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ORIGINAL ARTICLE

The role of land use change in developing city spatial models in Jordan: The case of the Irbid master plan (1970–2017)

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 Urban expansion;
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 City of Irbid;
 Spatial model

Abstract Irbid city witnessed a rapid population growth starting from 2003 up to now, which affected the expansion of the city form. This led to awareness of an urgent need to evaluate the current urban planning practices which have been implemented and how responsive they are to land use changes. This paper investigates the role of land use change in determining the spatial model of urban growth in Irbid. The study outlines the development of planning stages from 1970 to 2017. It also explores the temporal and spatial characteristics of urban expansion by analyzing Irbid city maps at different time intervals. Quantitative methods are used by employing GIS. The literature presents the impact of developing land uses on the expansion of the city borders, and identifies the spatial patterns of urban growth. The study concludes with a spatial model of the city comprising structural plans and practical recommendations for Irbid urban development for a better understanding of the city expansion pattern. It also predicts the way of city urban development, thereby identifying its influence on land use changes. This model is, therefore, valuable for informing policy or responding to current planning practices in Irbid and other similar cities nearly considered irregular pattern.

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1. Introduction

This research is about the application of urban models of land use to Jordanian cities using the case of Irbid city. Several decades of population explosion and accelerating urban growth have had profound environmental and socio-economic impacts felt in both developing and developed countries [1]. Urbanization in Jordan is the result of a rapid population

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increase caused by mass immigration and a flow of refugees for which conventional surveying and mapping methods have not delivered the necessary information in a timely and cost-effective manner. Therefore, this paper shows the increasing need to study the GIS maps which identify the development boundaries from 1970 to 2017 since there has been a lack of sufficient documentation for the Irbid master plan over the last 50 years. This approach will address the urban planning aspects and practices facing city development.

This study focuses on the city form of Irbid and its land uses. It looks at the nature of the city of Irbid in terms of form, land use, origin and development, as well as a comprehensive future understanding of problems and methods of treatment. A comparison process between the city in different interval times to see if this development is fully or partially compatible with one or more of land use models. This research includes: a study of the development of Irbid city according to the form and land use from 1970 to 2017, a brief study of land use models comparing the city development with these models, and determining a spatial model of the city development according to the models presented. This strongly contributes to determining the future problems and alternatives, strengths and weaknesses of the city plan throughout its historical development.

2. Methodology

New analytical tools are required to enrich and expand the conventional methods used ensuring sustainability of urban settings. Among these are Geographic Information Systems (GIS) - digital mapping systems that link spatial and non-spatial data of urban features - which help in documenting different urban features and their role in modelling the urban process. GIS techniques have been applied in this study for land use change detection. Given their cost-effectiveness and technological soundness, GIS is increasingly being used to develop useful sources of information and to support decision-making in connection with a wide range of urban applications [2]. Moreover, it can be used to identify and map urban form with a fine spatial resolution [3,4]. GIS tools are now being used to gather, store, retrieve, analyze, display, and output data related to the urban and suburban environment, as well as supply planners with certain data sets that help in managing the urban and suburban areas [5]. However, there are some limitations that may be experienced in the use of GIS technology. Such technology may require enormous data input in order to carry out other tasks, and the more data input that is needed the more will require providing a set of experiences for this method.

Master plan is a comprehensive plan that is used to structure land use plan that forms a key element of the master plan, and guides future urban growth and development of cities [2,5]. Therefore, the role of master plan in this research/methodology is represented in providing land use plan maps and urban expansion areas throughout the selected periods to be used in this study. In this context, the adopted methodology of analytical approach begins with: geographical analysis, satellite images, aerial photographs and land use mapping using data analysis via Geographical Information System (GIS). This paper focuses on the distribution of land use in

time intervals in addition to the physical and resource contexts of Irbid city. The paper presents a scientific analysis of aerial photographs and satellite images that propose administrative boundary maps using GIS and realistic solutions to enhance the urban environment. Statistical inventory used a GIS software to show the existing situation of Irbid city components and to calculate the land use classification upgrade till now, as well as analysis the expansion areas in the period of study, in addition to other charts or tables reflect the change of land use in interval periods.

The data was used in this study are Land use maps within the Irbid Master Plan for the following years 1970, 1980, 1990, 2010, 2017 acquired from Great Irbid Municipality (GIM), Landsat 7 ETM+ (resolution 30 m and 15 m) for year 2010, and Landsat 8 OLI (resolution 30 m and 15 m) for year 2017 were procured as our primary data source from the U.S. Geological Survey (<http://earthexplorer.usgs.gov/>). (<http://earthexplorer.usgs.gov/>), and vertical color aerial photograph with nominal scale of (1:25,000) the year of 1990 was acquired from the aerial photo archives at the Jordanian Royal Geographical Jordanian Centre (JRGC). All maps obtained from GIM were in hard copy form. Therefore, they were scanned at equal intervals throughout the whole image and scanned data were compressed and stored in a TIFF format and uploaded to computer for further use. The next step has consisted of geometric correction for the scanned images, where all maps were geometrically corrected using control points acquired from topographical map issued by JRGC and used as reference map for the current study. Finally, vectorizing the raster images using on-screen digitizing as a manual method using Arc GIS 10.3 software was done to extract patio-temporal land use boundaries over the period of 1970–2017.

The aerial photograph negative was scanned with a photogrammetric precision scanner at resolution of 20 μm resulting in an approximate ground pixel resolution of 0.50 m and later were compressed in a TIFF format. The photo was rectified using photogrammetric SOCET SET software packages using camera calibration report of the used camera (Leica RC 30 Aerial Camera Systems of focal length 153.28). The images orientation and point extraction procedures were carried out using standard procedure to generate an orthophoto based on fundamental steps that consist in interior orientation, exterior orientation (registration into a defined reference system) and point extraction [6]. The rectified aerial photograph was visually interpreted and vectorized by onscreen digitizing method using ArcGIS 10.3 to get the land use boundaries for the year 1990. While, Landsat 7 ETM+ and Landsat 8 OLI images were processed by correcting them by applying radiometric and geometric correction. The land use classification was performed for Landsat datasets using the A maximum likelihood method within the GEOMATICA PCI software [7] for the years of 2010 and 2017. The data sets that have the same period were used for cross validation and quality assurance of the data products, since the data sets were of different types, dates, scales and time after they were reprocessed into a uniform geo-reference. The resulted data were used to create a profile of urban extent of the study area and organized into spatiotemporal geographic information system (GIS) database using the spatial analysis tool in ArcGIS 10.3 for further manipulation and statistics calculations.

3. Literature review

3.1. Land use changes

The physical form of cities is the final result of a multitude of economic, environmental and social developments [8]. Al-Hashimi [9] stated that the morphology of cities has to be understood in terms of their processes, forms, shapes and scales. Therefore their statics and dynamics will enable us to map out our approach, which builds our understanding of urban form. To examine the relationship between potential socio-economic drivers and environmental constraints, land use patterns were correlated with population size and topography [8].

The graphic delimiter of the city's form is urban boundaries, while urban land-uses describe the obvious zones in a city [9]. The physical form expressed by boundaries was shown by analyzing Irbid GIS maps in the next section. The focus here is on the effect of land use change on urban boundaries of Irbid city plan since there is such a scarcity of detailed information, data, maps and archival records about urban land uses. The comprehensive and quantitative investigations of the socio-economic factors driving urban area growth, and the physical elements affecting urban land's spatial distribution are generally seldom reported [10]. Therefore, these comprehensive studies can supply city planners and decision-makers with information about the past and current spatial dynamics of land use change and urban expansion for better environmental and planning monitoring [11].

