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Evaluation of residential density of single-family housing in Erbil housing: Investment projects

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ABSTRACT

Density, as a spatial concept, can be used to predict and manage how land is used. It also plays a role in determining how much capacity is present within a given area. Due to the rapidly growing population in the Kurdistan region for local increase and attendants coming from other governorates, one of the major issues is housing. Over the past ten years, the Kurdistan Investment Board has started the construction of numerous residential complexes by investor companies. This study's objective is to evaluate the housing projects carried out by the investor sector to assess the population and housing density and land use balance and evaluate the relation of green area with neighbourhood components. For the current study, five residential complexes were invested in (Zeitun City, Italian I Village, Global City, Aynda II, and Andazyaran city). Since the data are numerical, the applied methodology is quantitative. According to the findings, the net population density of Andazyaran city is higher than the Iraqi standard however the gross population density of Andazyaran city is over moderate levels of single-family housing standards. Gross accommodation density is showing same problems including Aynda II, While Zeitun City's land use balance is below average, Global City and Aynda II are in line with Iraqi standards. Indicators show low commitments regarding density parameters of more than one-third of cases to updated housing standards while the remaining complexes follow density indicators limitations with not more than middle level.

1. Introduction

The spatial term Density is used for predicting and management of land. Having a role in determining the present capacity within a given area. For housing purposes, the term typically refers to the population or number of structures in a location. Understanding and measuring density is helpful for assessing how land is used as well as for making decisions about new developments [1]. In all areas of the city, the General Plan sets minimum and maximum densities for residential uses. Residential density is a magnitude that expresses the number of homes per hectare, moreover "density" describes the correlation between a specific physical area and the population that uses or inhabits there. It expresses ratio of population size or dwellings on the gross lot area before any rights-of-way, parks, or other public spaces are dedicated. When a project site includes multiple lots, the density might be averaged across the whole site [2]. The residential real estate market in Erbil shows continued growth potential. The layout of housing in Kurdistan has contributed to transforming the face of major cities across the Region. [3].

Density is a term that is neutral, objective, and quantitative. It is neutral in that it is impossible to tell whether a particular density level is positive or negative right away [4]. The term "density" describes the correlation between a specific physical 2 area and the population that uses or inhabits

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there. It is expressed as a ratio 3 of population size or number of dwelling units (the numerator) to area units 4 (the denominator) [5]. The main reasons for using and measuring density include helping to ensure that (i) housing is available for the population; (ii) what is built is suitable both of itself and in relation to the surrounding areas; (iii) households can access services, infrastructure and employment, and (iv) Available services and infrastructure are effectively used and well planned. (Ian Gordon, 2016) There are different methods to measure housing density in residential neighborhoods. These methods are as follows: [6]

Accommodation density

Refers to dwellings in any given area including all land uses in the neighbourhood. The land in gross density includes roads and parking, commercial services, schools, and public open spaces. While net density land includes pure land subjected to dwellings, it can be measured as in formula (1) [6].

$$\text{Accommodation density} = \frac{\text{Number of dwellings}}{\text{Residential area}} \quad (1)$$

Population density refers to the number of inhabitants in each area including all land uses in the neighbourhood, for gross and net types of land definition they are same as accommodation density, the term can be measured in the formula (2) in below.

$$\text{Population density} = \frac{\text{Number of inhabitants}}{\text{Residential area}} \quad (2)$$

Land use balance is equal to net residential area per gross residential area.

$$\text{Land use balance} = \frac{\text{Net residential area}}{\text{Gross residential area}} \quad (3)$$

The purpose of this study is to investigate gross and net accommodation and population densities through examining different residential investment projects in Erbil city then evaluating land use balance and comparison with Iraqi standards.

