implemented without any obstacles [54].

2.7.1.4 Existence of legal framework for planning residential areas

The existence of a legal framework for planning residential areas contributes to determining the extent to which infill development policy can be applied or not. This planning and building laws set the allowed values of (population densities- building heights- building ratio on total area or on land plot) [49, 37].

2.7.2 Principles of pre- infill development plan

This stage concerned with determining the validity of infill development policy for application, in addition to selecting suitable types of this policy for developing residential area. These goals are achieved through the following principles:

2.7.2.1 Existence of update database

There must be an up-to-date database about lands, buildings, properties, land prices, and other information that covers environmental, social and economic dimensions for using it in preparing infill development plan [52, 53]

2.7.2.2 Studying and analysis the characteristics of the residential area

The study of the environmental, economic, social and urban characteristics of the populated area contributes to determining the available possibilities for exploitation from vacant land plots, brownfield, greyfield, greenfield and vertical expansion of buildings [53, 54].

2.7.2.3 Survey the opinions of residents and stakeholders

This step is important to develop a vision about the possibilities that are easy or difficult to exploit according to the opinions of the residents, owners, or stakeholders. The opinions of these parties are considered very important before preparing infill development plan. [49].

2.7.2.4 Determine the final exploitable sites

The final sites that are suitable for implementing the policy are determined according to the characteristics of the residential area and the spatial distribution of its possibilities, in addition to the opinion of the residents and stakeholders about the possibility of using their properties in planning. On the other hand, the appropriate uses of these sites are proposed according to the requirements of development and the characteristics of the place. [49, 52].

2.7.3 Principles of formulation and implementation infill development plan

The principles at this stage focus on a set of elements that must be taken into account when preparing and formulating the components of infill development plan in order to achieve sustainable urban containment in its environmental, social, economic and urban dimensions. These principles are represented in the following points:

A. Urban sector' principles

They are principles related to the characteristics of buildings and land uses which added to the residential area.

A.1 Diversity in housing units' areas

Diversifying housing types and providing suitable areas for housing units in the same building are important principle of infill development to meet the needs of different social groups within the residential area as shown in figure 3 [49].

Fig.3 Correct diversity of housing types in the residential area (Author)

A.2 Encouraging mixed land use

Urban containment in the residential area aims to meet the population needs in the same development unit to reduce moving and transportation distance and achieve proximity between the different uses. This is done by infill a number of compatible uses within the same unit instead of existence of the residential use only as shown in figure4

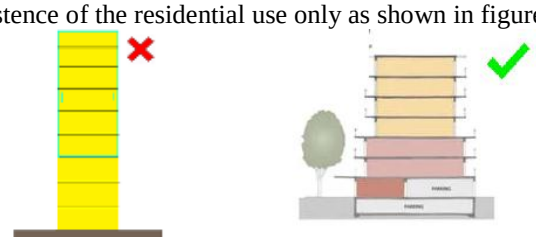


Fig.4 Infill mixed land use in the same building (Author)

A.3 Considering the size and shape of buildings

With the addition of new buildings on available land plots in the residential area, it is taken into account that they are similar to the sizes and shapes of the surrounding buildings to achieve urban harmony within the area as shown in figure 5 [50, 54].

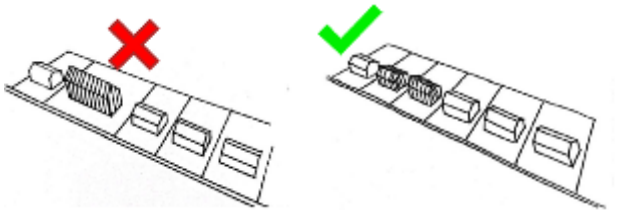


Fig.5 Suitable size and shape of added buildings through infill process (Author)

A.4 Application the average of building heights

One of the most important followed criteria in vertical infill buildings is the prevailed average building heights in residential area as shown in figure 6. In order to preserve the visual image and the sky line in addition to maintaining the environmental and social aspects of sustainable urban containment [52, 53].

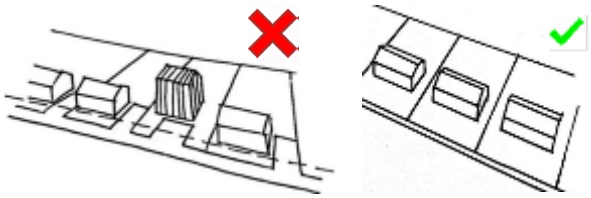


Fig.6 Adding floors to buildings with the same prevailing average height (Author)

A.5 Using the permissible building ratio

Planning and building laws set the permissible building ratios, whether on the level of total residential area or land plot. Therefore infill development policy must take these ratios into account to achieve a better quality of life and avoid randomness in planning as shown n figure 7 [54].

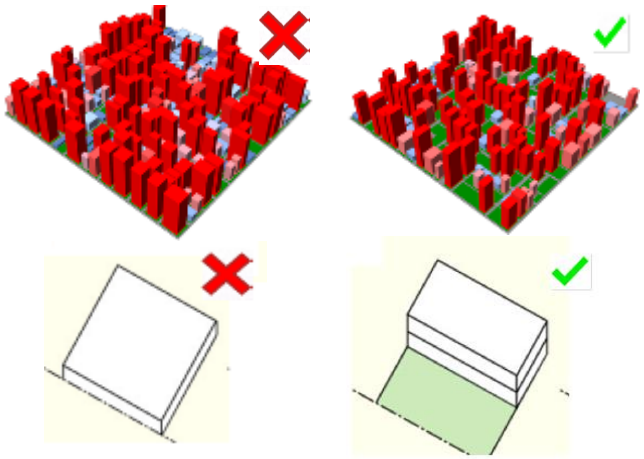


Fig.7 Applying the permissible building ratios by infill development (Author)

A.6 Building with the same construction materials

To maintain urban identity of the residential area, it is necessary to follow the same buildings designs and using the same construction materials in building process. Besides use the same colors in building facades to avoid incompatibility between old and new buildings as shown in figure 8 [50, 51].

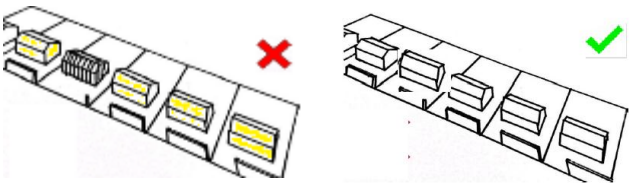


Fig.8 Using the same construction materials and colors in building by infill development (Author)

A.7 Compatibility with buildings ' direction

When adding new buildings on the available lands, the entrances and directions of the surrounding buildings are taken into account to achieve homogeneity in the residential block and facilitate their connection to the road network as shown in figure 9 [54].

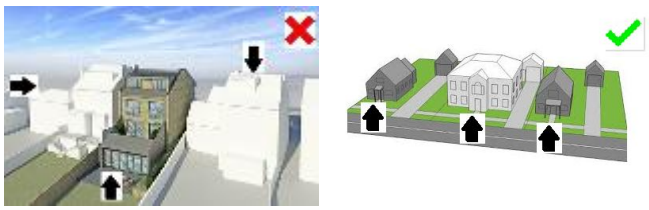


Fig.9 Unify the direction and entrances of buildings through infill process (Author)

A.8 Commitment to the distance between buildings

Infill new buildings in residential area are affected by the nature of current distance between buildings and whether they are connected or separate, where that distance is kept without increase or decrease through infill process as shown in figure 10. [19.52].

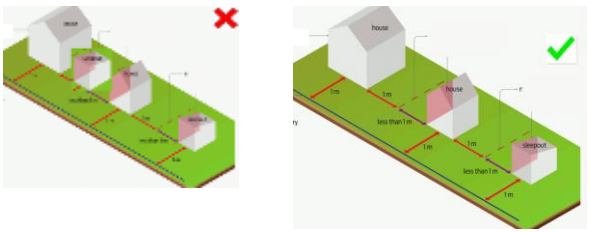


Fig.10 keeping the distance between buildings through infill development (Author)

A.9 Availability of green areas

The successful infill development policy is characterized by leaving specific areas for green areas without building on them, to achieve the goals of sustainability and create a natural outlet within the area as shown in figure 11 [49].

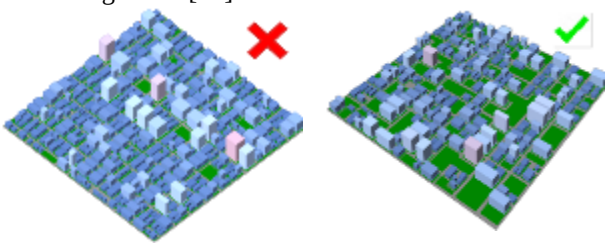


Fig.11 Infill green areas within the residential area (Author)

A.10 Infill suitable land uses for land plots' characteristics

To achieve sustainable urban containment within the residential area, it is necessary to propose land uses that meet the needs of the development parties on the one hand and achieve economic, social and environmental returns by settling them in appropriate locations as shown in figure 12 [49, 50].

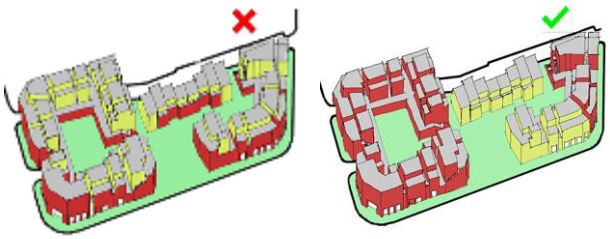


Fig.12 Compatible and incompatible land uses with the characteristics of land plots [51].

A.11 Providing services and commercial activities

The infill policy helps create a diversity of land uses and cover the needs for services and activities within the residential area to reduce the need to go outside it as shown in figure 13 [37, 49].

Fig.13 Providing integrated residential area though infill development [49].

B. Transportation and infrastructure sector' principles

These principles are the considerations that must be taken into account when implementing infill development policy in a way that does not negatively affect the transportation sector and infrastructure [49, 50, 53].

B.1. Linking with current road networks

It is intended to link the added buildings and land uses with the existing road network. So that there are compatibility between land use types and the characteristics of the roads (widths and levels.), besides each land plot is serviced by at least one road as shown in figure 14 [49, 50, 53].

Fig.14 Infill land plot which connection with roads [52].

B.2 Not causing an increase in congestion rates

The lowest congestion rates are achieved by selecting suitable sites for exploitation in accordance with the traffic characteristics therein. In addition to determining the land use types with the lowest frequency on roads with small widths. [54].

B.3 Improving the mobility' rates within the area

Mobility rates are determined by providing a sufficient percentage of road network and transportation stations that connect residential area with the surrounding area as shown in figure 15 [52, 53].

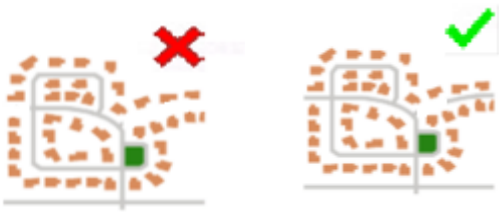


Fig.15 improving mobility networks in residential area (Author)

B.4 Availability of sufficient parking spaces

Residential areas need parking spaces with their areas increase in high income housing. These spaces may be allocated on the ground floor of buildings or on some land plots as shown in figure 16 [54].

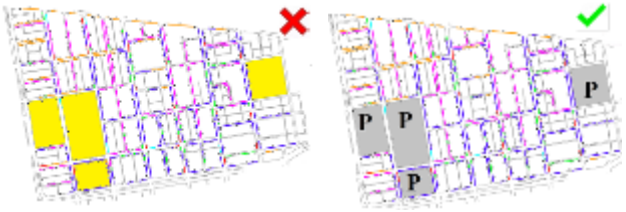


Fig.16 Availability of parking spaces in residential area [50]

B.5 Create emergency pathways

During the preparation of infill development plan, it is taken into account to provide emergency paths with suitable widths for the passage of ambulances and fire trucks, and achieving the security and safety requirements within the residential area as shown in figure 17 [52,53].