In other studies of Jordanian cities (such as the case of Amman city 2011 of Makhamreha and Almanasyeha), their methodological approach includes two main steps: the first is to define the current land use pattern and locate the spatial distribution of urban services. The second is to investigate the trend of urban growth during the period 1972–2009 using Landsat images and GIS [12]. The urban land use plan for the city of Amman was designed to transform the city from being mono-centric to a multi-centric metropolis. For decentralizing the population and economic activities, the satellite towns of Amman have had a significant impact on the pattern of development of urban growth and urbanization in the city [12]. This result confirms the findings of Al Rawashdeh (2006) who examined the Satellite Monitoring of Urban Spatial Growth in Amman. He concluded from the analysis that expansion over the years was shaped by the major roads that connect the major cities, and that expansion always took place over the agricultural land [5].

3.2. Land use models

This part of the research reviews the zonal models that emerged in the early 20th century and were adapted in urban planning processes based on the distribution of land uses from different perspectives. A wide range of economic, social, geographic and developmental factors contributed to changes in cities planning, and their formation based on segregation of land uses [13]. Zonal models were the result of these factors where they discussed city planning and its growth direction according to land uses and patterns [14].

These models are known as human ecological models or socio-ecological models. The underpinning literature review

comprised, amongst others, works by Lewinnek [13], Kupkova [14], Oluseyi [15], Manotham [16], Tupper [17], Planning Tank administrator [18], and found that the models that can explain the growth of the city in more dynamic ways are represented in the concentric zone model, sector model, multi-nuclei model, urban realms model and irregular urban pattern, as shown in Fig. 1.

3.2.1. Concentric zone model

This model was developed by Earnest Burgess, Robert Park and Roderick McKenzie in 1923 Kupkova [19]. Kupkova [14] describes the human relations and the physical, social and environmental surroundings which affect land patterns to distribute land uses in urban areas as a result of the ecological process Kupkova [16]. In this model, the urban area is divided into five concentric zones each with its own function Kupkova [13,20]. This model is characterized by its social and cultural homogeneity and an economy based on industry and commerce creating competition for space [15]. It is also based on equity in access and transportation, where the lower class is closer to the business centre, while the upper class is located in the suburbs [13]. However, this model does perpetuate social separation and an inequality in the distribution of income or welfare among classes [15]. Also it does not detail the transport system [18]. Furthermore, this model assumes that the Earth is flat and does not address natural and industrial determinants, therefore it is not an appropriate model for many cities [21].

3.2.2. The sector model

The radial sector theory was proposed by Hoyt in 1939 [14]. It was designed on the basis that land uses are distributed according to direction not distance [22], therefore, the patterns of land use are predictive and not random [16]. This model

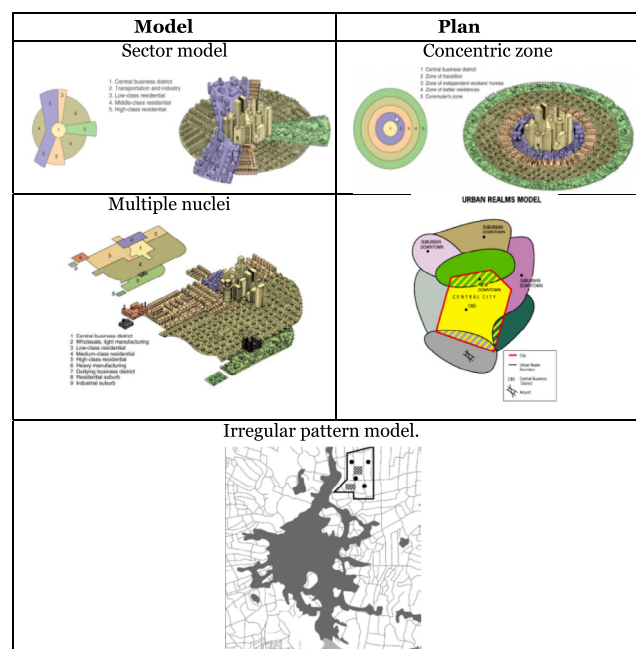


Fig. 1 Land use models (from: Oluseyi, 2006; Manotham, 2010; Kupkova 2010). Modified by the researcher.

includes mixed use of land within the various sectors at a limited level promoting a decentralization process especially in the middle and lower-income sectors [17]. It also takes into account natural features and vital facilities such as railways and ports, and it locates industrial activity away from the centre, thus providing access to the centre for all sectors [23]. However, this model does not lend importance to cars which facilitate transition around the city enabling people to live outside the city [19]. Furthermore, the lower-income group is located near industrial activities which generate pollution, inconvenience and traffic congestion [23]. It does not, therefore, promote fairness across the population distribution nor achieve adequate levels of well-being for all [17].

3.2.3. Multiple nuclei model

McKenzie suggested this model in 1933 which was then developed by Harris and Ullman in 1945 [14,18]. Manotham [16] stated that the city starts from a single growth centre and that, over time, activities become scattered and gain significance from the surrounding areas, and develop into distinctive points in the city like small nuclei that, in turn, begin to influence the growth of activities around them [25,14]. Carter and Polevychok [22] suggest that this model marks the transition of cities from mono-centric to poly-centric urban forms. The fairness in the distribution of resources, transport costs and residential areas in the city are considered the most important characteristics of this model [18,26]. In addition, the geographical factor is also taken into account as is the fact of each area having its own characteristics and features [25,26]. However, this model cannot be applied as it is to many cities, because it is based on the structure of the City of Chicago [17]. The model also requires large areas of land in order to be suitable, therefore, it is only suited to large cities [25]. In addition, this model is limited to a specific set of activities which is considered too rigid. Therefore, it needs to set the activities and uses in deeper and broadly, where it is descriptive rather than predictive [18,27]. Also it disregards the height of buildings and governmental policies [28]. Finally, this model does not take into account the different cultural, social, religious and political backgrounds that any society would necessarily comprise [24].

3.2.4. Urban realms model

This model was suggested by James Vance as the latest model created in 1964. It proposes that each realm is a separate social, economic and political entity that is linked together to constitute the larger metropolitan framework [29]. It also shows that the outer cities are not satellites of the central city, but are becoming cities themselves and shaping the metropolis [30]. This model has a set of strengths and weaknesses. On the one hand, it is characterized by taking advantage of all areas of the city (the geographical factor) and accommodates a growing population easily due to its automobile dependence [29]. Its overall economic strength is that the metropolis can become self-sufficient [30]. However, this model cannot be applied as it is to many cities because it is based on the structure of San Francisco, and has previously failed in other cities like Phoenix in Arizona [29]. It also displays a large amount of urban sprawl that witnesses uncontrolled expansion of urban areas, thereby isolating the suburban region affected by topography barriers [30].

3.2.5. Irregular urban pattern

The “third world” countries address concerns that differ greatly from cities in the West, and this has resulted in an irregular urban pattern with no rationale behind it is built [31,32]. Due to rapid population growth without economic growth, lack of legal planning or construction, burgeoning informal sector activities and a large poorly-housed or homeless population, extensive irregular settlements emerged [33,34]. Robinson [33] stated that this city has no clear plan for expansion, and so the city form can take on all kinds of appearances with, for example, industries being mixed quite heavily with other uses [35]. This model has some strengths and some limitations. On the one hand, it is characterized by dealing with irregular space located around the Global Command Centre CBD [31]. It also is characterized by affordability of land for those on lower income [35,33]. It is a model that can be used for the city effectively if the irregular portion of the urban area grows so that the urban region is based on external expansion. But, conversely, if the irregular portion of the urban area decreases, then most of the growth is dependent upon filling areas on the edge of the urban area [35]. It should be noted that this urban model is the result of a lack of legal urban planning or construction and without a specific order resulting in blocks with no fixed order, or permanent and temporary structures, and reinforces the separation of high and lower income earners [35]. In addition, it requires a wide systematic research targeting the renewal and recasting of old irregular settlement housing stock that is entirely lacking [31]. This model also has a narrow, dead-end street network in the city transportation structure [36].