2. Literature review

The effects of higher density on these issues are still debatable, even though the study (Mousavinia et al., 2019) discovered that neighborhood social connections and a sense of safety are crucial and have an inescapable impact on community sustainability and cohesion. According to earlier research, perceptions of density were the main cause of most negative associations with density. However, there is no proof of this relationship's causality. This gap is filled by the current study, which also explores whether territoriality acts as a mediator between perceived density and social interactions [7]. In order to create a framework utilizing structural equation modelling, this study combines data from three gated communities with various dwelling types, similar net residential densities, and distinct layouts. Additionally, perceived density has a favorable indirect association with social contacts through the growth of territoriality, which in turn has a favorable direct relationship with social interactions, according to mediational research. According to (Olowu et al., 2018), rental housing is a significant type of accommodation; Raising the standard of living and increasing the value of rental homes are both achieved by improving its quality. This study aims to investigate the variables affecting Ile-Ife, Nigeria's rental housing quality. Tenants were chosen for the study using a multi-stage sampling procedure [9]. This study looked on the availability of high-quality rental homes for renters in Ile-Ife, Nigeria. It offers details on the three residential densities in terms of the difference in their home morphology. The principal component analysis results indicated that variations in the number of factors produced and the percentage variance explained by the factors could be related to the peculiarities across densities in terms of the socioeconomic characteristics and housing characteristics of the renters. They came to the conclusion that these characteristics are excellent predictors of the quality of rental housing. (1999; Ying-Keung Chan) area , achieved privacy, and satisfaction with living quarters on the perception of crowding are examined in this paper using survey data from 414 urban residents in Hong Kong. According to the study's findings, people who live in small spaces may not always feel crowded. While achieved privacy affects how space and crowding are related, its impact is indirect and only very mildly noticeable. Instead, a major factor in the feeling of crowdedness is the dissatisfaction with the physical environment rather than the amount of space itself these results suggest that in situations of spatial constraint. The findings indicate that factors other than physical space have a significant direct and indirect impact on how people perceive being crowded. In influencing how people perceive being crowded, happiness with living quarters is the most important aspect among the variables under examination. [10]. (Kupke et al., 2012) He argued that in order to improve the efficiency of land use, reducing the cost of providing government services, and promoting home ownership, individual states in Australia have prioritized the introduction of higher density housing development within suburban areas [11]. However, it has been suggested that such development might have a negative impact on the neighborhood's social structure, for example, by decreasing diversity as measured by family structure and economic status or in the effectiveness of the local housing market as measured by price. [12].

This paper seeks to add to the existing research on the effects of higher density development in Australia in three different ways. The first method uses social constructs, a byproduct of principal components analysis, to assess the effects of higher density development on community or household change. The second section of the paper examines regional developments that are most likely to have an impact locally. Thirdly, the analysis identifies a before and after scenario for those suburbs where higher density development has been most significant [13]. The methodology employs principal components analysis to identify the fundamental social structure of the Adelaide Statistical Division. Social constructs, a byproduct of principal component analysis, are used to quantify community or household change because of higher density development. Because they demonstrate that increasing medium densities and varying tenure may not always increase the chances for socioeconomic mix or cultural diversity, the results have implications for policymakers who want to pursue strategies based on the promotion of mixed communities [8]. The English Housing Survey (EHS), which collects information on both the population and total floor space of houses, offers a way to calculate occupant density. The distributions of residential occupant density and their effects on occupant load are examples of data-driven, transparent distributions in this research. Future probabilistic assessments that take into account potential outcomes can employ the determined distributions. The likelihood, effects, and risks that fire occurrences pose to residents of residential buildings. [19]

(Evans and Unsworth, 2012Unsworth) A study of the long-term consequences of the constraint policy, which has been in place for the past 50 years, is conducted, but the increase in density is primarily attributed to revised planning guidelines that were released in England in 2000 and