Fig.17 Emergency pathway for safety residential area [52]

B.6 Providing safe pedestrian paths

Providing pedestrian paths is one of the basic requirements when formulating infill plan, so that sidewalks and pedestrian paths are provided in front of shops and services, which must be separated from motorized traffic as shown in figure 18 [52,53].

Fig.18 Safe pedestrian paths in residential areas [54]

B.7 Connectivity to existing infrastructure networks

The characteristics of the infrastructure affect the locations of added buildings and uses, so that infill plan benefits from the paths of the water, electricity and sewage networks without exceeding their absorptive capacity to avoid any pressure on them or the emergence of environmental problems [52,53].

C. Economic sector' principles

Economic principles are concerned with minimizing costs and maximizing returns of infill development process.

C.1 Optimal utilization of land economic value

In order to achieve the land economic efficiency, it is necessary to achieve compatibility between infill land use type and the economic value of the place. So there are uses that achieve profitability in land plots with high prices and vice versa [49, 50, 51].

C.2 dealing with public and private property

The characteristics and types of infill development are affected by the boundaries of land plots, whether public or private property. In which infill policy can exploit each piece of land plot individually or combine them according to the opinions of the owners [50, 51].

C.3 Low development cost

Reducing development costs depends on choosing buildings or land plots that contain development ingredients as their connection and proximity to road network, utilities, and services [48,49].

D. Environmental sector' principles

They are the principles that the infill policy must achieve to preserve the environment and its resources, beside create a livable environment for the population.

D.1 Improving the quality of life

The highest rates of life quality are achieved by observing a number of criteria, including reducing pollution and waste rates, improving the urban environment and the efficient use of the land. This is achieved by linking what is existing and what is being added, both at the level of the building, spaces and whole residential area [53, 54].

D.2 Preserving agricultural lands and natural areas

The environmental elements which are located within the residential area or on its borders such as natural resources, protected areas or agricultural lands must be preserved through not using them in development purposes to avoid wasting their environmental values [54].

D.3 Energy efficiency in the residential area

When urban densification is applied by using infill policy, it must take into account that energy use is managed and rationalized. This is come through choosing suitable uses that consume less energy, in addition to mixing in land uses to reduce their consumption rates [53].

E. Social sector' principles

Social principles cover the elements which related to the social characteristics of the population and the needs of different social groups, as well as their participation' roles in preparing the development plan.

E.1 Using the permissible population density

Residential uses are added in areas with low and medium population density, while the areas with high population densities, open areas and uninhabited uses are settled in them [51, 52].

E.2 Compatibility with social characteristics

Social characteristics affect how infill development policy is applied, in terms of site selection for exploitation, type of land uses, and the intensity of development [52].

E.3 Achieving privacy and security

Applying of Infill development types contributes to the achievement of privacy and security for the residential area, especially with distinguished social characteristics. This is done by arranging the locations of the buildings, filling the voids, and providing sufficient distances between the buildings [50].

E.4 Residents' acceptance for infill plan

One of the most important principles which are necessary for the success of infill development plan is the acceptance of the population and stakeholders by presenting it to them and receiving their suggestions to achieve a balance in meeting their needs [50, 54].

3. Infill development policy in Egypt

3.1 Background and history

Infill development policy was applied informally during the fifties in Egyptian cities through localization of land uses in different urban spaces that were located inside the city and extensions 'areas [55]. These lands absorbed about 48% of the housing demand during that period but with an ill-conceived way. One the other side, these expansions were greatly influenced by the patterns of ownership within the cities that imposed a shape and direction of urban infill for offering the most demanded and profitable land uses [55, 56]. During the sixties and seventies, urban infill expansions extended on agricultural lands around cities, whether owned by the state or individuals. Most of the construction operations have been in favor of low-cost housing units without providing sufficient roads, services and basic infrastructure that are necessary for creating sustainable urban communities [23].. Furthermore, informal building rates on agricultural lands have continued on increasingly in the late seventies as a result of an increase in purchasing power and real estate investment by Egyptians working in Arab countries [23, 55].In which these rates amounted to more than double the building rates inside cities. This led to the loss of larger agricultural lands at the expense of neglecting existing possibilities within the cities [23].

Therefore, the Urban Planning Law No. 3 of 1982 appeared as an attempt to control urban expansions by following a set of planning and building requirements. The most important requirements were the population and building density to put a limit the unregulated urban infill in existing urban agglomerations because of its negative environmental, social and economic effects [57].

Coinciding with the 1982 law, there was the New Urban Communities Law No. 59 of 1979, which lays down the urban infill requirements for neighborhoods in accordance with the requirements of cities' authorities and their allocations for land uses within the new cities. During that period, there were no detailed constructive requirements or standards governing the process of urban fill other than densities and building ratios [58]. This led to a number of problems such as loss of urban character, decrease in open and green areas, excess in building heights and high rates of roads congestion, as well as the presence of untapped potentials in some areas at the expense of high densities in others [23, 58].Therefore, Unified Law No. 119 of 2008 was formulated, which specified a number of additional requirements related to land plots, street widths, percentages of voids and building for preparing detailed plans and land division in existing areas. But it focused on specific types of possibilities, which are vacant lands only without dealing with different unexploited areas for horizontal and vertical expansions which are necessary to restructure urban communities instead of unplanned urban expansions [59].For these reasons, in 2016, the new urban agenda appeared to confront the increasing urban expansions and make an urban transformation capable of creating opportunities to enhance economic growth and improve the quality of life for urban communities, in addition to providing services and job opportunities within cities [23, 56]. This agenda includes the development of the National Urban Policy, which was formed in 2014 to complete the objectives of Egypt's Vision 2030 and the Strategic Plan for Urban Development 2052 [56]. The urban agenda is also being developed recently by suggesting basic pillars to contain urban, including (urban growth management - social cohesion – compact cities – urban

Table 2 Measuring the principles of infill development for sustainable urban containment in residential areas (Author)

	Principles	Its measuring
Principles of district plan	Estimating the development needs	Proposed land use budget
	Finding the potential areas	Total potentials areas within the district
	`Putting suitable plan	The type, location and area of the proposed uses
	Existence of legal framework	Existence of planning and building laws
Principles of pre- infill development plan	Existence of update database	up-to-date information on all sectors about the area
	Studying and analysis area' characteristics	Preparing and analyzing different studies
	Survey the opinions of residents and stakeholders	Meetings and questionnaires with residents and stakeholders
	Determine the final exploitable sites	Total area of exploitable sites within the area
Principles of formulation and implementation infill development plan	Urban sector' principles	
	Diversity in housing units' area	The proportions of different residential units' areas, whether in the building or in the area
	Encouraging mixed land use	$LUM= -\sum_{i=1}^{n} P_i * LN\ P_i/LN\ n$ Where Pi (ratio of land use types – n (number of land use types – LN (natural logarithm
	Considering the size and shape of buildings	Area and design of buildings
	Application the average of building heights	Average building heights
	Using the permissible building ratio	Building ratios in land plot and whole area (70-80%)
	Building with the same construction materials	Followed construction materials and systems
Principles of formulation and implementation infill development plan	Compatibility with buildings ' direction	Direction of building entrances
	Commitment to the distance between building	Distance between buildings
	Availability of green areas	Percentage of green areas
	Infill suitable land uses for land plots' characteristics	land use types for land plots
	Providing services and commercial activities	Percentages of activities and services
	Transportation and infrastructure sector' principles	
	Linking with current road networks	Type and number of road connections for land plots
	Not causing an increase in congestion rates	Road congestion rates
	Improving the mobility' rates within the area	Percentage of roads
	Availability of sufficient parking spaces	Percentages of parking spaces and stations
	Create emergency pathways	Number of emergency pathways
	Providing safe pedestrian paths	Locations of pedestrian paths and motorized traffic
	Connectivity to existing infrastructure networks	Infrastructure connection ratios
	Economic sector 'principles	
	Optimal utilization of land economic value	Land use types and land economic value
	Dealing with public and private properties	Public and private land plots
	Low development cost	Total cost of development
	Environmental sector' principles	
	Improving the quality of life	Pollution rates
	Preserving agricultural lands and natural areas	The decline rate in agricultural land
	Energy efficiency in the residential area	Energy consumption rate
	Social sector' principles	
	Using the permissible population density	Population density
	Compatibility with social characteristics	Social compatibility for added land uses
	Achieving privacy and security	Privacy and security rates
	Residents' acceptance for infill plan	Population satisfaction rate

governance - local economic development), in an effort to reach high-density cities, but without any negative future impacts. This is done by following a set of policies such as infill development policy, which the Egyptian government seeks to activate at the level of cities and residential areas to limit unplanned expansions. The following figure 19 shows the evolution of infill development implementation in Egypt [24, 25]

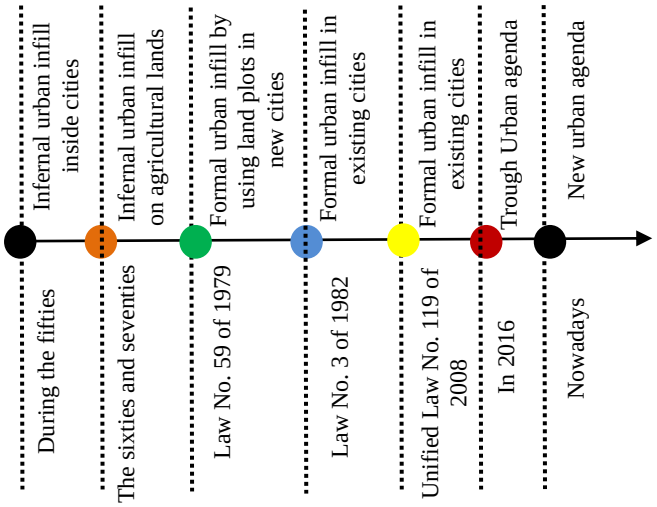


Fig.19 The evolution of infill development implementation in Egypt (Author)

3.2 Legislative framework and its requirements

The application of the infill development policy in residential areas is currently controlled by a set of laws and decisions, including: [57, 58, 59].

- Provisions of the Building Law which promulgated by Law No. 119 of 2008 and its executive Regulations.
- The requirements of the administrative authorities concerned with planning and organizing affairs contained in Article 4 of Law No. 119 of 2008.
- The height restrictions issued by the Ministry of Defense and the requirements of civil aviation.
- The basics of designing and implementing buildings and facilities according to the Egyptian codes.
- Conditions and requirements for approved land divisions in accordance with Law No. 119 of 2008.
- Regulations of National Organization for Urban Harmony which approved by the Supreme Council for Urban Planning and Development.
- Regulatory lines controls approved by the competent administrative authority.

Therefore the main followed requirements for applying infill development policy in residential areas were represented:

- The frontage of each piece of land should be located on at least one road.
- The area of the smallest residential plot shall not be less than 150 m2 within the cities.
- The width of roads overlooking land plots of land must not be less than 8 m.
- The width of land plot' façade shall not be less than 10 meters, and its depth shall not be more than double of façade' width.
- The length of residential block does not exceed 250 m.
- One-third of residential area shall be in favor of roads and open areas, and the percentage of roads shall not be less than 20%.
- The permitted building heights are up to 10 meters (ground floor and two upper floors) in the case of street widths 8 meters. While building heights reach 13 meters (ground floor and three upper floors) when street widths between 8 to 12 meters. On the other side the heights up to 16 meters (ground floor and 4 upper floors), in the case of street widths more than 12 meters.
- The percentages of building on land plots are 100% without any setbacks for land plots with areas of up to 175 m2. While the percentage is a maximum of 70% for land plots with areas of more than 175m2 and with setbacks of 2,5 m on one side at least.
- The maximum area of land plot for the residential building is 4200 square meters.

4. Principles of infill development policy in Egyptian residential areas (results and discussion)

This part answers some questions, including what are the principles currently followed to implement infill development policy in Egyptian residential areas in order to achieve urban containment. And what are the aspects of compatibility or difference between these principles and what put forward internationally. Also are the current legislative frameworks sufficient to achieve successful principles, or is there a need for additional, more effective principles? These questions are answered by selecting case study (one of residential area), in addition to exploring the opinions of experts in the field about the deduced principles to identify their relative importance as an attempt to use them in redeveloping current detailed plans or preparing future plans.