3.3. The case of Irbid city

During the last century, the city of Irbid offered a safe haven for immigrants from neighbouring countries at war. It is located in the northern part of Jordan, in the highland areas with an average elevation of 620 m, at longitude 35,851479 and latitude 32,551445 [12]. It is located about 70 km north of Amman, 20 km south of the Syrian border and it has a Mediterranean climate as shown in Fig. 2. Its population was 739,212 inhabitants in 2015 [37–39].

This study seeks to offer the change of land use pattern during the period from 1970 to 2017 by creating GIS maps of the land use of Irbid city. It also concludes with a prediction of urban growth boundaries. The whole region was subjected to demographic changes affecting Jordan due to wars in the region. As Irbid city was affected by the migration waves that moved into Jordan, this led to the return of more than 350,000 people to Jordan after the first Gulf War in 1991 [40] and about 450,000 Iraqis entered Jordan after the second Gulf War in 2003 [38,41]. Consequently, the population has increased in Irbid from 201,208 inhabitants in 1995 to the current 740,123 inhabitants making Irbid the second largest metropolitan population in Jordan after Amman [42].

Understanding the change that occurred due to urban development is a crucial issue to those who manage resources and provide services in these rapidly changing environments, and those who study urban dynamics [38]. This situation is more severe in developing countries where the fast pace of urbanization is mainly unplanned, therefore it presents a real



Fig. 2 Map of Jordan: Irbid city location, (Sources: Makhamreha, 2011).

threat to different social, cultural and natural resources. In this context, Shunnaq and Schwab [39] argued that urban changes in Irbid occurred because of the social dimension which is reflected first and most clearly in the use of space within a society's cities. These changes occur in the primary city and then diffuse to other surroundings in the urban hierarchy. Irbid displays a broad spectrum of neighbourhood types.

In the current situation, an analysis report was prepared of the city of Irbid and approved by the Ministry of Municipal Affairs; it consists of two parts: the first part introduces the concept of master planning. The second is in a form of round table discussions where a short survey took place evaluating the existing conditions of Greater Irbid Municipality and citizens' aspirations for the present and future of the city [43].

Stakeholder consultation includes a set of interviews conducted with different public and governmental agencies, and community representatives during every phase of the project. A series of focus groups, a survey and interviews were held to shape the city that is modern, embraces its heritage, is well planned and sustainable, is economically prosperous, is a regional hub for education and is actively investing in its natural environment [43]. In addition, the Ministry of Municipal Affairs and partner municipalities offered a phasing plan predicts a framework of the city expansion. This plan is divided into three broad phasing strategies over the life of the plan, which are defined as follows [44]:

1. Near-Term (approximately 2009–2016)

Areas to be developed in phase 1 reflect the investment priorities of consolidating development in intensification areas of urban growth areas including corridors and centers and Rural Growth Areas maximizing the use of existing infrastructure and services.

2. Medium-Term (approximately 2017–2023)

This phase includes expansion areas within Urban Growth Areas that allow the efficient extension of the urban service networks.

3. Long-Term (approximately 2023–2030)

This phase includes expansion areas within Rural Growth Areas and Rural Settlement Intensification Areas.

To achieve the main purpose of this research, the study will examine the expansion areas of the city of Irbid. As such the urban expansions of the city were observed and analyzed during the periods indicated in Fig. 3. In 1980, there was an increase of 68 km² due to population growth as a result of movement from rural areas to Irbid city. The city expanded a further 52 km² in 1990 due again to the same population movement. Thereafter, the first Gulf War in 1991 and the second Gulf War (Iraqi refugees) in 2003 played a key role in expanding the city boundaries (51 km²) in 2010. Finally, There was only slight urban expansion (2 km²) in even though the region was exposed to a wave of Syrian refugees in 2011.

4. Analysis

In this part of the research, each stage of the land use plan of the Irbid master plan development stages starting from 1970 to 2017 is separately documented, analysed and compared with the models discussed in the previous part. This gives an opportunity to determine whether the Irbid city plan conforms to the models by reviewing their similarities and differences.

It is noted that the refugee camps represent a fixed area block for all stages and that this has special political and social considerations that limit the level of intervention by the municipal authorities since the camps are linked to private organisations. They can be considered low-level residential areas in comparison with other residential areas in the city.

4.1. Irbid city growth, 1970s stage

According to Fig. 4, the Irbid organizational plan is not compatible with the Burgess model. The shape is not concentric where there is no concentric division in the plan. Also there is no social separation or separation purely by use, so the residential uses in the Irbid city plan are divided according to the characteristics of the land and the services available and not on

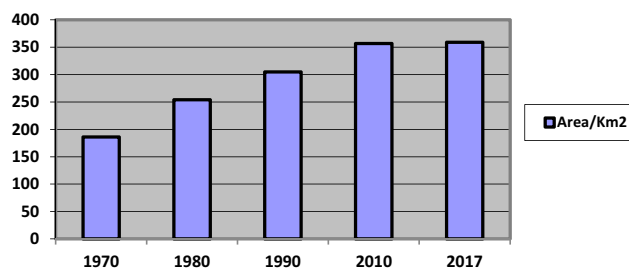


Fig. 3 The expansion areas of the city of Irbid from 1970 to 2017. (Source: GIM, 2015). Modified by the author.

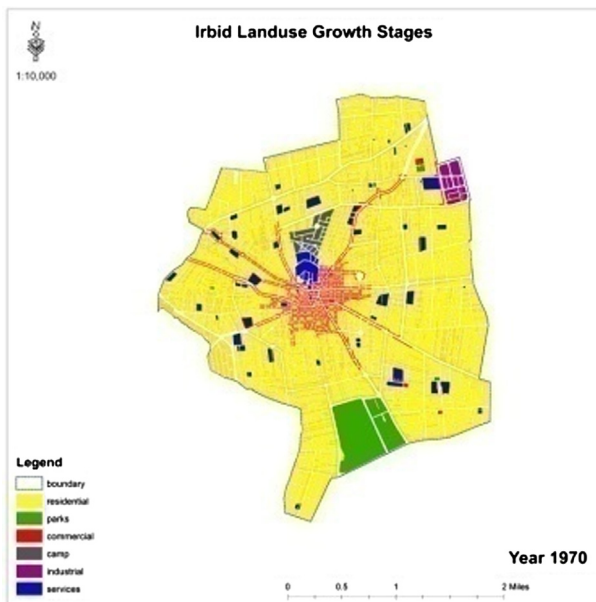


Fig. 4 Land use plan for Irbid city in 1970, Source: The Author.

the basis of social class. Moreover, the existence of a complex and integrated system of dense and interlocking transport routes is not addressed in the Burgess model, and the presence of the hill in the city of Irbid plus the diversity of terrain with hills and valleys are contrary to the model. As for the points of compatibility, these are partial and limited to the uses in the centre. Both include commercial uses, services and offices, but Irbid city centre has residential, parking and other mixed uses that are not located in the centre for the Burgess model but can be found in the transition zone. Therefore, this model cannot be conformed to the Irbid city plan within this stage.

For the Hoyt model, the points of difference between it and the city plan are also numerous, for example: there are no wedges, no separate or independent service sectors or features and no social or class separation of the population. Irbid city constitutes one integrated unit so the growth does not emanate from the centre in the form of radial wedges through the radial roads starting from the centre. The car is the most important means of transport in the city of Irbid, but this is not reflected in the Hoyt model and, conversely, no railway or tram considerations are included within the city plan. As far as the common points, they are limited and partial: the existence of a road network in the city corresponds only to an implied existence of roads by virtue of the presence of commercial and service uses in the model. However, the roads in the city are entangled and dense, not radial, and have not directly brought about growth but have rather been one contributor. This is because some roads in the city were built in anticipation of growth and some as a consequence of growth depending on government policies. Furthermore, the city centre has various commercial and business uses as well as residential which the Hoyt model does not include. In addition, there are industrial zones on the periphery but, unlike the Hoyt model, they are not for low-income residents. Therefore, this model is not a good representation of the Irbid master plan at this stage.