discouraged low-density development. To support this, it is noted that Scotland's guidance was not altered to support high-density residential development, unlike England where the change did occur. Surveys of residents of new high-rise developments in Leeds support the conclusion that the change is the result of planning policies rather than a change in taste. [14]. The majority of the new flat residents were young adults without children who stated that they intended to leave the city center as soon as they were able and move into houses. So, to sum up, over the past 40 years, has resulted from a longer-term implicit policy of limiting the amount of land available for development. However, the phenomenon of high-density housing in a densely populated area did not emerge as a result of consumer preference as much as it did as a result of planning restrictions, and a specific set of financial market conditions during a period of "turbo-capitalism. “Many young households have been able to afford this high-density living because the supply increased quickly at a time when the demand for family homes was nowhere close to being met. (Carolyn Dehring and Neil Dunse, 2006) investigate that locally. It is probably more effective to provide open space for recreation through taxes than to do it for a bigger population (state and national parks). Additionally, it's possible that eliminating non-payers from urban parks is provided by local governments to enhance the health and well-being of inhabitants, both wealthy and poor because they would otherwise be prohibitively expensive. The findings highlight how crucial it is to build and maintain public parks in our towns and cities. The research offers policymakers direction when determining how much open space should be provided for future housing complexes. If families are to equally benefit from the provision of open space, these rules should clearly reflect the size and density of the development. Our findings may also help to explain how housing density affects the establishment of public open space and sustainability across cities. [17]. (H.W. Chan et al., 2002) It argues that Hong Kong's floor area regulating mechanism has a major detrimental effect on the standard of living space and the ability of private housing to develop. Private dwelling buildings are erected in accordance with the legal requirements set forth by the government. Currently, private developers prioritize usable floor area efficiency over communal space in an effort to maximize their profits. As a result, building designs produce the most dwelling units grouped around a compact, cruciform high-rise core. Living quality issues are not given enough consideration in the built environment. Despite its negative effects, the dense cruciform floor plate design is currently commonly used in numerous cities on the mainland of China. It contends that while such a built shape seems contemporary to some city dwellers, it is the direct outcome of an antiquated density control mechanism that doesn't match modern standards. [18]

(Hopkin et al., 2019) The number of residents in the building must be calculated in order to evaluate the evacuation of residential structures in the case of a fire. The distributions of residential occupant density and their effects on occupant load are examples of data-driven, transparent distributions in this research. Future probabilistic assessments that consider potential outcomes can employ the determined distributions. The likelihood, effects, and risks that fire occurrences pose to residents of residential buildings. [19-20]. Table 1 lists the reviewed papers regarding to distinguish their variables and findings.

2.2 Iraqi housing standard

The State Commission on Housing presented a brief and simple manual for the previous version of 1980’s in year 2014 then followed by a more comprehensive and new version in 2018 adopted by State Commission on Housing in Iraq. Both deal with the most important planning and design criteria that are used by different housing authorities in the preparing of detailed programs of planning and designing housing complexes.

Table 1. Summary of literature review

Author/s	Variables	Finding
1. (Mousavinia et al., 2019)	Safety, social interaction, territoriality, housing layout, perceived density	There is a significant difference between cases in terms of perceived density and social interactions of residents. Importance of layout in comparison to quantitative densities. Perceived density relates indirectly to social interactions
(Olowu et al., 2018)	Socio-economic ,rental housing quality, housing characteristics, density	Rental housing quality can be well predicted by renter socioeconomic variables and housing attributes.
(Ying-Keung Chan, 1999)	Density, crowding, housing type	There are factors other than physical space that influence significantly on the perception of crowding directly and indirectly; among the variables under study, satisfaction with living quarters is the most important determinant of the feeling of crowdedness.
(Kupke et al., 2012)	Density, family income, efficiency of land use,	Although it may not necessarily have affected neighborhood structure or housing market performance, densification has had a significant impact on some neighborhoods in the Adelaide Statistical Division, particularly in relation to their built form.
(Evans and Unsworth, 2012)	Housing density	longer-term implicit policy of limiting the land available for development
(Carolyn Dehring and Neil Dunse, 2006)	Housing density, public park, housing types , satisfaction, socio-economic	The findings highlight how crucial it is to build and maintain public parks in our towns and cities
(H.W. Chan et al., 2002)	Population density, floor area ratio, residential satisfaction	It contends that while though such a built shape seems contemporary to some city dwellers, it is actually the direct outcome of an antiquated density control mechanism that doesn't match modern standards
(Hopkin et al., 2019)	Population density, floor area ratio, housing type	The distributions of residential occupant density and their effects on occupant load

Table 2. Residential area planning indicators in1982 standards

Type of houses (single family housing)	Plot area /m²	Iraqi Housing standards version	Population gross density Inhabitants / hectare	Population net density Inhabitants / hectare	Accommodate gross density /dwelling /hectare	Accommodat e net density /dwelling /hectare	Land use balance
Detached	400-600	1982	50 - 130	80 - 130	09---21	13 - 21	0.63--0.80
Semi-detached	300-400	1982		110 - 160		18 - 27	
Row houses	200-350	1982	80 - 200	140 - 250	12---32	24 - 42	0.55--0.70
Courtyard/ atrium	150-300	1982		170 - 290		28 - 48	

Table (3) Residential area planning indicators in 2018 standards.