4.1 Study area (Location and characteristics)

Ezbet El Lemon in Al-Mataria district (Cairo Governorate) was selected as a case study for a number of reasons, the most important of which are (the application of infill development policy in it– the diversity of its urban expansion' possibilities – existence of a detailed plan for it- availability of necessary data and information – it is considered one of the urban containment areas for Al-Mataria district) . Ezbet El Lemon is located southeast of Al-Matareya district, and it is part of its old urban areas. El Lemon area is bordered by Al-Matrawy Street to the west, Al-Hurriya Street to the south, Abu Farid Shamalat Street from the North and Dyer Al-Nahiya Street to the east as shown in figure 20 [60, 63] . The area of old part is about (11.8 acres), in addition to 3 acres for the area which extending to Al-Hurriya Street. Thus the total area of El Lemon is (14.4 acres) with total population (5681 person), which represents about 0.017% of the total residential areas in Al-Mataria according to statistics of 2016 [62].

The current land uses in El Ezba are represented in residential use with an area (8.6 acre), some commercial uses (0.8 acre) and road network (1.4 acre) in addition to some vacant lands within the region and on its borders (3.6 acre) as shown in figure 21 [62, 63].

This area suffers from a lack of basic educational, health and social services, in addition to small area from sufficient commercial activities and the narrow internal road network. Therefore, the infill plan aimed to exploit all that is available within the area to contain the population's requirements from services and activities inside the area [63]. El Lemon area includes a range of development possibilities, such as extension areas in the south (3 acres) which are vacant lands that have not been exploited before, lands of dilapidated buildings (3.7 acres), buildings for vertical expansion (1.2 acres) and buildings that can be reused (0.8 acres) as shown in figure 21 [62]. Therefore the infill development plan for El Lemon area suggested some land uses in different locations by using some principles and legal requirements to address the problems of the high population density, which exceeded 600 people / acre and cover all development needs as shown in figure 22 [60,62].

Despite these efforts, a number of failures and challenges appear in the plan as a result of not applying complementary principles that help the plan to be succeeded, and this will be identified and analyzed in the following points.

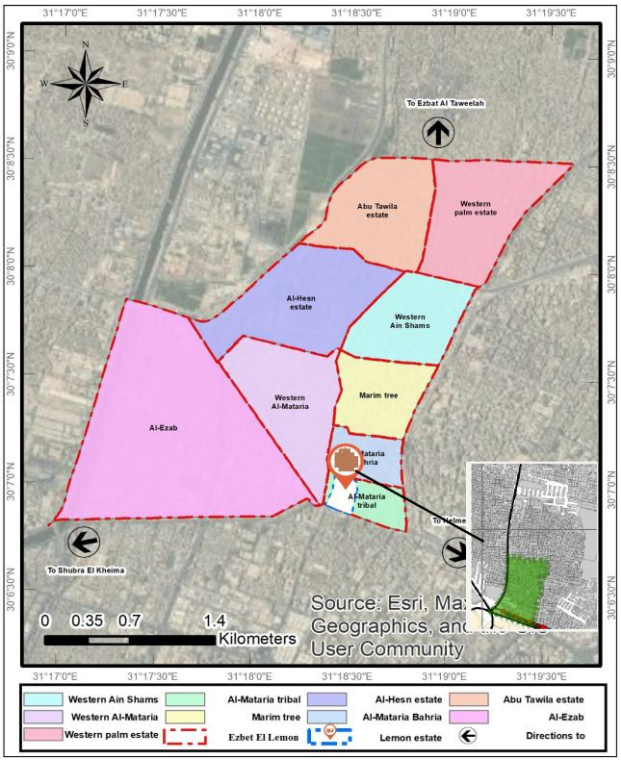


Fig 20. Location of Ezbet El Lemon in El Matareya district Author according to [63].

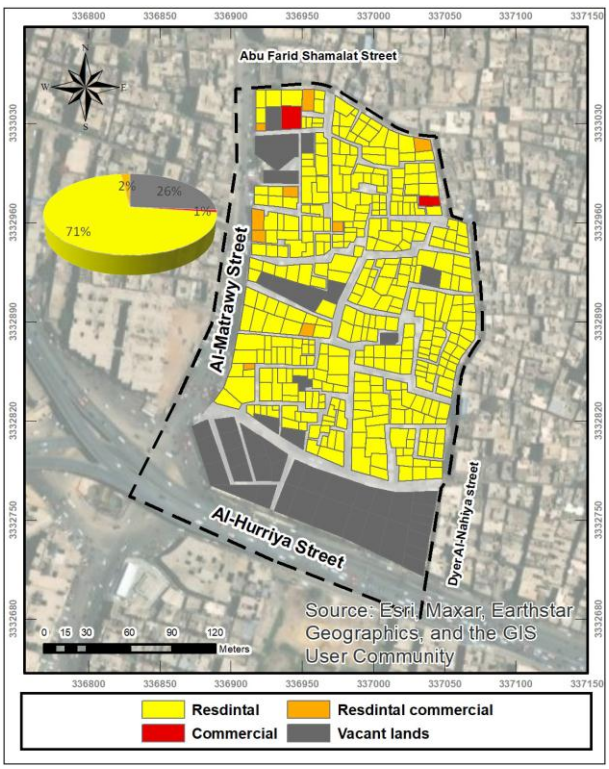


Fig 21. Land uses in Ezbet El Lemon before preparing the infill plan (Author according to [62, 63].

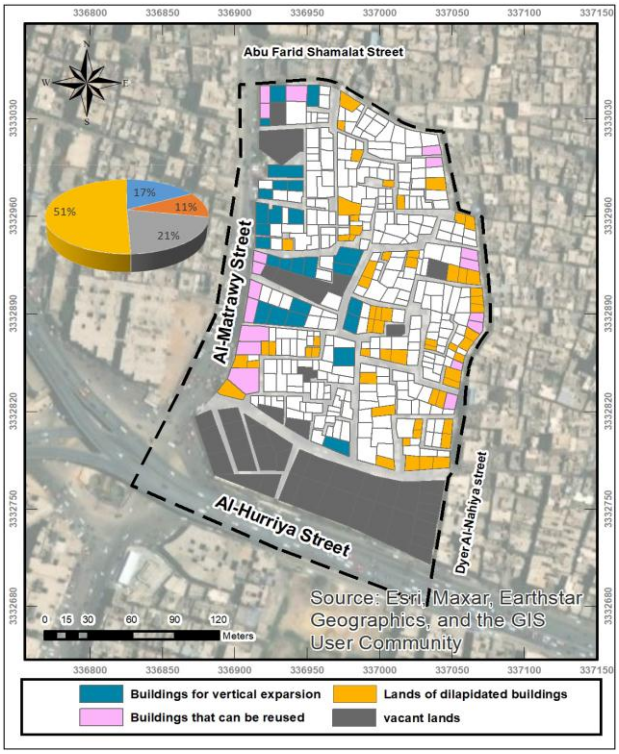


Fig 22. Available development possibilities in Ezbet El Lemon (Author according to [63].

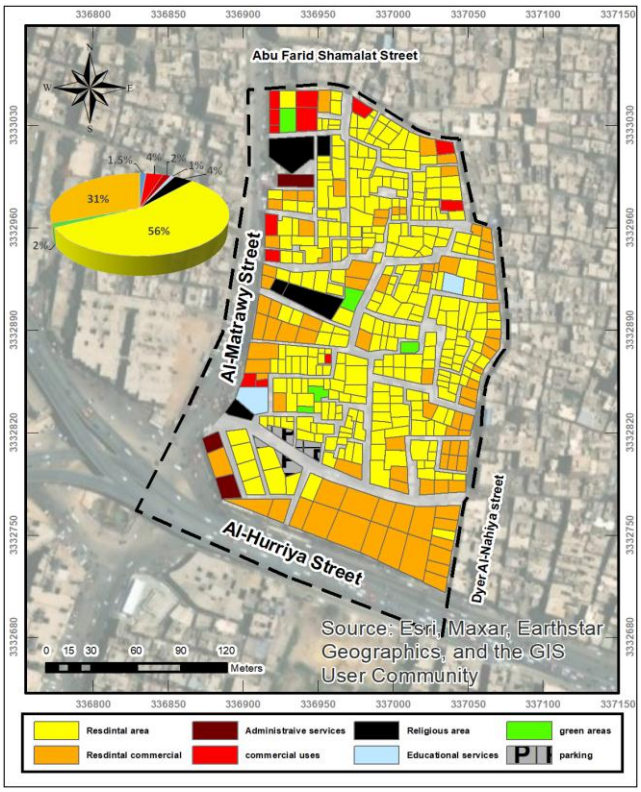


Fig 23. Infill development plan for Ezbet El Lemon (Author according to [63].

4.2 Results of testing the principles of infill development plan in Ezbet El Lemon

This part aims to identify the most important used principles in Ezbet El Lemon' development plan and the extent of compatibility and differences between this plan and what has been proposed internationally. As well as this part clarify the main most challenges which face the implementation of infill development policy in El Lemon area to try to achieve sustainable urban containment.

For achieving these goals, the paper relied on a set of tools to collect and analyze data and information about infill plan. The information about the population and buildings were collected through a number of sources represented in (the statistics of central agency for pubic mobilization and statistics in 2006 and 2016, in addition to collecting some information from Al-Matariya district such as the properties of housing, services and activities sectors and development plans whether for district (2013) or El Lemon area (2015).Also the paper collected the available reports about the detailed development plan of El Ezbea from the General Authority for Urban Planning and Cairo Governorate, besides the personal interviews with some engineers in the authorities to know the characteristics of this plan and its application 'challenges.

For analysis process, Geographic Information Systems (GIS) are used to identify the followed infill principles in case study and determine the sites that have been infilled correctly or in wrong way. All those help in developing a vision of suitable infill principles to achieve sustainable urban containment in residential areas. The following points show the results of testing infill plan' principles in case study according international principles by using GIS

4.2.1 Compatibility with the district development plan

Al-Mataria district plan aims to improve the urban environment, provide the necessary services and activities for the population and absorb the population increase, in addition to redistributing population densities within it. The area of Al-Mataria district is about 1,650 acres, with a total of 831,740 people [60, 62]. There are three areas were chosen to contain the urban growth of the district, including (Elmasala area- Sameka market area- Ezbet El Lemon) as shown in figure 24. Each area has a role, so that Elmasala area qualifies as a tourist and recreational area and Sameka area would be a commercial and service area, while Ezbet El Lemon would be a residential area with craft and commercial [63]. Thus, there is compatibility between infill plan' components of Ezbet El Lemon (2015) and district development plan (2013) as a results of its location close to squares and the main roads.

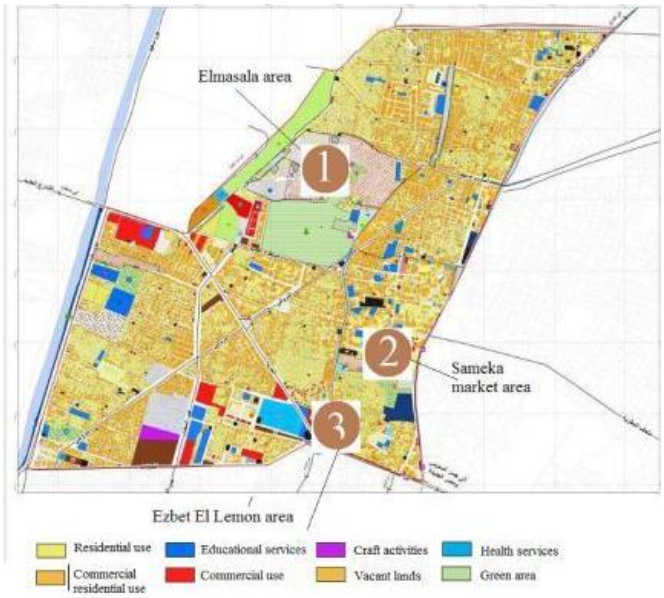


Fig 24. The strategic plan for Al-Mataria district 2013 [62].