As for the multi-nuclei model there are more points in common. The land is not flat in both the Irbid master plan and the model both of which show the different terrains. Also the pres-

ence of equality in the distribution of resources, features and services in the regions is evident in both. The existence of universities, parks and other important uses that affect growth in the city are not separated or independent as in the model. In addition, the presence of the industrial zone is treated as a specialized area and this is reflected in the model. As for the contradictions, it is clear that the city of Irbid does not consist of separated areas that are independent from the centre, and its uses are diverse, mixed and wider in a more profound way than in the model. Also growth in the city follows municipal and government policies as well as various internal and external influences upon decision-making, and this is lacking in the model. Moreover, the growth in Irbid city was not the result of the presence of important uses that scattered and attracted growth around it over time, therefore Irbid's plan cannot be the product of the expansion of these scattered nuclei or their integration together. These disparities as well as the lack of ports, airports and railways in the city render this model inapplicable to the city plan at this stage.

The commonalities with the realm model are also discussed here. As mentioned before, some of the current road networks in the city have been established and developed to meet the requirements of growth, where other roads came after the expansion of the city plan according to government policies. The realm model has not taken the transportation system as an issue where there has been automobile-dependency. This model does well at explaining suburban growth which simulates the expansion of Irbid city in terms of outer suburbs. The points of difference between this model and the city plan are numerous, however. Irbid city is a single unit with a clear centre, while this model consist of several realms each of which has its own central business district "CBD" which is represented by the different focal points. Therefore, the presence of equality in the distribution of resources, features and services in each realm cannot be applied to Irbid city. Another point is that there are areas within the city that do not permit the existence of edge cities and different realms. Also there is a lack of airports in the city which is a main feature of the model. These differences, therefore, mean that this model cannot be applied to the city plan at this stage.

Finally, for the irregular pattern model, there are more points in common. The city of Irbid has no specific expansion direction, and unclear urban expansion is the most important feature characterizing the irregular model. Also the narrow and dead-end street networks are featured in both the Irbid plan and the irregular model. Therefore, Irbid city in this stage is suitable for this model since there is a lack of legal planning, construction or a specific order, where it includes blocks with no fixed order, or permanent and temporary structures. In addition, Irbid city has the second largest metropolitan population after Amman where, during the last 20 years, urban expansion was very noticeably driven by a high natural growth rate of 2.3% leading to rapid population growth which in turn resulted in the lack of services and poverty, and this was one of the main reasons for the appearance of this model. Therefore, this model indeed does explain the plan of Irbid at this stage. However, the end result in the study to identify the model that fits Irbid city plan according to the different stages of its development and growth from 1970 to 2017, will be reached in the next part of the research.

As shown in the land use Table 1 and the organizational Fig. 5 above, the total area of the city was 186,132 square kilo-

Table 1 Land Use Zones Areas of the city of Irbid in 1970, Source: The Author.

Land use	Area/km ²	Ratio %
Residential	11.64	62.51
Commercial	0.63	3.36
Services	0.64	3.41
Parks	1.49	8.15
Industry	0.15	0.8
Camp	0.17	0.62
Total	14.71	78.85
Streets = 100-78.85 = 21.15%		
Area of boundary = 18.61 km ²		

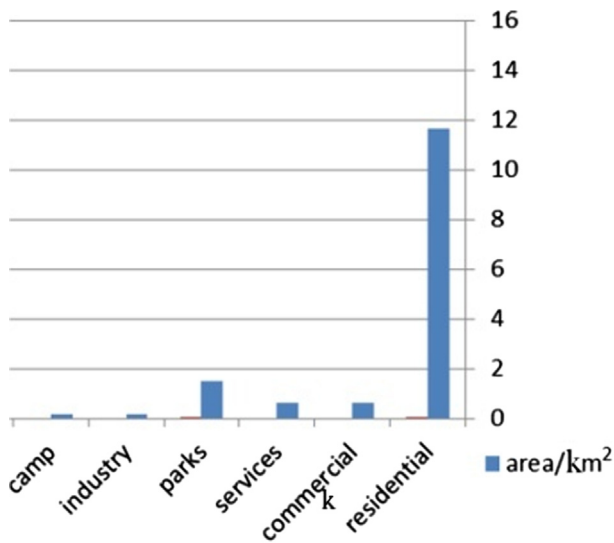


Fig. 5 Land use zones areas for Irbid city in 1970, Source: The Author.

meters in 1970. Residential use occupied the largest proportion of the city area at 62.51% where the residential areas were distributed around rather than in the centre. Also, the centre had a large concentration of commercial activities which spread across the main streets to the surrounding residential areas. Road networks in the city occupied 21.15% of the total regulatory area of the city, where there are retina intensively and nested. The industrial area located at the upper end of the planned north-east constituted 0.8%, which is the lowest proportion of land use among existing uses. According to Fig. 4, the general outline of the city's growth pattern was irregular.

4.2. Irbid city growth, 1970s & 1980s stage

It should be noted that there were no significant changes in the Irbid city plan that would affect the result obtained by analysing the previous phase. Consequently, the results will remain the same for the five models reviewed and compared to the Irbid city plan in 1970s stage from the last century (Fig. 6). This section discusses what happened to change the city plan. This is not only simply to do with the increase of the regulatory area as a result of urban sprawl and population growth. It should be noted here that this is a continuous process due to

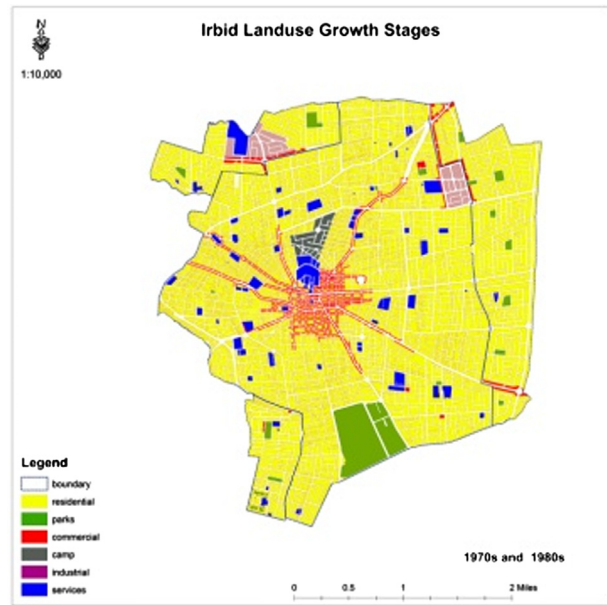


Fig. 6 Land use plan for Irbid city in 1980, Source: The Author.

the existence of a positive relationship between the variables of growth that drives decision-makers to introduce new areas within the regulatory city plan to cover this increase. This is, therefore, an imposed predictive direction by different factors and influences.