Type of houses (single family housing)	Plot area /m²	Iraqi Housing standards version	Population gross density Inhabitants / hectare	Population net density Inhabitants / hectare	Accommodat e gross density /dwelling /hectare	Accommodati on net density /dwelling /hectare	Land use balance
Non defined	250-300	2018	110 – 190	180 - 240	22 – 33	25 - 35	0.70--0.83
Non defined	200-250	2018		180 - 240		30 - 40	
Non defined	150-200	2018	160 - 290	210 - 330	26 – 44	35 - 55	0.53–0.75
Non defined	120-150	2018		300 - 390		50 - 65	

2.3 Planning indicators of neighborhood

Planning indicators of neighborhood depends on whether projects are single family or multi-family ones, Type of dwelling depends on multiple factors or indicators has been presented in tables (2) and (3) respectively for old and new versions of standards, both been used for referencing to cover evaluation of current research. It is worth to say that the Kurdistan region

is carrying on its private standards and that is by the addition of some modifications for local conditions of the whole country version not completed yet.

2.4 Research gap

Population in the Kurdistan region is growing at a rate of 3% per year due to new residents from the countryside into cities, new residents from other Iraqi governorates and neighboring countries for work or for refuge that occurred in 2013, and later the growth approached above 5 million. (AG Reporter, 2013). These population increases led to increased demand for housing projects, while the large number of housing projects were built, there is significant low care subjected to adopt proper density levels within neighborhoods.

2.5 Problem statement

The housing problem is one of the serious problems in the Kurdistan region, due to the rapid increase in population and the implementation of many housing projects in the Kurdistan region by the investors' sector in a rapid manner with arbitrary levels of density that caused distortions in land use balance, regardless to specific housing limitations or regulation which affected the quality of life and participate in upgrading residential satisfactions. Due to ignorance and non-controlled development of housing projects, there have been different levels of acceptance for such projects in Erbil city. This research tries to focus on and evaluate density and land use balances in residential investment complexes, finding out their relationship with site parameters and human factors in single-family housing projects for different reasons mentioned below.

2.6 Research questions

1) Had single-family housing projects in Erbil city been designed according to standards regarding density?
2) Is there a clear relationship between the density and land use balance?
3) The level of correlations available between main land use items?

2.7 Research aims and objectives

This research aim is to investigate and evaluate the density level and land use balance of single-family housing in investment residential complexes in Erbil city. Different density levels may create different land use balance ratios. This study seeks to achieve the following specific objectives:

- To attract the focus of experts to value and difference in density (net and gross) levels in (5) residential complexes with comparison to available Iraqi standards to know whether they have been designed according to standards.
- To evaluate the value of the population capacity of a site area at given plot ratios within single-family housing.
- To estimate the site area required to accommodate a given population at a given plot ratio.
- To indicate internal relationships of main site items within each other and to land use balance.

3. Methodology

In this study, a comparative and quantitative methodology was applied to calculate existed density in 5 housing projects in Erbil City which are (Aynda II, Italian I village, Global City, Andazyaran, and Zeitun City presented in Fig. 1) followed by an investigation of the land use balance indicators comparing those with Iraqi Housing Standard.

The comparison is supported by measuring the population and accommodation density and then comparing them with the Iraqi standard as the only valid reference. Finally, correlation analysis is adopted to find major items within sites that formulated land use balance differences.