4.2.2 Diversity in housing units' area

According to the population statistics for the year 2016, there are two social groups living in Ezbet El Lemon, those who work in services and some tourism activities, and those who work in craft and commercial activities. [61].Their housing needs in the year of preparing the detailed plan (2014) were represented in (60% of families need units with areas not less than 70 m2 and 40% of the families need units with areas of more than 100 m2 [63].This diversity in units' areas was not achieved except in the southern part of residential area, due to the presence of land plots with areas of more than 200 m2. Therefore only 22% of housing units of more than 100 m2 were provided in infill plan, as shown in figure 25.

4.2.3 Encouraging mixed land use

The indicator of mixed land use refers to the degree of land use diversities by using infill development policy. The value of the (LUM) ranges from zero to one, which means the more mixing, is achieved in land uses when the indicator value approaches one [3,6].. By calculating the value of in the study area through using geographic information systems, it becomes clear that its value is weak (0.22) due to the lack of land use diversity in buildings, whether new or existing, due to the presence of commercial use only with residential use along the outer roads as shown in figure 26.

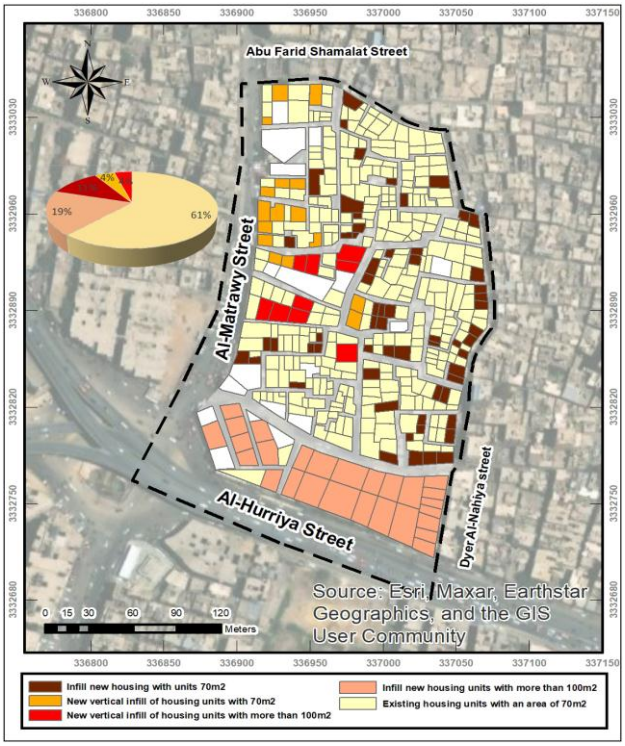


Fig 25. Diversity in housing units' area in infill plan (Author by using GIS)

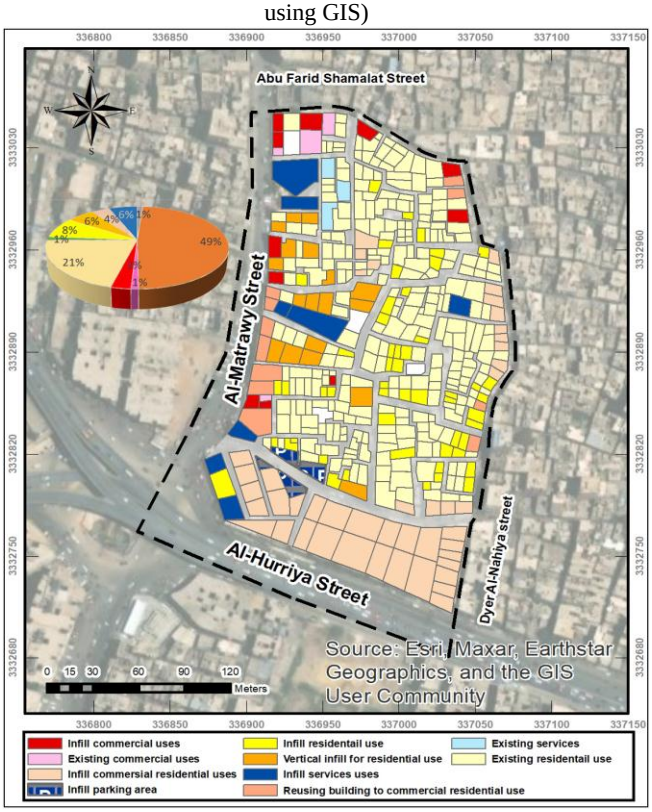


Fig 26. Mixed land use index in infill plan (Author by using GIS)

4.2.4 Considering the size and shape of buildings

Infill development plan for Ezbet El Lemon relied on the exploitation of the vacant lands and land plots of dilapidated buildings to provide housing and services [63]. According to the analysis the suggested residential buildings, it is clear that 60% of housing buildings take into account the shape and size of the surrounding buildings, while 40% were not compatible with this principle. This may be due to the private ownership of most of these lands and the inability to collect land to obtain suitable sizes and areas for development as shown below in figure 27.

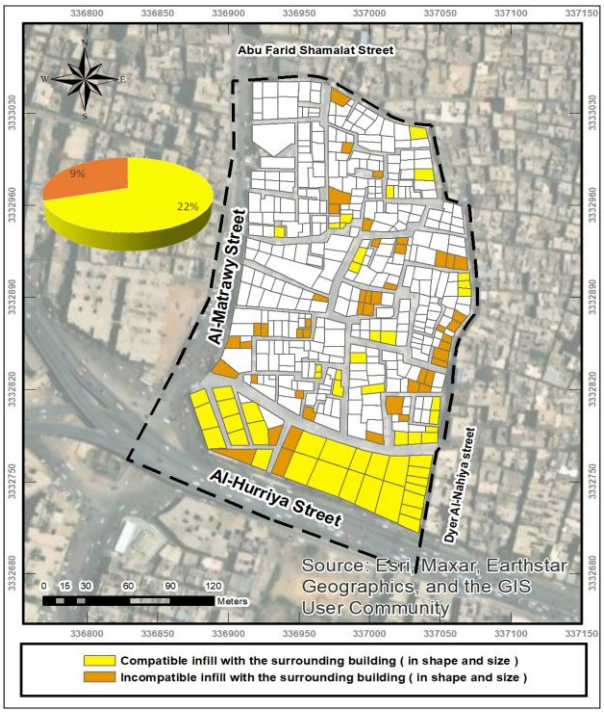


Fig 27 Degree of considering the size and shape of buildings in infill plan (Author by using GIS)

4.2.4 Application the average of building heights

The buildings heights in El Ezaba range from 2 to 4 floors. Buildings with two and three floors appear in the old eastern part, while the heights increase in the relatively modern western part. The plan suggested increasing the heights of the buildings to 6 floors in the new southern part and 5 floors in some areas with vertical expansion, in addition to replacing buildings with heights of four floors in the sites of the removed buildings [62, 63].. In its entirety, it corresponds to the average building heights, except for the buildings located on the narrow internal road network (6% of total dilapidated buildings), as shown in the figure 28.

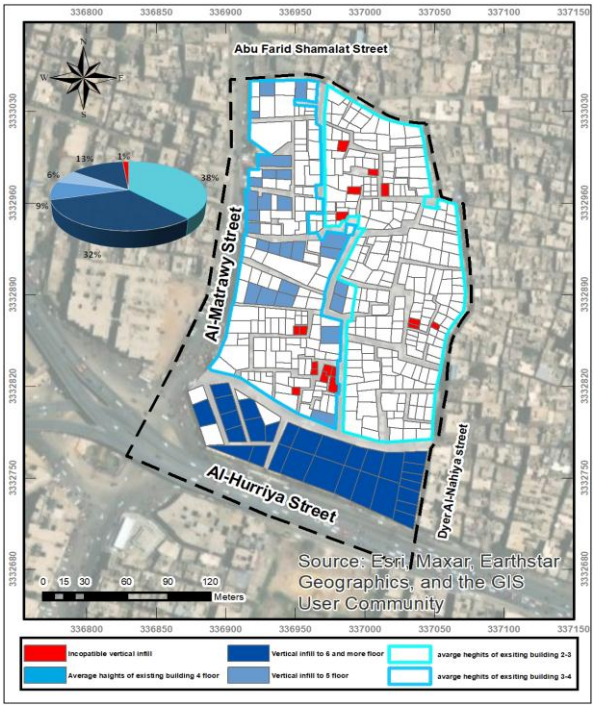


Fig 28. Average building heights in infill plan (Author by using GIS)

4.2.5 Using the permissible building ratio

Infill plan suggested the application of building ratio for land plots with small areas (less 150 m2) to be 100%, while the ratio for land plots with areas (more than 200 m2) is (80%) to accommodate the need from housing units (400 units) as shown in figure 29 [62,63]. Although these ratios contain urban growth and its requirements, it contradicts the proposed requirements and principles, which leads to a reduction in spaces and road network ratios.

4.2.6 Compatibility with building materials, direction and distance

The construction materials and systems in the current situation of Ezbet El Lemon are represented in (63% of buildings are built by load-bearing wall system in the eastern part) and 37% of buildings are built with a structural system in the western part and the southern part. The infill plan follows the same building systems, in which the structural system is used for the new buildings in the southern part and the buildings that are raised in the western part. Besides it uses load-bearing wall system for the buildings in the eastern part. As for the direction, all the buildings' entrances within the main or internal road network, and there is no distance between the buildings which appear only after the residential block in the form of roads and pedestrian paths as shown in the figure 30.

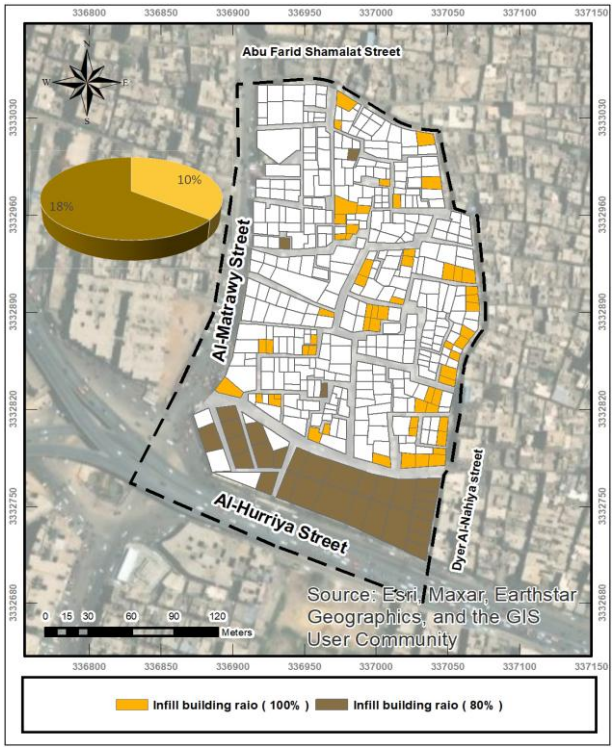


Fig 29. Building ratio on land plots in infill plan (Author by using GIS)

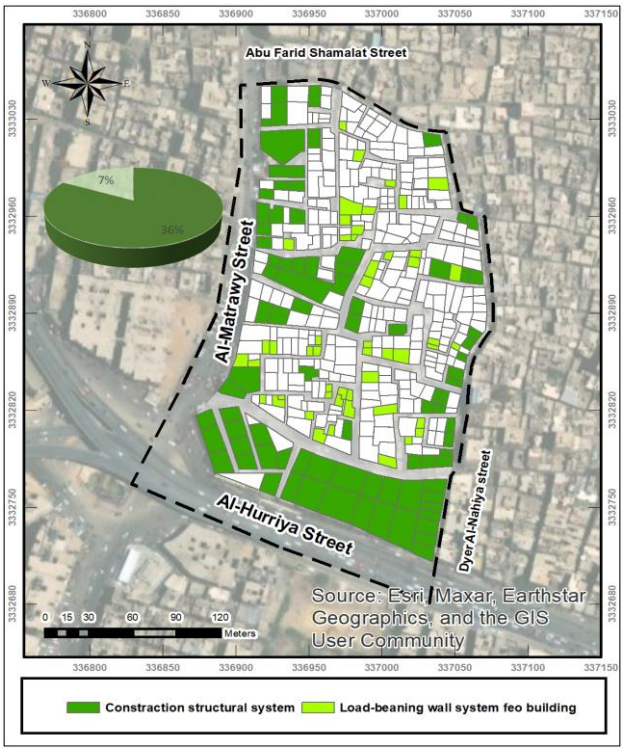


Fig 30. Compatibility with building materials (Author by using GIS)

4.2.7 Availability of services and green

The plan was concerned with providing residential and commercial uses in comparison to add services and open areas that did not exceed (10% from the total area). On the other hand, only some religious, administrative and educational services were provided, represented in (schools - mosques - and administrative buildings) as shown in figure 31, due to the lack of sufficient land plots. And the area depends on the other services located in El Matareya district.