The geographical factor has played an important role in the growth and expansion of Irbid city. Expansion was stopped at the western boundary of the plan due to the presence of Al-Ghafr valley along the western side of the city's borders, whilst expansion began in the north-western and southern directions. As a result, it is observed from Fig. 7 and Table 2 above that the city has become an area of 254,195 square kilometres, where residential use still occupies the largest area of the plan with an increase to 63.03%. In addition, the road network increased to 22.02% and the industrial zone expanded to 1.4% of the plan area. This shows an increase of industrial

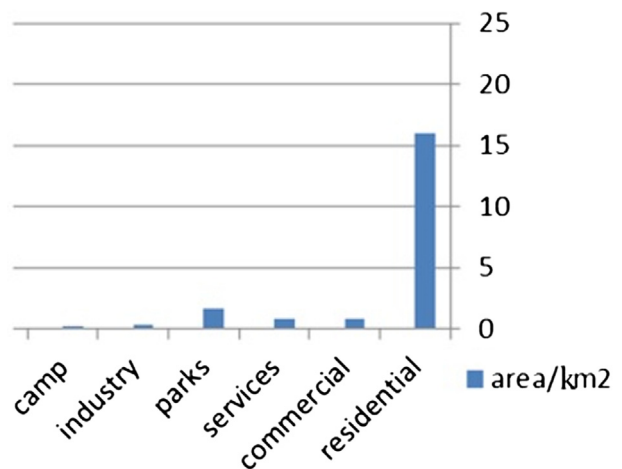


Fig. 7 Land use zones areas for Irbid city in 1980, Source: The Author.

Table 2 Land Use Zones Areas of the city of Irbid in 1980, Source: The Author.

Type	Area/ km ²	Ratio %
Residential	16.02	63.03
Commercial	0.79	3.11
Services	0.78	3.1
Parks	1.68	6.63
Industry	0.35	1.4
Camp	0.17	0.71
Total	19.79	77.98
Streets = $100 - 77.98 = 22.02\% = \hat{E}5.62 \text{ km}^2$		
Area of boundary	25.42 km ²	

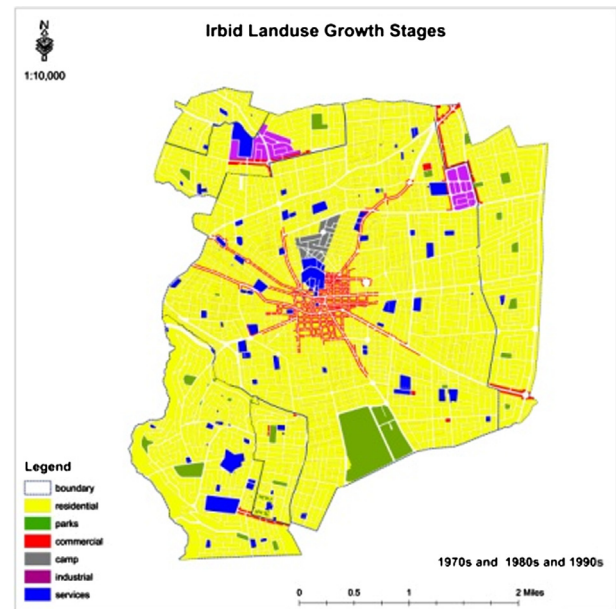
activity in the city remaining on the edge of the upper eastern city. The increase in the area that was occupied with different activities, is a result of the expansion of city through other areas to be joined to the organizational city plan (Fig. 6). The decline in commercial activity is attributed to an increase in the area of organized planning as well as its lack of expansion in the new areas that were added at that stage, in addition to the percentage of uses that decreased of total percentage of the area of organizational city plan. Moreover, there was an expansion of some residential and commercial activities at the expense of other activities such as open areas. As a result of this stage, the irregular model was the most appropriate for the 1980 Irbid city plan.

4.3. Irbid city growth, 1980s & 1990s stage

At this stage, the expansion process continued and the plan included other areas after joining the regulatory area. The organized area of the region increased to become 306,533 square kilometers with residential use the largest area organized at 63.65%, and an increase in the road network to 22.31% (Fig. 9). But there was a decrease in other land uses: most notably there was a decline in commercial use to 2.66%, as well as in parks and open spaces to 6.11%. All this decline favoured the construction of residential and service uses (Table 3). It is noted that this decline in some uses occurred as a result of the increase in the organizational plan area. There had actually been an increase in the spread of commercial activity and open spaces, especially in the city centre, as the centre had become a exclusion zone for residential

Table 3 Land Use Zones Areas of the city of Irbid in 1990, Source: The Author.

Type	Area/km ²	Ratio %
Residential	19.51	63.65
Commercial	0.81	2.66
Services	1.05	3.41
Parks	1.83	6.11
Industry	0.35	1.14
Camp	0.22	0.72
Total	23.77	77.69
Streets = $100 - 77.69 = 22.31\% = 6.88$		
Area of boundary = $70 \text{ s} + 80 \text{ s} + 90 \text{ s}$	30.65 km ²	

**Fig. 8** Land use plan for Irbid city in 1990, Source: The Author.

use, to be replaced instead by commercial and service activities (Fig. 8). In addition, Fig. 8 indicates the spread of commercial activity along the main streets to meet the population needs. However, the proportion of total area of the city organizational plan actually decreased as a result of the increase in the city organized area. Accordingly, the result of this stage is still the irregular model which was also the most appropriate for the 1990 Irbid city plan.

4.4. Irbid city growth, 2010 stage

At this stage, it is noted that the regulatory region increased to 35,740 square kilometres as a result of the expansion of city, but the space occupied by residential use fell to become 58.07% of the planned area. However, there was in turn a significant increase in commercial use to 8.45% of the regulatory area (Fig. 10). In addition, there was a remarkable rise in the proportion of services use to 6.01% of the planned area. Also the industrial use reached 1.65% of the plan, whilst there was a clear decline in the proportion of open areas to 1.24% of the planned area (Fig. 11 and Table 4). In this case, the spread of residential use increased as a result of the city expansion, but the rate declined because of the increase in the total organizational city area. Furthermore, residential use declined in the city centre which could no longer accommodate many households. It should be noted that the situation at this stage remains the same as previous stages in comparing Irbid city plan with the five models.

4.5. Irbid city growth, 2017 stage, the current city land use plan

For this stage representing the current phase of the city plan, it remains the regulatory area of the city as in the previous stage, where the city continues to grow and expand within the available regulatory space without needing to include new areas of the organizational plan for the city. Fig. 13 shows that there is

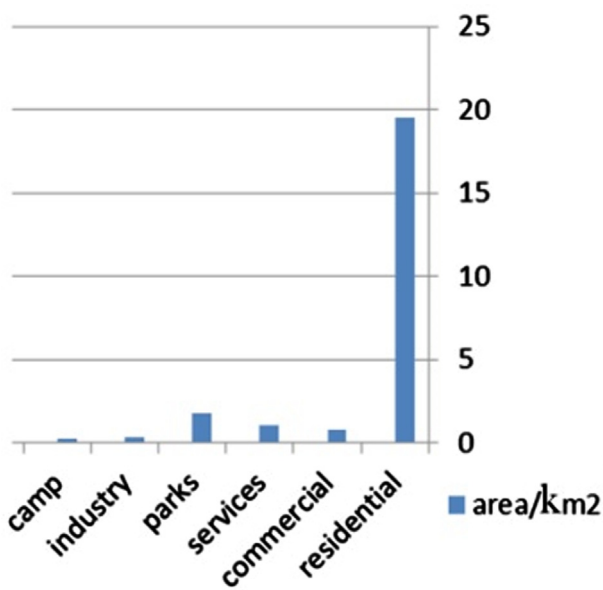


Fig. 9 Land use zones areas for Irbid city in 1990, Source: The Author.