3.1. The case studies

Five different investments in housing projects at different density levels were chosen as case studies, in Erbil, Table 4 and Fig. 1. They were selected according to the following criteria:

- Type of complexes (single-family housing)
- Location of the complex according to ring and axis
- Different density levels (complexes with various densities

Table 4. Selected complexes

Complexes	Location	
	Ring	Axis
Aynda II city	Koya Road	Outside 150 m
Italian I city	Center	Inside 120 m
Global city	Koya Road	Outside 150 m
Andazyaran city	Koya Road	Between 120.-150m
Zeitun city	Kirkuk-Binslawa	Between 120.-150m

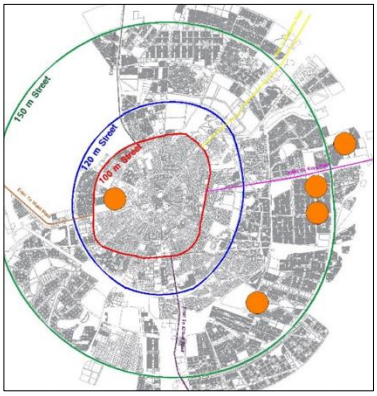

Figure 1. Selected case studies on Erbil's master plan

3.1.1. Aynda II city

Aynda II city is an investment housing complex of single-family housing which is located on Koya axis road and outside 150 m roads. It's around (20.5) hectares, and the total number of dwellings is (460) houses with a 200 m² area. The project includes a commercial area, school, mosque, kindergarten, and health center.

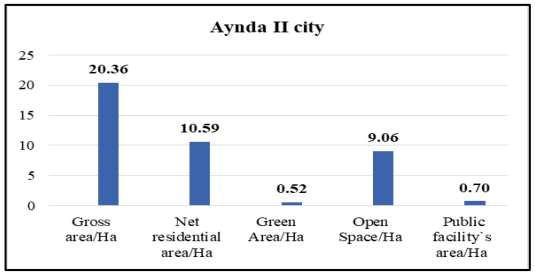

Figure 2. Aynda II city site plan main components

3.1.2. Italian I city

It is an investment housing complex of single-family housing which granted a building license in 2007, located on the center axis and inside 120 m roads. It's around (37.5) hectares, and the total number of dwellings is (694) houses. It contains various areas of housing like (140 m², 220 m², 320 m², 600 m²). The project includes a commercial area, school, and mosque, kindergarten, and health center.

3.1.3. Global City

Global City is an investment housing complex of single-family housing located on Koya axis road and outside 150 m roads. It's around (45.3) hectares, the total number of dwellings is (960) houses. It contains various areas of housing like (250 m², 300 m², 400 m², 500 m²). The project includes a commercial area, school, mosque, kinder garden, and health center.

3.1.4. Andazyaran city

Andazyaran City is an investment housing complex of single-family housing located on Koya axis road and between 120-150 m roads. It's around (36.4) Hectare, and the total number of dwellings are (974) houses with (160 m² and 205 m²) area. The project includes a commercial area, school, mosque, kinder garden, and health center.

3.1.5. Zeitun city

Zeitun city is an investment housing complex of single-family housing which granted a building license in 2009, located on Kirkuk- Binaslawa axis road and between 120-150 m roads. It's around (163.6) hectare, the total number of dwellings are (2821) houses. It contains various areas of housing like (200 m² and 300 m²). The project includes a commercial area, school, mosque, kinder garden, and health center. Population density and accommodation density either net or gross have been calculated in Table 5, At the first step area of residential complexes assessed including