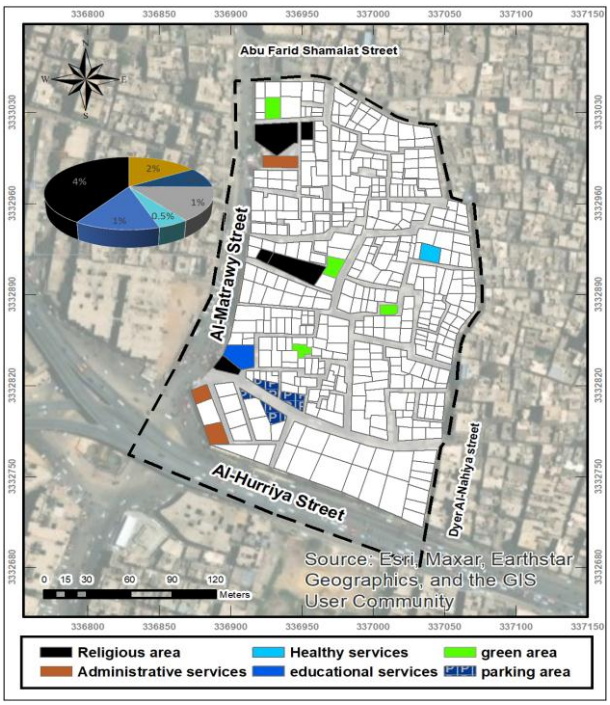


Fig 31. Availability of services and green areas (Author by using GIS)

4.2.9 Infill suitable land uses for land plots' characteristics

Some of proposed uses in the plan are compatible with the environmental, social, economic and urban characteristics of land plots, such as the commercial uses on the main roads' axes in the north and west, in addition to the commercial residential uses on the eastern and southern axes. But there are some educational services located on the narrow roads axes (less than 8 m) as well as some commercial uses within the area are on roads axes (6 m) , which leads to a conflict of those uses' locations as shown in figure 32.

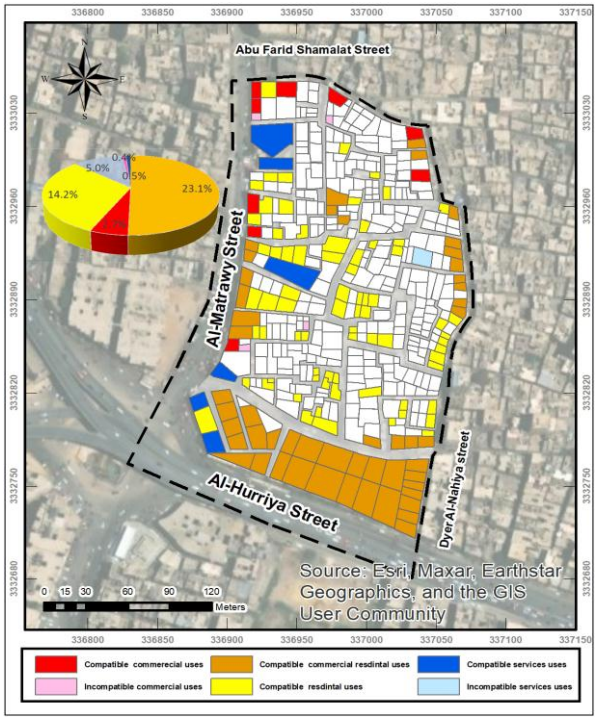


Fig 32. Infill suitable land uses for land plots' characteristics (Author by using GIS)

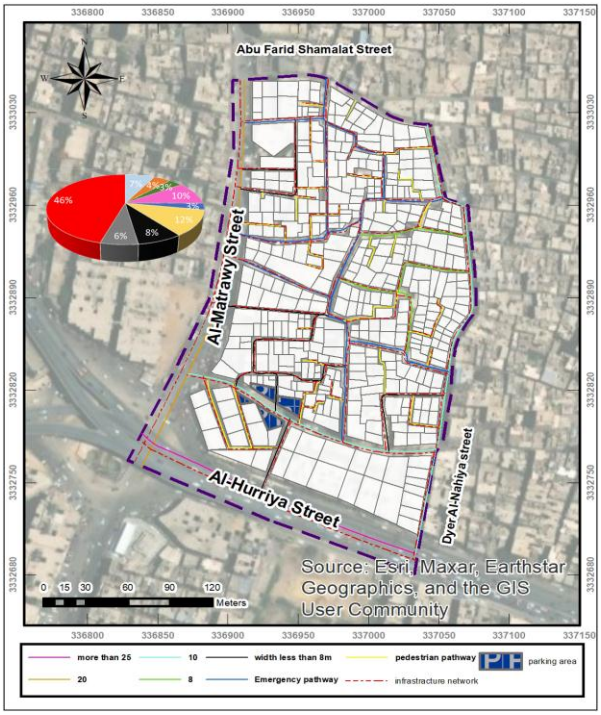


Fig 33. Relation with roads networks and infrastructure (Author by using GIS)

4.2.8 Relation with roads networks and infrastructure

The analysis of road network and infrastructure in infill plan is represented in measuring a set of elements (the extent of connectivity with road network, the number of connecting links, road network' ratio in the area - roads widths - the area of parking - the pedestrian paths and their relations to the motorized axes – location of emergency paths – capacity of infrastructure networks) as shown The in the following points and figure 33.

- 80% of land plots connected with one road only, and the remaining percentage is connected to two roads.
- The percentage of the main road network which used in motor traffic is (10%), and most of these roads whose widths (8m) except for the external roads, whose widths range from 10 – 30m.
- As for waiting places, they are located in the south of the area with an area of 411m2, and they do not meet the needs of the population or services as they cover only 30% of total needs from parking area.
- The plan proposed one main emergency path in the southern part due to the narrow roads widths in internal areas. There is an infrastructure network with road axes, but it needs to increase its capacity to accommodate horizontal and vertical urban densification.

4.2.9 Optimal utilization of land economic value

Although services and commercial activities are proposed on the axes of main roads which surrounding Ezbet El Lemon area, some services and activities (60%) do not correspond to land economic value of land on Al Hurriya Street and Al Matrawy Road as shown in figure 34.Where most of the services and activities are represented in religious services and some commercial activities for only consumer goods.

4.2.10 Dealing with public and private properties

The plan dealt with public properties located on the main roads in the west by settling religious and administrative services in addition to some open areas. while the private properties were not dealt with for the development (90% of el Ezbea) except using some land plots for commercial activities and school in the east as shown in figure 35, due to the clinging the owners to exploit their land plots for residential and commercial uses.

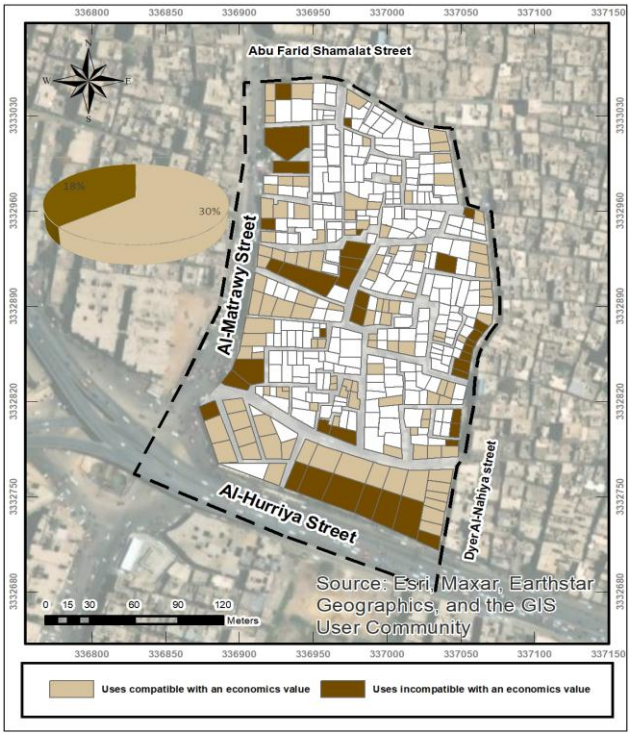


Fig 34. Optimal utilization of land economic value (Author by using GIS)

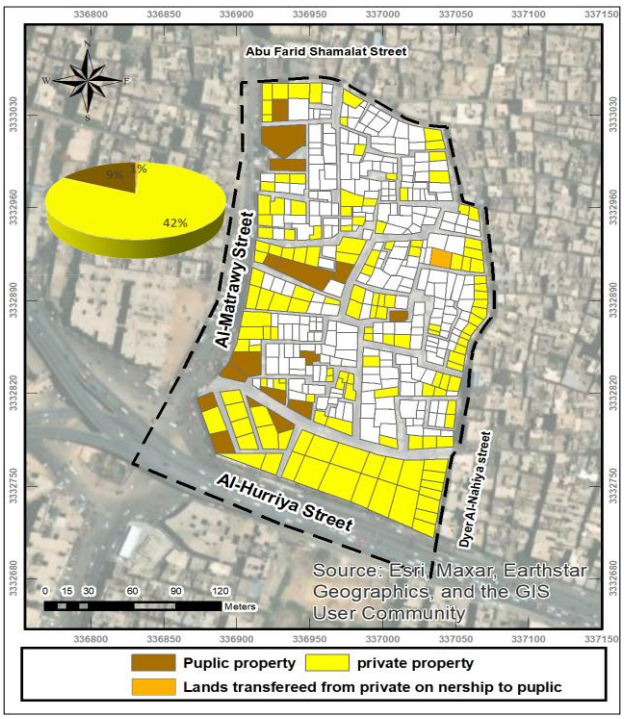


Fig 35. Dealing with public and private properties (Author by using GIS)

4.2.11 Low development cost

The infill plan is characterized by the relatively high cost of development, due to the construction of new residential buildings in the south with an area of 3 acres and the rebuilding of removed deteriorated buildings (3.7 acres) in addition to the construction of services and commercial activities in the vacant lands.

4.2.12 Improving the quality of life

By applying quality of life standards, the most important of which is the decrease in pollution rates and the provision of green areas with necessary basic services for current and future population' needs, it is clear that the plan did not propose any polluted uses. But it did not provide sufficient green areas, as well as it did not cover all the necessary services for current and future population (8000 people) and it did not deal with private properties to expand narrow streets and roads.

4.2.12 Preserving agricultural lands and natural areas

This principle did not appear in the study case due to the absence of agricultural lands or areas with special nature within the area.

4.2.13 Energy efficiency in the residential area

The plan did not suggest high energy-consuming uses within Ezbet El Lemon. But the increase in the building rate to 100% in addition to the vertical expansion of some buildings (6 floors) and decreasing of mixed land use mixes (0>22), will lead to a higher rate of energy consumption.

4.2.14 Using the permissible population density

Ezbet El Lemon had high population density before preparing its infill plan, which reaching 600 people / acre, . And through the plan, the density decreased to 509 by exploiting the added vacant area in the south, but the population density is still higher than the average border of 250 people / acre as shown in figure 36.