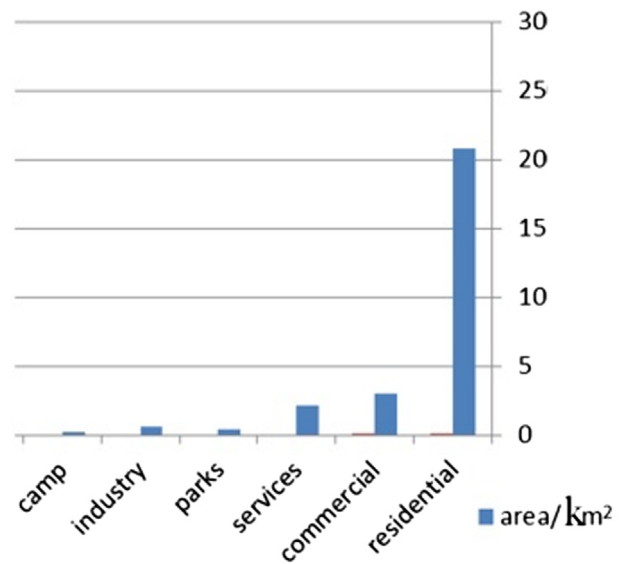


Fig. 11 Land use zones areas for Irbid city in 2010, Source: The Author.

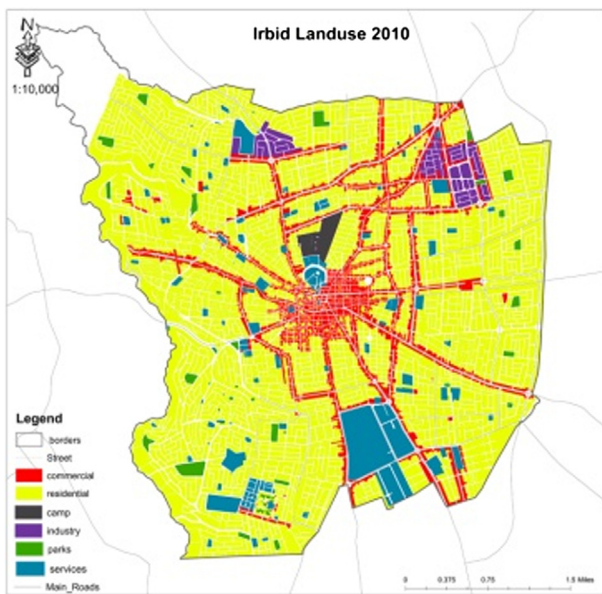


Fig. 10 Land use plan for Irbid city in 2010, Source: The Author.

a clear decline in residential use to 56.37% and services use to 6.95% of the regulatory area for the city. On the other hand, industrial use at 1.63% has remained stable. Open spaces fell to 1.21% but there is a marked and continuing increase in commercial use ratio to 11.57% of the city's organizational area (Table 5). It should be emphasized that the decline in the proportion of residential use and open areas and services, despite the increase in the plan area, is the result of the increased regulatory plan area for the city. Also it should be

Table 4 Land Use Zones Areas of the city of Irbid in 2010, Source: The Author.

Type	Area/km ²	Ratio %
Residential	20.75	58.07
Commercial	3.019	8.45
Services	2.15	6.01
Parks	0.44	1.24
Industry	0.59	1.65
Camp	0.22	0.62
Total	27.17	76.04
Streets = 100-76.04 =	8.57	23.96
Area of boundary = 70s + 80s + 90s =	35.74 km ²	

Table 5 Land Use Zones Areas of the city of Irbid in 2017, Source: The Author.

Type	Area/km ²	Ratio %
Residential	20.79	56.37
Commercial	4.27	11.57
Services	2.56	6.95
Parks	0.44	1.21
Industry	0.60	1.63
Camp	0.22	0.61
Total	28.89	78.34
Streets = 100-78.34 =	6.85	21.66
Area of boundary	35.74 m ²	

noted that the growth in commercial and residential uses has been at the expense of open spaces as shown in Fig. 12. It can be concluded, then, that the change in the proportions of use (either as an increase or decrease) is a result of municipal policy for the classification of regulatory areas and existing uses.

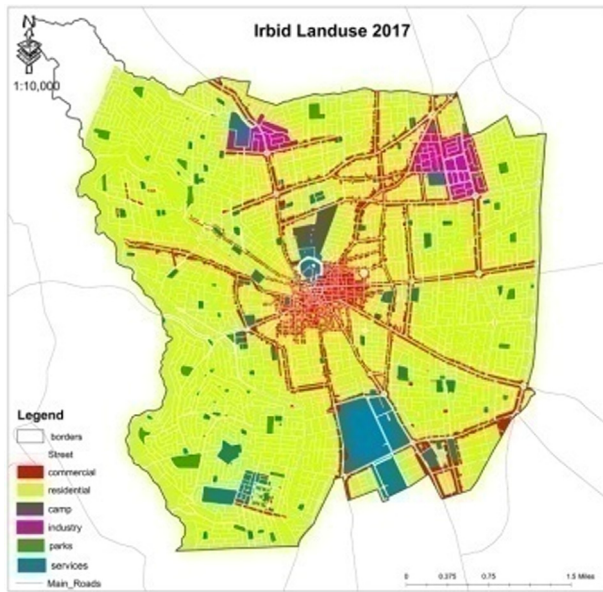


Fig. 12 Land use plan for Irbid city in 2017, Source: The Author.

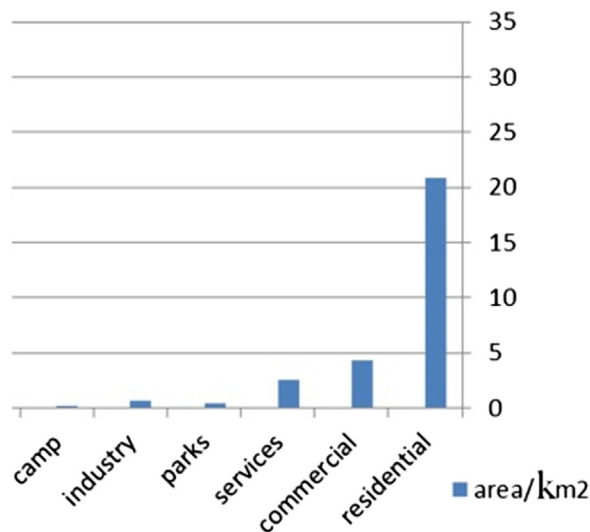


Fig. 13 Land use zones areas for Irbid city in 2017. Source: The Author.

5. Discussion

After reviewing the identified models it is concluded that the irregular pattern model is the most applicable for the city of Irbid. Irbid city has no specific direction of expansion, has a clear uncontrolled urban sprawl in the shape of the city and the areas within the city centre feature narrow and dead-end street networks. In addition, there is a complex overlap of activities and uses making it difficult to separate them out. On the other hand, the government policies and Greater Irbid municipality play a simple role in directing the expansion of

city. Therefore, this model indeed does explain the plan of Irbid city at this stage.

According to the comparison between the current Irbid city plan and the land use models based on their individual criteria as shown in Table 6, it is evident that the irregular model has the highest percentage of match with Irbid city plan (100%), therefore it is consistent with this plan. This confirms the findings extracted from the last section. In contrast the other models yielded a low percentage of match with the Irbid city plan (43%). This accords with the findings extracted by the research analysis above, so these models were excluded by this research as inapplicable to the Irbid city plan.

The expansion of Irbid city occurred in different stages. In this study, the concentration is over the last 50 years: in the 1970s Irbid expanded over nearly 18.6 km², increased to 25.4 km² in the 1980s and then expanded to 30.7 km² in the 1990s. These equate to a relative increase of 26.8% between the 1970s and 1980s, and about 17.26% between the 1980s and 1990s. In 2010 the city expanded by 13.9% to an area of 35.7 km² and remained the same until 2017 due to the stability of the boundaries of the city of Irbid which, since 2001, has been part of the Greater Irbid Municipality (GIM) and considered its urban area (Figs. 14 and 15).

According to Fig. 14 the shape of city has been developed through previous periods starting from the 1970s, and expanded in three directions: to the east, the north-west and the south-west in terms of the subdivision projects that took place. From the 1980s and continuing in the 1990s it expanded in two directions of the city: to the north and the west as well as acquiring additional zones in particular places. Finally, in 2010 through 2017 the city expanded to the south and north-west taking the current shape known as the urban area of GIM.