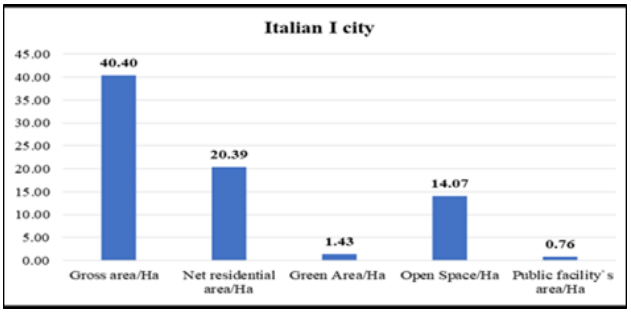

Figure 3. Italian I city site plan components

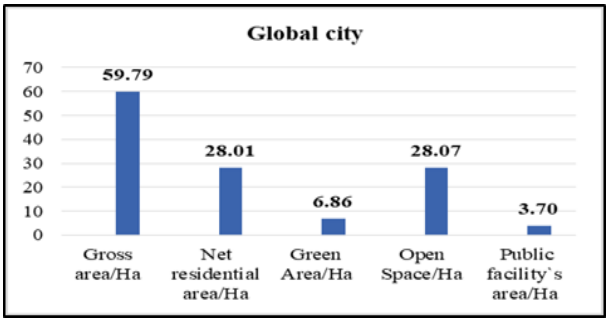

Figure 4. Global city component

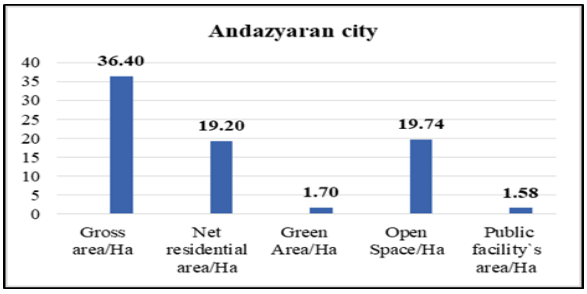

Figure 5. Andazyaran city site plan main components

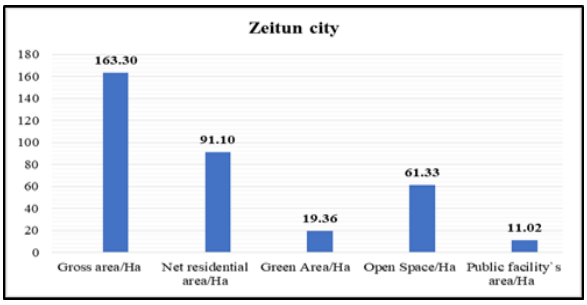

Figure 6. Zeitun city component

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Table 5. General findings of selected housing projects

Residential Complexes	Area / HA		No. of D.Us	Average household size	Population	Population Density (person/area)		Accommodation Density (dwelling/area)		Land use Balance	green area/Ha	public facilities area/Ha	open space area /Ha
	gross area	net area of S.F.H				Gross	Net	Gross	Net				
Aynda II	20.36	10.59	460	5.80	2576.00	126.54	243.25	22.60	43.44	0.52	0.52	0.7047	9.06
Italian I village	40.4	20.39	649.00	5.92	3842.00	95.09	188.40	16.10	31.80	0.51	1.425	5.9385	14.07
Global city	59.79	27.7	960	5.08	4877	81.57	174.09	16.06	34.27	0.463	4.83	3.70	28.07
Andazyaran city	36.4	19.216	974	5.8	5648	155.16	293.90	26.80	50.70	0.528	1.70	3.3	19.74
Zeitun city	163.3	91.1	2821	4.79	13513	82.75	148.33	17.30	31.00	0.558	19.358	11.03	61.33

4. Results and discussion

To get results for the main goals of the current study including the net and gross (population and accommodation) density of case studies with land uses balance, comparisons with Iraqi standards, and comparing them with each other referencing to Figs.7, 8, and 9, the housing estates were arranged according to number of dwellings to make results clearer and better discussable.

a) Aynda II had a population of (2576) inhabitants living in (460) dwelling units, the gross population density is about (126.54) P/Ha, net population density (243.2) P/Ha, gross accommodation density (22.6) Du./Ha, net accommodation density (43.4) Du./Ha, and land use balance (0.520).
b) Findings of Italian city housing showed (3842) inhabitants living in (649) dwellings the land size is around (40.4) hectare area holding (649) dwelling units the gross population density of about (95.09) P/Ha, net population density (188.4) P/Ha, gross accommodation density (16.1) Du. /Ha, net accommodation density (31.8) Du./Ha, and land use balance (0.505).
c) Andazyaran city`s contains (974) dwellings on (36.4) hectare, the gross population density is about (155.16) P/Ha, net population density (293.9)

P/Ha, gross accommodation density (26.8) Du. /Ha, net accommodation density (50.7) Du. /Ha, and land use balance (0.528).

d) Global city is inhabited by (4877) inhabitants living in (960) dwellings with a gross population density of about (81.57) P/Ha, net population density (174.2) P/Ha, gross accommodation density (16.1) Du./Ha, net accommodation density (34.7) Du./Ha, and land use balance (0.463).

e) Zeitun city has around (163.3) hectare area and (2821) dwelling units with (13548) inhabitants, has a gross population density of about (83.0) P/Ha, the net population density (148.7) P/Ha, gross accommodation density (17.3) Du. /Ha, net accommodation density (44.6) Du. /Ha and land use balance (0.558) have been found.