4.2.15 Compatibility with social characteristics

The plan dealt with low- and middle-income social groups, and its proposals depended on the same groups without any changes. However, it did not meet all the needs of these groups from basic services, and the dependence of El Ezba continued on the services which located in Al-Mataria neighborhood.

4.2.16 Achieving privacy and security

The plan kept some closed pedestrian paths for some residential buildings to achieve privacy and security, but not in all areas due to the inability to change the road network and pedestrian paths as a result of private ownership.

4.2.17 Residents' acceptance for infill plan

According to the meetings in which the plan was presented to the residents, only 70% of the population was satisfied as a result of not covering all their needs from services and activities and not expanding internal roads in a satisfactory way due to the refusal of some owners to give up their land or part of it in favor of development [62, 63].

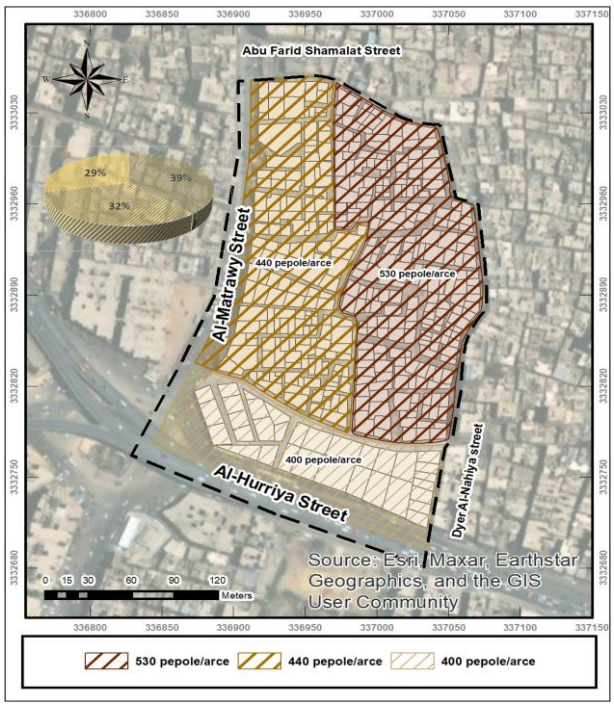


Fig 36. Using the permissible population density (Author by using GIS)

4.3 Degree of application Infill development' principles in Ezbet El Lemon

According to the results of testing the international principles of infill development policy in the case study, it is possible to determine the degree of application those principles and the extent to which they are taken into consideration. This comes through using geographic information system (GIS) in determining the percentage of application each principle which helps, in identifying the hidden principles as shown in table 3 and figure 37.

Table 3 Degree of achievement the infill principles in case study

Infill principles	The degree of achievement			Not achievement
	High	medium	weak	
Development needs	0.85			
Potential areas		0.7		
Putting suitable plan			0.55	
Legal framework			0.62	
Update database			0.63	
Area' characteristics		0.74		
Opinions of residents and stakeholders			0.59	
Exploitable sites		0.78		
Diversity in housing			0.58	
Mixed land use	0.81		0.35	
Size and shape			0.6	
Building heights	0.82			
Building ratio			0.59	
Building materials, direction and distance		0.79		
Services and green area			0.53	
Suitable land uses			0.66	
Roads networks and infrastructure			0.61	
Land economic value			0.64	
Public and private properties				0.33
Development cost			0.6	
Quality of life			0.66	
Natural areas				Not exist
Energy efficiency			0.65	
Social characteristics		0.77		
Privacy and security		0.76		
Residents' acceptance		0.7		

(Source: Author by using GIS)

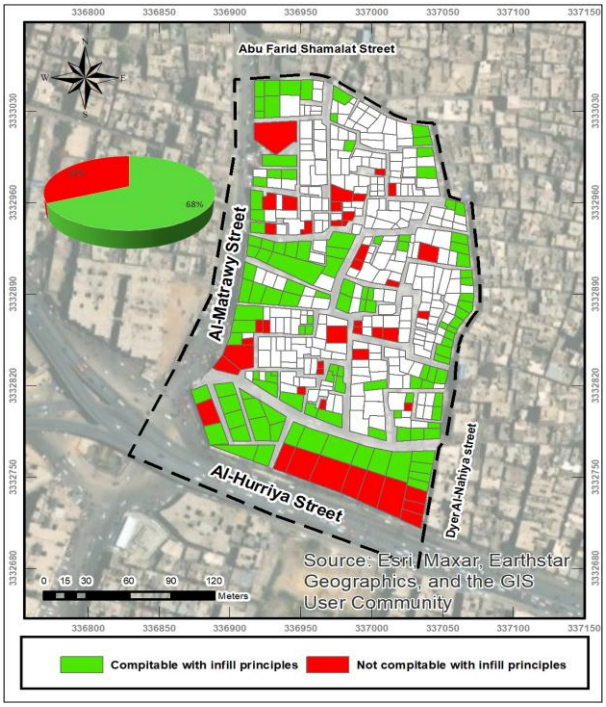


Fig 37. Degree of achievement the infill principles in case study (Author by using GIS)

The previous table and figure show the percentages of application the principles in infill plan of selected study area, which indicate that not all the international principles were taken into account, as the methods of dealing with private property were neglected in suggested infill development plan. On the other side there are disparity in the application of principles that range from high values in some principles such as (the estimation development needs in the level of district – the prevailing of average building heights in El Ezba.

While some other principles are achieved in acceptable average rates, as (studying the current situation - identifying development possibilities - compatibility with the building construction system - taking into account the social characteristics of the population). And for the rest of the principles, the plan applied them in weak rates.

4.4 The main challenges of applying infill development policy in Ezbet El Lemon

The infill plan for the study area faced a set of challenges that affected the application' degree of successful infill principles. These challenges contribute to identifying the most important failures that must be addressed in future plans to get integrated principles. The paper in this step depends on GIS for synthesizing the results of the previous current situation analysis and what was suggested in the plan to formulate those challenges that illustrated in the following points:

- The small land areas of the deteriorated buildings are less than 70 m2 (more than 80% of the total deteriorated buildings), which led to the difficulty of using these buildings except for residential use or as open areas for non-residential uses.
- The opinions of the owners revolve around allowing commercial use only to exist in their residential building, which led to a lack of versatility, whether at the level of the buildings or the total area of El Ezba.
- The owners refused to sell their land plots or to offer part of them for the benefit of the road network and open areas.
- Informal construction of buildings in different shapes and designs, led to the difficulty of adhering to these standards in the proposed infill plan.
- Most of land plots in Ezbet El Lemon are privately owned, compared to only some public plots on the main roads west of the area appear, in which the endowments own them.
- The narrow width of the internal roads (less than 8 meters) led to the difficulty of applying vertical infill or the building heights exceeded 4-5 floors.
- Most of buildings in El Ezba are constructed with load-bearing walls which have affected on not exceeding the buildings heights to more 4 floors.
- The inability to reduce the building rate in some land plots less than 100% due to the small size of its area. In which the reducing of building rate make land plots are not suitable for residential use.
- The disappearance of distances between buildings in the current situation and the contiguousness of private properties led to the inability to provide additional pedestrian paths or roads networks.
- Most of the public properties belong to the endowments, which led to the provision of only religious services compared to the rest of other services that population need them (educational - social services).
- The high land prices located on Al-Hurriya Road

heading to Al-Mataria Square led to the suggestion of commercial activities in it compared to service uses.

- The types of land use surrounding available the possibilities for development impose some types of land uses that do not generate a high volume of traffic.
- The poor efficiency of infrastructure affected the difficulty of increasing the concentration of activities or uses that consume more water and energy.
- The increase in current population density (more than 600 people / acre) also did not allow a greater concentration of housing units, except in the southern and western parts of El Ezba.
- The spatial distribution of public and private properties imposes the existence of some land uses that are not compatible with land economic value.

4.3 Results of experts' opinions

This part aimed at subtracting a group of questions to experts in the field of urban planning, whether academics or engineers in governorates and districts or in the Urban Planning Authority (specialists in the field of research) as shown in appendix. These questions cover two parts, the first one focus on determining the relative importance of the suggested principles to implement an integrated infill plan for residential areas. On the other side, the second part identifies the impact degree of the challenges which facing the process of infill plan and their solutions, as well as the roles of various parties in applying the principles and solutions. The following points show the main results of analysis the expert opinions:

4.3.1 Results of questions' part one

The following figure 38 shows the results of experts' opinions about the relative importance of the principles and their contribution to formulating an integrated infill plan for achieving urban containment in residential areas. It is clear from the figure that the principles of greatest importance in formulating infill plan in residential areas are represented in:

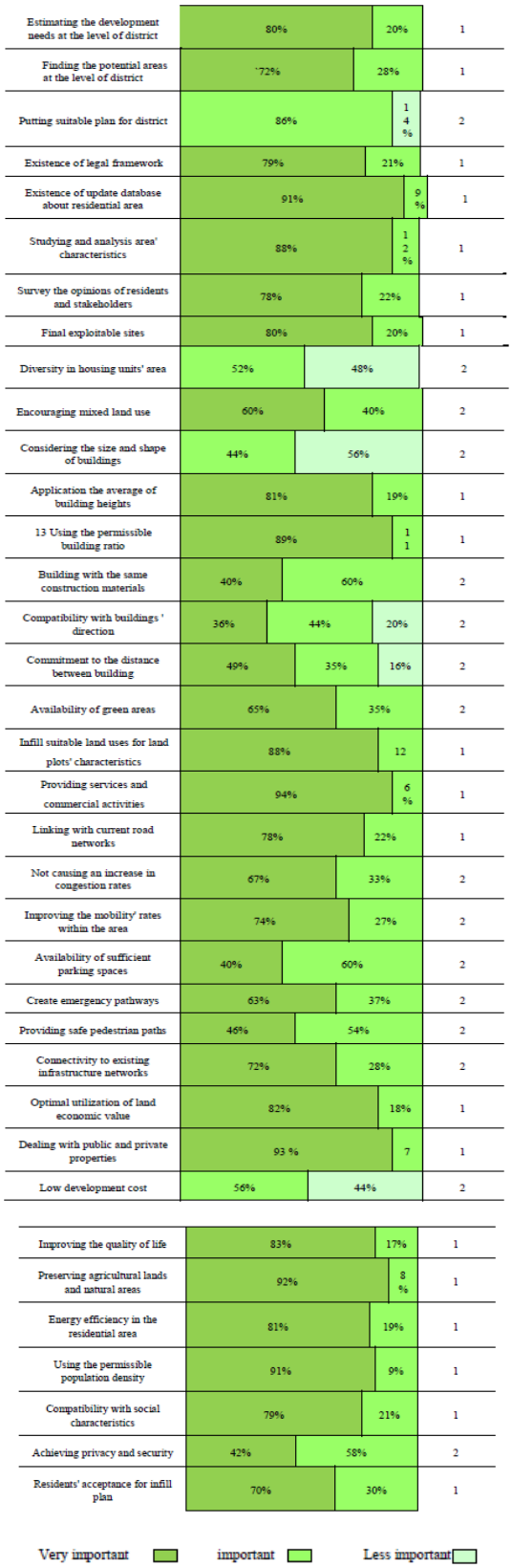


Fig 38 Results of expert opinions about the relative importance of infill' principles (Author)

Estimating the total needs at the level of district- determining the locations of available potentials for development in district - suitable legal framework for infill development policy - having an updated database about the residential area - taking into account the opinions of residents and stakeholders about the type and size of needs.

Also among the most important principles in the stage of preparing infill plan for residential area (taking into account the average buildings heights- maximum building ratio - providing sufficient areas for services and open areas – localization appropriate uses with the social and economic characteristics of land plots - the importance of connection to road network and infrastructure -the possibility of dealing with private properties particularly- the population's acceptance for the proposed plan.

4.3.1 Results of questions' part two

According to the results of the experts' opinions about the impact degree of the challenges on the implementation of the infill policy, it is clear that there are a group of challenges that have a high impact degree as shown in figure 39, including (area of land plots, whether small or large - the owners' refusal to participate in selling or deduction a part from their land for development - the narrow widths of internal road network- the high population density beyond the permissible limits - the presence of specific types of land uses that encourage infill only some uses. While the rest challenges have an impact degree ranged between medium and weak.