Table 7 and Fig. 16 explore the changes and development in terms of uses. It is noted that in the 1970s the highest percentage of zoned area was residential at 62.51% whilst the lowest was industrial at 0.8%. In the 1980s the trend continued with the highest again being residential at 63.03% and the lowest 1.4% for industrial. In the 1990s residential was about 63.65% and industrial remained the lowest with a percentage of 1.14%. In 2010 and 2017 the residential category was still the highest percentage (58.07% and 58.12% respectively) whilst the lowest percentage was parks at 1.24% in 2010 and 1.25% in 2017. This was because of the stability of borders and expansion within the city itself in the land uses, especially conversion to commercial use which witnessed a rapid increase in the transitional period of the nineties to the period beyond 2000s. This contributed to minimizing open and green areas in the city. As for services, streets and open spaces were stable at the middle level of the change from 1970s to 2017.

This overview of the evolution of land use through the years shows that the residential area was the highest in 2017, nearly the same in 2010 at 20.7 km² and the lowest in the 1970s with 11.6 km². However, it varied as a percentage from the highest in the 1990s at 63.65% to the lowest in 2010 at 58.07% (Table 7 and Fig. 17). This can be explained as long as we calculate the percentage relative to the total area so that, and as the boundary expanded (whilst a few changes occurred in uses expansion), the percentage decreased. Looking at com-

Table 6 Comparison between the current Irbid city plan and the land use models.

Model	Criteria	Rings Growth	Concentric Zones	Flat land	Shift of Land use	Centralization	Invasion and Occupation Process	Transportation	Matching ratio
Concentric Model		x	x	x	x	x	x	x	0%
Sector Model	Sectoral Growth	x	Predictive land use ✓	Central radial roads x	Land prices ✓	Population classes x	Decentralization ✓	Transportation means x	Matching ratio 43%
Multi-nuclei model	Nuclei growth	x	Specialized areas ✓	High cars ownership ✓	Descriptive process x	Sources distribution x	Decentralization ✓	Activity set x	Matching ratio 43%
Urban realm model	Realm growth	x	Specialized areas ✓	Topography ✓	Suburban ✓	Sources distribution x	Decentralization x	Transportation x	Matching ratio 43%
Irregular model	Irregular pattern	✓	Illegal areas ✓	Topography ✓	Land prices ✓	Sources distribution ✓	Decentralization ✓	Transportation ✓	Matching ratio 100%

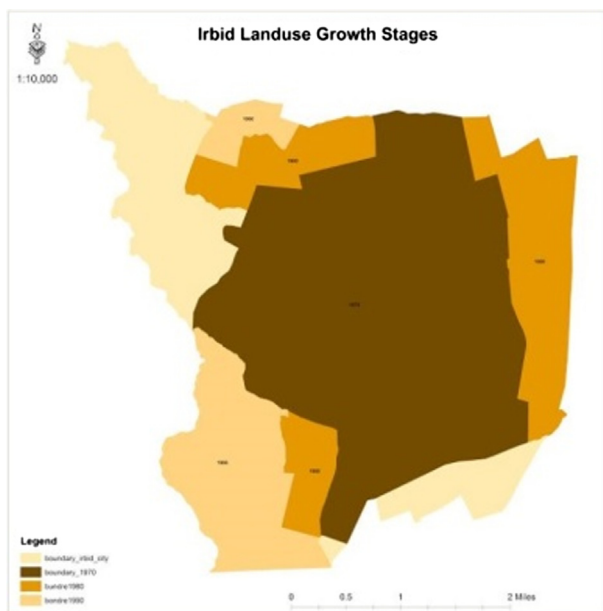


Fig. 14 Irbid city plan expansion during the period 1970 to 2017.

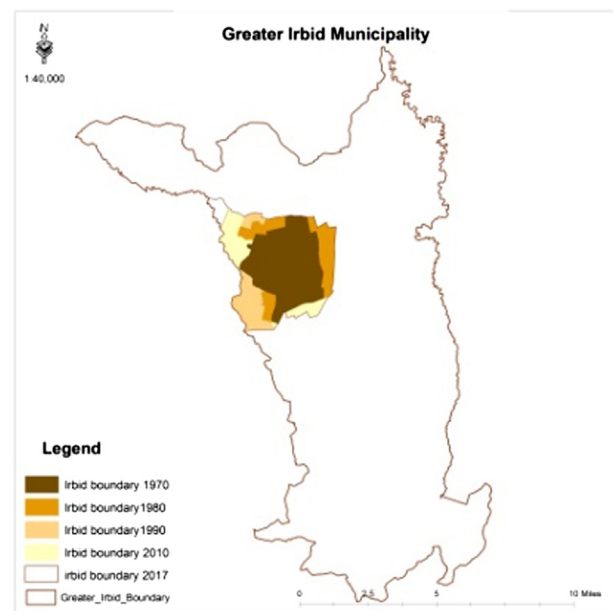


Fig. 15 Greater Irbid Municipality boundaries.

mercial uses, the highest was 4.27 km² in 2017 with a percentage of 11.94%, with the lowest at 0.63 km² in the 1970s with a percentage of 3.36%. As a percentage of the zoned boundary, however, the lowest was 2.66% in the 1990s (Table 7). For parks the highest was 1.83 km² in the 1990s with a percentage 6.11%, while 2010 and 2017 represent the lowest at 0.44 km² and 1.25%. For industrial zones the highest was 0.62 km² in 2017 with a percentage of 1.68%, while the lowest was 0.15 km² with a percentage of 0.8% in the 1970s (Fig. 17). As for services the highest was 2.56 km² in 2017 with a percentage of 7.17%, while the lowest was 0.64 km² with a percentage of 3.41% in the 1970s despite the fact that the lowest percentage of the zoned boundary was 3.1% in the 1980s. Finally, the

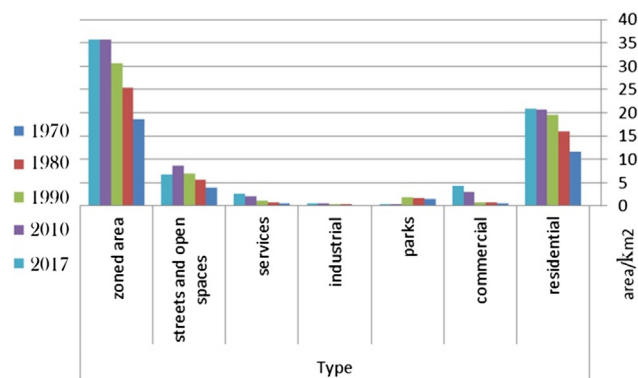
street and open spaces ratios are almost consistent over the 1970s, 1980s, 1990s and 2010 peaking at 23.96% and beginning to decrease in 2017 due to the consistency of the city boundaries (Fig. 17).

6. Conclusions and recommendations

This study enhanced the knowledge levels required to understand the extent of land use change impacts on the urban development of Jordanian cities. The paper's contribution lies in devising a spatial model of the city of Irbid comprising structural plans and practical recommendations for Irbid urban development for a better understanding of the expan-

Table 7 Comparison between land use categories distribution-percent in km² from 1970 to 2017 for Irbid city.