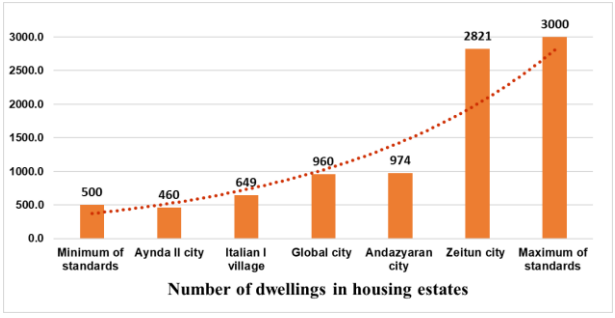

Figure 7. Comparison between the number of dwellings in cases of study and standard housing estate

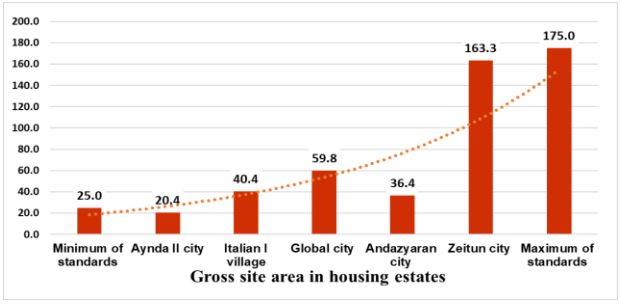

Figure 8. Comparison between the number of inhabitants in cases of study and standard housing estate

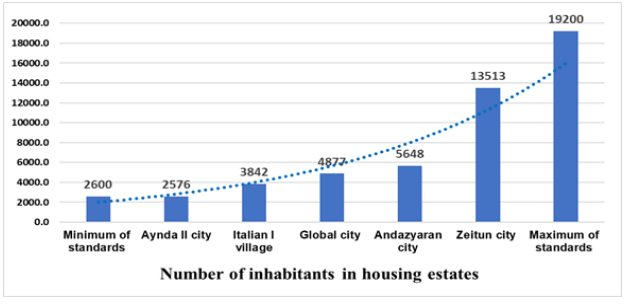

Figure 9. Comparison between gross site areas of study and standard housing estate.

Figures 7 and 8 show that all housing estates or settlements are within the range of 1-2 neighbourhood standard dwelling numbers except Zeitun city is approaching community level within Iraqi housing standards of 4-6 neighbourhoods. The site area in Zeitun is so far larger than others as shown in figure (9) gap of existence of 3-4 neighbourhoods is witnessed in Erbil city as seen in carefully selected projects in current research.

Table 6. Density indicators comparison between selected projects and Iraqi housing density standards.

Residential Complexes	Population Density (person/Ha)		Accommodation Density (dwelling/Ha)		Land use balance	Iraqi Standards Population Density (person/Ha)		Iraqi Standards Accommodation Density (dwelling/Ha)		Iraqi Standards Land use balance
	Gross	Net	Gross	Net		Gross	Net	Gross	Net	
Aynda II city	126.54	243.2	22.6	43.4	0.52	80-160	120-210	12__32	24 - 42	0.55 - 0.75
Italian I village	95.09	188.4	16.1	31.8	0.505	80-160	140-240	12__32	24 - 42	0.55 - 0.75
Global city	81.57	174.2	16.1	34.7	0.463	80-160	140-240	12__32	24 - 42	0.55 - 0.75
Andazyaran city	155.16	293.9	26.8	50.7	0.528	80-160	120-210	12__32	24 - 42	0.55 - 0.75
Zeitun city	82.75	148.3	17.3	31	0.558	80-160	120-210	12__32	24 - 42	0.55 - 0.75