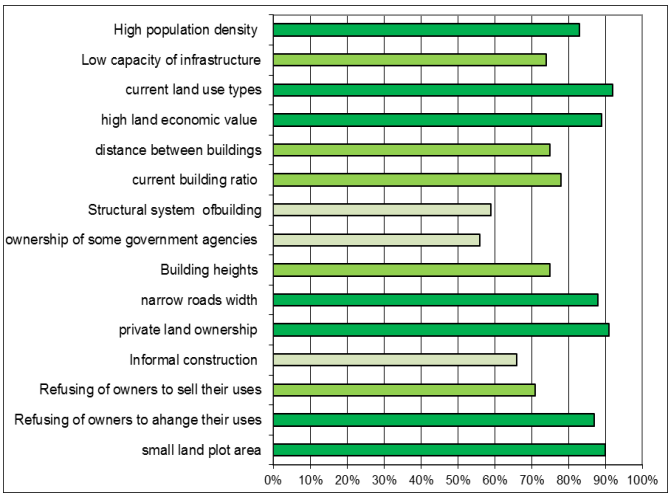


Fig 39 Results of expert' opinions about the impact degree of challenges on applying infill plan (Author)

The most important proposed solutions to address the previous challenges; can be summarized in the following points:

- Dividing lands with large areas to suit with the proposed uses' needs
- Combining more than one piece of small land plot' area to provide large uses.
- Provide sufficient incentives for building or land owners to give part from their ownerships for development (for example allowing them to change their uses or build additional floors in their buildings).
- The state purchases of some private lands to provide the necessary services.
- Cooperation between the different governmental institutions that own the lands for changing the use to what is most needed.
- Providing green areas in land plots with small areas.
- Restructuring buildings for the possibility of vertical expansion
- Adhere to the building ratio which listed in the planning and building laws
- Replacing old infrastructure networks with new ones and increasing their capacity for infill process.
- Suggesting land uses that are more compatible with land economic value of the place.

The results of the experts' opinions also indicated that to implement the infill' principles in residential areas and addressing their challenges, there are some parties that must be present in all stages of preparing infill plans, which are represented in:

(Land and building owners- residents - stakeholders from private sector, investors and owners of activities- transportation authority- Urban Planning Authority- Governmental institutions for all public ownership- National Organization for Urban Harmony).

5. Conclusion

The research deals with one of the important new policies which targeted by the Ministry of Housing in recent times which called (infill development policy), in order to develop the national urban policy (NUP) to reach higher density cities (compact cities and residential areas and contain their various requirements within them. The Egyptian government has recently tried to put forward a set of principles to implement this policy in a balanced

way. Therefore, the research paper attempted to formulate these principles based on a set of axes, which is a review of international reports and experiences in this field, in addition to testing the principles in one residential area (as a case study) by using GIS to determine the appropriateness of these principles and their application challenges. While the last axis aims to survey the experts' opinions to identify their relative importance and try to put suitable solutions to their challenges. The connection between these axes helps to reach the suitable infill principles for urban containment. The following points show the most important findings of the research

Firstly, the different used types of infill policy to get optimum benefit from the available capabilities within the residential area. These types differ from one residential area to another according to its characteristics and must select suitable types in each case, these types represented in: Infill vacant land- Infill greenfield areas – Infill brownfield and greyfield areas - Infill removed deteriorated buildings- Infill reusing building - Infill building heights- Infill vacant units - Infill low development density - Infill medium development density- Infill high development density - Residential infill development - Commercial infill development- Infill industrial uses - Infill service uses - Infill green areas - Infill mixed uses - Block infill development - infill land plot development - Infill small separate land plots – Infill small connected land plots – Infill large separate land plots – Infill large connected land plots.

Secondly, the basic principles that must be taken into account to prepare a balanced infill plan capable of containing urban' needs, which are represented in:

Principles at level of district: (Estimating the development needs- Finding the potential areas- Putting suitable plan - Existence of legal framework).

Principles at the level of the residential area before preparing infill plan, which are:

(Existence of update database - Studying and analysis area' characteristics- Survey the opinions of residents and stakeholders - Determine the final exploitable sites).

Principles in the stage of preparing infill plan which are represented in a set of sectorial principles:

Urban principles (Diversity in housing units' area - Encouraging mixed land use - Considering the size and shape of buildings - Application the average of building heights - Using the permissible building ratio- Building with the same construction materials - Compatibility with buildings 'direction - Commitment to the distance between building- Availability of green areas - Infill suitable land uses for land plots' characteristics- Providing services and commercial activities).

Principles of transportation and infrastructure, namely (Linking with current road networks - Not causing an increase in congestion rates - Improving the mobility' rates within the area - Availability of sufficient parking spaces - Create emergency pathways - Providing safe pedestrian paths- Connectivity to existing infrastructure networks).

Economic principles, including (Optimal utilization of land economic value - Dealing with public and private properties- Low development cost).

Environmental principles such as (Improving the quality of life - Preserving agricultural lands and natural areas- Energy efficiency in the residential area).

Social principles (Using the permissible population density- Compatibility with social characteristics- Achieving privacy and security - Residents' acceptance for infill plan).

Third, the implementation of pervious infill policy' principles requires cooperation between a group of parties such as (Land and building owners- residents - stakeholders from private sector, investors and owners of activities- transportation authority- Urban Planning Authority- Governmental institutions for all public ownership- National Organization for Urban Harmony).

Finally, the paper recommends some auxiliary tools to address the challenges facing the implementation of infill policy in Egyptian residential areas, including: (Dividing or merging land plots to implement the proposed land uses in infill plan- provide sufficient incentives for owners to benefit from their participation in applying infill plan- purchasing some urgent land plots by state or private sector for development purposes- suggesting green areas in high-density residential areas and on small plots that are not suitable for other uses- developing current infrastructure for future plans - compliance with planning and building laws- cooperation and coordination between the various government agencies to prepare and implement a good infill plan- taking into account the environmental, social, economic and urban dimensions when offering new land uses in infill plan).

Appendix:

Personal information

Name: ..... Job: .....
Field of specialization: ..... Workplace: .....

The research aims to identify the principles that the planner must take into account when preparing infill development plan to achieve sustainable urban containment that meets the needs of residents and stakeholders in a balanced way.
Questionnaire form consists of three parts:
The first part measures the relative importance of the proposed principles by international studies and experiences.
The second part investigates the most important challenges facing the application of the infill principles in residential areas and attempts to find solutions to them.
The third part tries to know the roles of the responsible authorities for applying infill principles to improve and contain urbanization in a sustainable way.

Part 1 (Measuring the relative importance of the proposed principles
(Choose the relative importance for each following principle for achieving successful infill development policy in residential areas)

1/1 Estimating the development needs at the level of district
very important ☐ important ☐ less important ☐

1/2 Finding the potential areas at the level of district
very important ☐ important ☐ less important ☐

1/3 `Putting suitable plan for distict
very important ☐ important ☐ less important ☐

1/4 ` Existence of legal framework
very important ☐ important ☐ less important ☐

1/5 Existence of update database about residential area
very important ☐ important ☐ less important ☐

1/6` Studying and analysis area' characteristics
very important ☐ important ☐ less important ☐

1/7 Survey the opinions of residents and stakeholders
very important ☐ important ☐ less important ☐

1/8 Determine the final exploitable sites
very important ☐ important ☐ less important ☐

1/9 Diversity in housing units' area
very important ☐ important ☐ less important ☐

1/10 Encouraging mixed land use
very important ☐ important ☐ less important ☐

1/11 Considering the size and shape of buildings
very important ☐ important ☐ less important ☐

1/12 Application the average of building heights
very important ☐ important ☐ less important ☐

1/13 Using the permissible building ratio
very important ☐ important ☐ less important ☐

1/14 Building with the same construction materials
very important ☐ important ☐ less important ☐

1/15 Compatibility with buildings ' direction
very important ☐ important ☐ less important ☐

1/16 Commitment to the distance between building
very important ☐ important ☐ less important ☐

1/17 Availability of green areas
very important ☐ important ☐ less important ☐

1/18 Infill suitable land uses for land plots' characteristics
very important ☐ important ☐ less important ☐

Part 2 (Determine the influence degree of the challenges which derived from the case study on the success degree of infill plan
(Choose the influence degree of each challenge on the success degree of infill plan)

2/1 the small area of available land plots in the residential area
High impact ☐ Medium impact ☐ low impact ☐

2/2 Refusing of land and building owners to change their uses
High impact ☐ Medium impact ☐ low impact ☐

2/3 Not allowing landowners to sell their land plots or part of them for development purposes
High impact ☐ Medium impact ☐ low impact ☐

2/4 Informal construction of buildings in different shapes and designs
High impact ☐ Medium impact ☐ low impact ☐

2/5 Existence large proportion of private land ownership in the residential area
High impact ☐ Medium impact ☐ low impact ☐

2/6 The narrow width of the internal roads
High impact ☐ Medium impact ☐ low impact ☐

2/7 Building heights in the residential area
High impact ☐ Medium impact ☐ low impact ☐

2/8 Owning some government agencies to some land plots
High impact ☐ Medium impact ☐ low impact ☐

2/9 Structural system of current buildings
High impact ☐ Medium impact ☐ low impact ☐

2/10 The current building ratio in land plots and total residential area
High impact ☐ Medium impact ☐ low impact ☐

2/11 The distance between buildings
High impact ☐ Medium impact ☐ low impact ☐

2/12 The high land economic value of some land plots
High impact ☐ Medium impact ☐ low impact ☐

2/13 The types of land use surrounding available the possibilities
High impact ☐ Medium impact ☐ low impact ☐

2/14 Low capacity of infrastructure networks
High impact ☐ Medium impact ☐ low impact ☐

2/15 High population density in the residential area
High impact ☐ Medium impact ☐ low impact ☐

2/16 Are there other challenges affecting the success degree of infill plan?
Yes ☐ No ☐

2/ 17 If the answer is yes, what are the additional challenges affecting the infill plan?
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2/18 What are the appropriate solutions to address these challenges in infill plans?
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What are the entities that should be included to apply the principles of infill plan?
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REFRENCES

[1] Abedini A. and Khalili, A. "Determining the capacity infill development in growing metropolitans: A case study of Urmia city", journal of Urban Manag, 2019, 8, 316–327, https://www.researchgate.net/publication/332594686_Determining_the_capacity_infill_development_in_growing_metropolitans_A_case_study_of_Urmia_city/link/5e78fff7a6fdcceef972f9ff/download

[2] Aly S. and Attwa Y. "Infill development as an approach for promoting compactness of urban form", WIT Transactions on Ecology and The Environment vol173, Department of Architecture and Environmental Design, Arab Academy for Science and Technology and Maritime Transport, Egypt, 2013, pp457– 459, https://www.witpress.com/Secure/elibrary/papers/SDP13/SDP13038FU1.pdf

[3] Angel S., Sheppard S. and Civco D. "The Dynamics of Global Urban Expansion" , Washington: The World Bank,2005,http://www.citiesalliance.org/publications/homepage-features/feb-06/urban-expansion.html

[4] Al Kubaisi A K. "Measuring the quality of life of the faculty members at the university", (a comparative cultural study) for samples (Libyan, Iraqi and Egyptian)(Libya: Omar Mukhtar University / Libya Faculty of Arts and Sciences / Department of Behavioral Sciences) No49 p432, 2016.

[5] Barton J.R. and Ramírez M.I. "The role of planning policies in promoting urban sprawl in intermediate cities: Evidence from Chile", . Sustainability (Switzerland), 11(24), 1–17, 2019 https://doi.org/10.3390/su11247165

[6] Healey E. and Birrell B. "Housing and community in the compact city"Australian Housing and Urban Research Institute, Swinburne-Monash Research Centre, AHURI Positioning Paper No.66, 2009 , http://www.ahuri.edu.au/publications/p50224/

[7] Kang M. and Austin B. "Infill Development in A Post-Redevelopment World " , California: Domus development Agency January, pp2–4, 2014.