Category km ²	Type km ²				
	1970s	1980s	1990s	2010	2017
Residential	11.64 62.51%	16.02 63.03%	19.51 63.65%	20.76 58.07%	20.79 58.12%
Commercial	0.63 3.36%	0.79 3.11%	0.82 2.66%	3.01 8.45%	4.27 11.94%
Parks	1.51 8.15%	1.69 6.63%	1.83 6.11%	0.44 1.24%	0.45 1.25%
Industrial	0.15 0.8%	0.35 1.4%	0.35 1.14%	0.59 1.65%	0.62 1.68%
Services	0.64 3.41%	0.78 3.1%	1.05 3.41%	2.15 6.01%	2.56 7.17%
Streets	3.91 21.15%	5.62 22.02%	6.88 22.31%	8.57 23.96%	6.85 19.22%
Zoned area	18.61	25.42	30.65	35.74	35.74

**Fig. 16** Compliance with different categories of land use 1970–2017 for Irbid city.

sion pattern of the Irbid master plan. It also predicts the manner of city urban development, therefore identifying its impact on land use changes. This particular model, therefore, is valuable for responding to current and future planning practices and informing policy of the future update of the Irbid master plan and other similar cities also considered irregular pattern. This paper examined the different urban models according to their positive and negative points and their growth manner, and also explored the city of Irbid in terms of main land uses over the last fifty years at different periods (1970s, 1980s, 1990s and beyond 2000s). It then compared the results of study with the five urban planning models. It was found that the urban development of the city of Irbid could be considered irregular pattern and this provides an opportunity for the city to avoid the main problems identified and overcome the key challenges facing the urban development of Irbid city. A set of natural barriers have played a significant role in shaping the city and its surroundings such as Alghafar Valley to the west. This finding concurs with past research (Al-kheder, Haddad, Fakhoury, and Baqaen, 2009) which pointed out the existence of

unplanned urban growth associated with mixed-use problems, and the absence of a comprehensive master plan organizing land use in the city of Irbid which led to excessive urbanization processes at different places.

This type of analysis can be applied to all cities in Jordan in order to discover and predict the pattern of urban development for each city. Jordan needs such studies for better decision-making and planning. This can help as well in avoiding the uncontrolled sprawl of the cities. For the administrative roles and shared responsibilities of the Ministry of Municipal Affairs and partner municipalities as set out in the cities, it is necessary to activate building and land uses laws, and to consider environmental and historical site preservation along with the urban development process. This task, therefore, is the responsibility of the Irbid authorities.

This paper recommends an increase in green areas of the city and moving the industrial zone to the outer areas of the city. In addition there is a recommendation to evaluate the transport system by spreading services across the newer neighbourhoods to reduce population pressure and traffic in the city centre. Overall, this study's findings confirm similar past research results for developing cities like Coskun, Alganci and Usta [45]; Srinivasan and Rogers [46] i.e. that urban sprawl and enormous growth in private vehicles become an issue in developing cities that can be considered irregular pattern. Further, this paper highly recommends that urban planners and decision-makers make use of remote sensing and GIS techniques for effective monitoring of urbanization trends. This finding therefore concurs with past research like Reis et al., [47]; Muzein [48]; Al-kheder et al. [38]; Dos Santos et al. [49] that analysing broad areas using GIS is far more easy and faster than the classical surveying methods, especially for decision-makers and professionals, and provide a high likelihood of overall urban improvement. Therefore, growing urban areas have to be channeled under the control of local authorities using GIS, especially in urban planning stages and monitoring urban area development. This can improve their predictions of the extent of urbanization changes and enhance

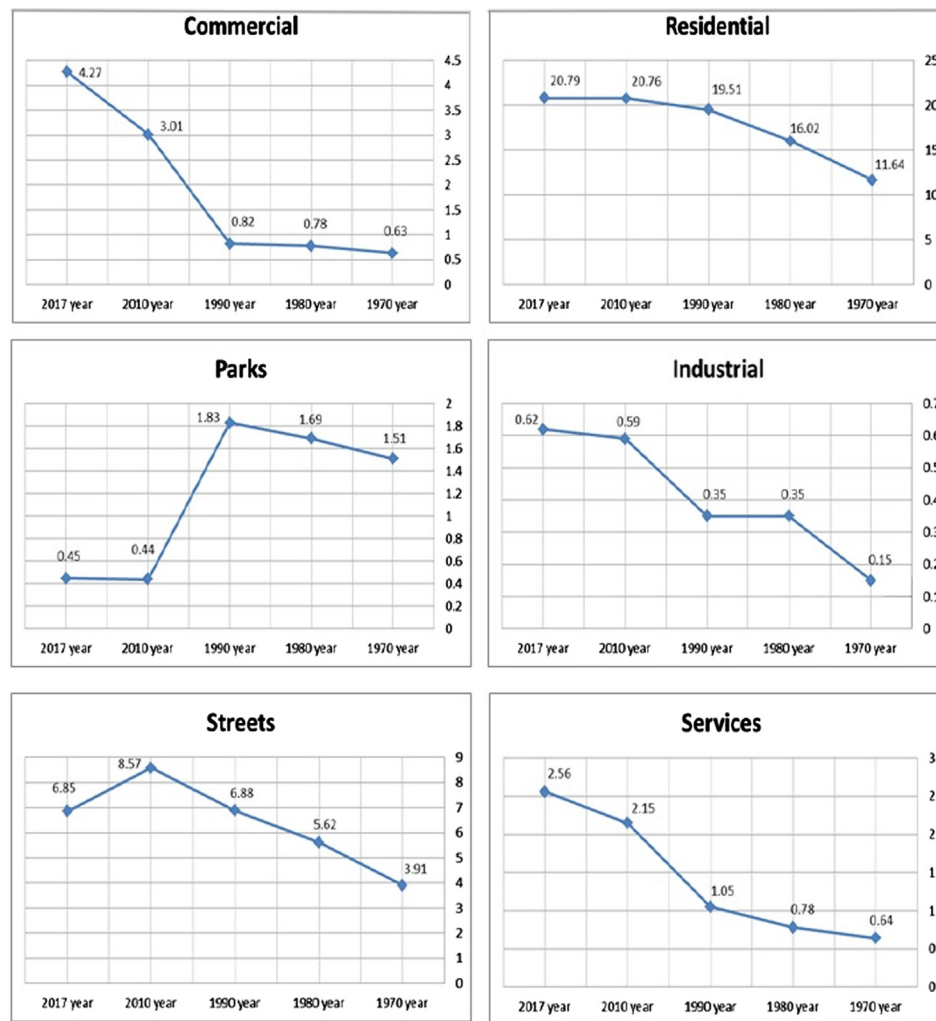


Fig. 17 Charts of compliance with different categories of the Irbid city land uses 1970–2017.

the existing urban strategies for better sustainable land management.

7. Reflections

The decision to focus on a single case study was made so as to understand and appreciate the complexity and uniqueness of the individual case. Authors like Yin [50], Alzouby [51] and Alshawabkeh and alhaddad [52] considered the limitations of the single case study approach in that it could only reflect the uniqueness, or special conditions, that apply to the case study in question. Whilst recognising this, researchers who support a single case study strategy, like Alshawabkeh [53] Tunnard and Wilson [54] and Flyvbjerg [55] and Alshawabkeh [56], state that one can generalise on the basis of a single case.

Upon reflection, the greatest limitations of the spatial model in terms of practical application to the Irbid context are: dealing with the highest rule imposed by the municipality of the city on the use of land; if the new areas are added to the city's organizational chart whether or not they are already occupied by population and various activities; finding usable (not cloudy) satellite images despite the mountainous and sloping topographic structure of the region and complex vegetation of the area.

For future research, this study is put forward to help planners and guide decision makers to further exploration of urban expansion at different geographic scales and adopting appropriate policies for urban planning. The research has set out a set of future questions are represented in; (1) How will social segregation affect the city of Irbid by dividing the land into categories A, B, C and D? (2) How would external migration and associated political and economic conditions impact the development of the city? (3) How do the existing actual uses/violation of uses affect the structural plan of the municipality and what is the extent of their impact on the development of the city?

Conflict of interest

There is no conflict of interest.

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