[8] Cunningham C. " House price uncertainty, timing of development, and vacant land prices: Evidence for real options in Seattle", Journal of Urban Economics, 59, 1-31,2006, https://www.sciencedirect.com/science/article/abs/pii/S0094119005000537

[9] Fakhr A.S.M. " Future of urban development planning by emphasizing determined infill vacant land use (case study: Do Gonbadan), Msc thesis, Tarbiyat Modare university, 2006

[10] Coupland A. "Reclaiming the City: Mixed Use Development" London, E & FN Spon, 1997, https://www.routledge.com/Reclaiming-the-City-Mixed-use-development/Coupland/p/book/9780419213604

[11] Birrell B. Connor K., Rapson V. and Healy E. "Residential infill and its threat to Melbourne's liveability. In Melbourne 2030: Planning Rhetoric Versus Urban Reality (Vol. 1), 2005, Monash University ePress,

[12] Clegg E. and Vogt K. "Quality Infill Recommendations and Tools" , City of Boise: Idaho Smart Growth, Urban Land Institute ULI , Idaho District Council January, 2010 , pp3–4, https://www.idahosmartgrowth.org/quality-infill-recommendations-and-tools/

[13]ARC Smart Growth Tool Kit, 2017, Retrieved from https://www.dekalbcountyga.gov/sites/default/files/user18/infill_development.pdf

[14] Fariss J. and Terrence "The Barrier to using urban infill development to achieve Smart growth, Housing policy debate, 12, 1. 2001.

[15] Felt, E. "Patching the Fabric of the Neighborhood: The Practical Challenges of Infill Housing Development for CDCs" Citeseer: State College, PA, USA, 2007.

[16] Grant J. "Mixed Use in Theory and Practice: Canadian Experience with Implementing a Planning Principle" , Journal of the American Planning Association, 2002, https://www.researchgate.net/publication/235363384_Mixed_Use_in_Theory_and_Practice_Canadian_Experience_with_Implementing_a_Planning_Principle

[17] Kamal A. "Suitability for Infill Development: A multi-criteria and Spatial Assessment Approach", In Proceedings of the ARCC Conference Repository, Manoa, HI, USA, 12–15 February, 2014, pp. 336–345, https://www.researchgate.net/publication/317690920_Suitability_for_Infill_Development_A_multi-criteria_and_Spatial_Assessment_Approach

[18]Landis J. D. “The Future of Infill Housing in California: Opportunities, Potential, and Feasibility.” Housing Policy Debate 17, no. 4 (2006): pp681-725, https://www.tandfonline.com/doi/abs/10.1080/10511482.2006.9521587

[19] Robinson and Cole LLP Best Practices to Encourage Infill Development. Association of prepared for the National Associaion of Realtors, 2002.

[20] Fariss J. and Terrence "The Barrier to using urban infill development to achieve Smart growth" , Housing policy debate, 12, 1, 2001, https://www.tandfonline.com/doi/abs/10.1080/10511482.2001.9521395

[21] Mohammadi M. R. P., Shahrivar, R. and Ahmad, A. " Infill Development Potential for Urban Deteriorated Areas (Case Study: Zanjan City)" International Journal of Scientific Management and Development, ISSN:2345-3974, 2005, Vol.3 (2), pp. 678 -678 , https://www.academia.edu/10668463/Infill_Development_Potential_for_Urban_Deteriorated_Areas_Case_Study_Zanjan_City_

[22] CAPMAS “General Statistics for Population and Housing: Population Census, Central Agency for Public Mobilization and Statistics" , Egypt, 2017.

[23] GOPP, “The National Urban Development Framework: in the Arab Republic of Egypt”, The Arab Republic of Egypt, Ministry of Housing, Utilities and Urban Communities, General Organization for Physical Planning, 2014.

[24] Khalifa M. A. “Redefining Slums in Egypt: Unplanned Versus Unsafe Areas,” Habitat International, Vol. 35, No. 1, pp. 40–49, 2011. https://www.sciencedirect.com/science/article/abs/pii/S0197397510000024X

[25] Sims, D., "Understanding Cairo: The Logic of a City Out of Control", the American University in Cairo Press, Cairo, 2012, https://www.jstor.org/stable/j.ctt15m7mmr

[26] Lucas, B. "Infill development- an efficient use of resources" ,Washtenaw County planning and environment, solid waste programs, 2005.

[27] Listokin D., Walker C.C., Ewing R., Cuddy, M. and Cander A. "Infill Development Standards and Policy Guide", New Jersey, 2006, https://nj.gov/state/planning/assets/docs/publications/179-infill-standards-060106.pdf

[28]Mirmoghtadaee, M. " Demands and Feasibilities of Infill Development in Iranian Urban Areas-the Case Study of Tehran", In Proceedings of the W101-Special Track 18th CIBWorld Building Congress, Salford, UK, 10–13 May 2010; p. 1, https://www.irbnet.de/daten/iconda/CIB18895.pdf

[29] Phan T., Peterson J. and Chandra, S. " Urban infill: extent and implications in the City of Monash. People and Place" 16(4), 23-31, 2008,

[30] Rafieian M., Barati N. and Aram, M. "Measurement of the Development Capacity of Useless Spaces in the Center of Qazvin with Emphasis on the Infill Development. Architecture and Urban Planning Letter", 2010, 45, 2010

[31] Razavian M. and Samadi, R. "Evaluation of Infill Development Potential in Zone 8 of Tabriz by Analysis Network Process Method", Curr. Urban Stud. 2016, 4, 125–139, https://www.scirp.org/journal/paperinformation.aspx?paperid=66798

[32] Rafieian M., Barati N. and Aram M., Measurement of the Development Capacity of Useless Spaces in the Center of Qazvin with Emphasis on the Infill Development. Architecture and Urban Planning Letter, 2010, 45, 2010.

[33] Sharifian E. " Infill Development. Utilization of Internal Capacities of the City", Periodical of Manzar, 10, 50, 2010.

[34] Schiller G., Blum A., Hecht R., Oertel H., Ferber, UMeinel, G. Urban infill development potential in Germany: Comparing survey and GIS data. Build. Cities 2021, 2, 36–54

[35] Sheppard, Stephen, " Infill versus Outspill: the microstructure of urban expansion, William College Working Papers in Economics, 2006,

https://web.williams.edu/Economics/UrbanGrowth/Papers/Infill_versus_Outspill_motu_org.pdf
[36] Stollman S., Hague S. And Alexander G. "Attracting Infill development in distressed communities:30 Strategies (United States: United States Environmental Protection Agency EPA230-R-15-001, Office of Sustainable Communities, Smart Growth Program, California Strategic Growth Council May 2015) P1–7
[37] Monmouthshire Country Council," Supplementary Planning Guidance Infill Development" , 2019, https://www.monmouthshire.gov.uk/app/uploads/2020/02/Appendix-2-Infill-Development-SPG-Latest-Version-for-Final-Adoption-2020-Dave-adjustments-00000002.pdf
[38] Irwin E. and Bockstael, N. " Measuring and Modeling Urban Sprawl: Data, Scale and Spatial Dependencies, unpublished working paper, 2006, https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=3b47932bef227d072ef3a0a31314dfca325afcbb
[39] Aytur S.A., Rodriguez D.A., Evenson K.R. and Catellier, D.J. Urban Containment Policies and Physical Activity. A Time-Series Analysis of Metropolitan Areas, 1990–2002. Am. J. Prev. Med. 2008, 34, 320–332.
[40] Eichhorn, S.; Rusche, K.; Weith, T. "Integrative governance processes towards sustainable spatial development—Solving conflicts between urban infill development and climate change adaptation.", J. Environ. Plan. Manag. 2021, 64, 2233–2256.
[41] Lee K., Kim T.., Lee W. and Kim E. "A Study on Effects of Neighborhoods Environments on Residents Walking Trips Using Household Travle Diary Survey Data in Seoul" . Seoul Stud. 2014, 15, 95–109.
[42] Mirzaei H. A. " Capacity Building of District Development Based on the Approach of Urban Infill Development (Case Study: Shadabad District in Zone 18 of Tehran). Tehran: Department of Architecture and Urban Planning, University of Science and Technology, 2006.
[43] Mirmoghtadaee, M. "Demands and Feasibilities of Infill Development in Iranian Urban Areas-the Case Study of Tehran". In Proceedings of the W101-Special Track 18th CIBWorld Building Congress, Salford, UK, 10–13 May 2010; p. 1.
[44]Winig B., Wooten H., Allbee A and Gladstone E. Building in healthy infill (ChangeLab Solutions Report) ChangeLabSolutions.org. Law &Policy Innovation for the Common Good (California) p4–15, 2014.
[45] Stollman S, Hague S, And Alexander G . "Attracting Infill development in distressed communities:30 Strategies" , (United States: United States Environmental Protection Agency EPA230-R-15-001, Office of Sustainable Communities, Smart Growth Program, California Strategic Growth Council May 2015) P1–7, 2015, https://www.epa.gov/smartgrowth/attracting-infill-development-distressed-communities
[46] Wheeler S. M. "Infill Development in the San Francisco Bay Area: Current Obstacles and Responses. November 2001. Paper Presented at the Association of Collegiate Schools of Planning (ACSP) Conference in Cleveland and Published Electronically by HUD's Regulatory Barriers Clearinghouse, 2001
[47] MRSC report, ":empowering local Governments, 2023, https://mrsc.org/explore-topics/planning/development-types-and-land-uses/infill-development
[48] Ghodsi N., Nastaran M. and Izadi, A. "Infill development approach: A smart transition way to the sustainable future urban development. Sustain. Comput. Informatics Syst. 2021, 32, 100614, https://www.researchgate.net/publication/355507842_Infill_development_approach_A_smart_transition_way_to_the_sustainable_future_urban_development
[49] Maryland city, " Maryland's Growth models and guidelines for Infill development", 2001 , https://planning.maryland.gov/Documents/OurProducts/publications/modelsguidelines/infillfinal_1.pdf
[50] City of El Paso report, " infill development" ,2017, https://www.elpasotexas.gov/assets/Documents/CoEP/Planning-and-Inspections/Applications/Zoning-Applications/Infill-Policy-Guide.pdf
[51] City of Chilliwack report, 2020, https://www.chilliwack.com/main/page.cfm?id=2065
[52] Richmond Hill report, " residential infill development", 2021, https://www.richmondhill.ca/en/shared-content/resources/documents/Zone-Richmond-Hill/Residential-Infill-Zoning-Bylaw-Paper.pdf
[53] Edmonton City report, "complementary infill Plan for residential areas" , 2022, https://www.edmonton.ca/sites/default/files/public-files/documents/PDF/Residential_Infill_Guidelines_Sept_2009.pdf
[54]Atlanta Home Builders report, 2023, https://atlantahomebuilders.com/wp-content/uploads/2018/07/Residential-Infill-Development.pdf
[55] Sims D., "Understanding Cairo: The Logic of a City Out of Control", the American University in Cairo Press, Cairo, 2012, https://aucpress.com/product/understanding-cairo/
[56] Alternative policy solution, Developing a National Urban Policy for Egypt: Towards Compact Cities, 2019, available online: https://aps.aucegypt.edu/en/articles/85/developing-a-national-urban-policy-for-egypt-towards-compact-cities
[57] Law no. 3. (1982), "Urban planning Law", Ministry of Justice, Egypt.
[58] Law no. 59. (1979), " New Urban Communities Law ", Ministry of Justice, Egypt.
[59] Law no. 119. (2008), "Unified Building Law", Ministry of Justice, Egypt.
[60] El Matareya, Cairo, avalible online : https://en.wikipedia.org/wiki/El_Matareya,_Cairo
[61] CAPMAS, "General Statistics for Population and Housing: Population Census, Central Agency for Public Mobilization and Statistics," Cairo, 2016.
[62] Ministry of Housing , General Authority for Urban Planning, Al-Matareya district plan , 2013.
[63] Ministry of Housing , General Authority for Urban Planning, Urgent projects in Al Mataria district, 2015