With the data of Table 6 and Figs. 10, 11, and 12, the following findings are listed:

a) Considering population density in both categories gross and net of all selected estates indicates that gross density category figures are low with more middle levels which means alignment to norms or standards. While net density is more related to moderate approaching high level which is obvious in Andazyaran and Aynda cities as smaller plots were used that is near to multifamily housing density characteristics, this may lead to overcrowding problems especially in using outside spaces and public functions.

b) Regarding accommodation density the net indicator ranges between moderate to over standard conditions in both cases of Aynda II and Andazyaran projects, this is a not welcomed indicator of crowding, supporting findings of population density.

c) Car parking problems were observed and extensive street coverage of land, except in neighborhoods that had a low to middle gross accommodation density. So Aynda II and Andazyaran are classified as middle to moderate density correspondingly.

d) Exceptional high levels of population density indicators about both of gross and net Accommodation density are due to higher family sizes than expected by current trends even though they were within range of current Iraqi standards, Erbil city indicators tend to shift towards slightly less than the average family size of Iraq.

e) These findings can point out a recommendation regarding revision for average family size in new Iraqi housing standards is needed. Until that time, it is recommended that a careful balance might be taken to make the population a little lower than current standards depending on local or city conditions but in any case, is much away from 1982 standards, hence keeping current accommodation around mid-range or a little above that mid-range.

f) Planning neighborhoods would need a more careful land use balance as it is obvious in current projects concerning Fig.12, that two projects out of 5 are below standard.

g) This finding means either availability of vacant areas not developed as leftovers to be decided later after implementation or smaller parcels of dwellings plot that make streets and public facilities overspill their optimum levels that been indicated in adding some services that aren't recommended within pure residential areas.

h) In Table 7A precisely the above correlation part the relation of all density indicators with land use balance has been tested against each other in addition to main projects indicators, very interesting findings have been adopted as the very high degree of correlation between them, however, their relationship with land use balance is significant but with low negative direction, meaning more land use balance tends to occur with lower densities.

i) This finding is reasoned by increase in population within city will apply

for more external spaces and functions to serve residents, however low correlation indicates low commitments of those projects to follow the trend.

j) For same density indicators with main projects determinators as population size, net residential and gross projects areas, observed in table (7B) below part B, the correlations show a good relation of negative trend between density items and net with gross residential area, the unexpected finding is that with land use balance the trend should be positive, but reality showed opposite as an indicator of defect in planning of projects regarding land use balance.

k) Also unexpected results are found in relation to dwellings and population numbers as indicators of defects in planning of projects by negative direction meaning less use of site sizes to serve more residents.

l) Relations with open spaces, green areas and whole public facilities shows negative trend with density indicators with significant and moderate values, those are counted as normal trends absence of very high magnitudes is a sign of middle level of correlation.

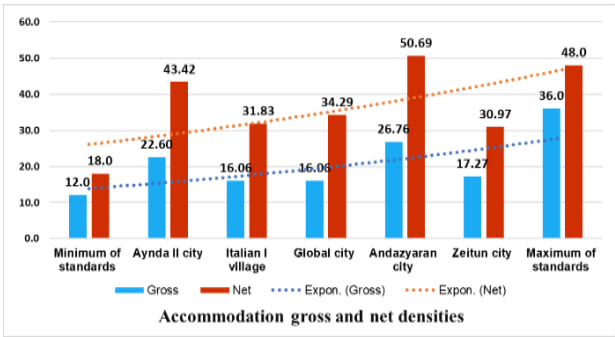

Figure 10. Comparison between accommodation gross and net population density with standards.

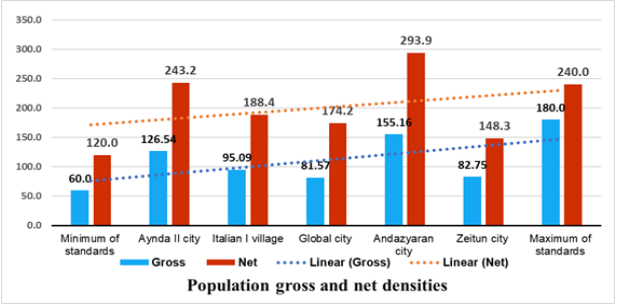

Figure 11. Comparison between population gross and net population density with standards.

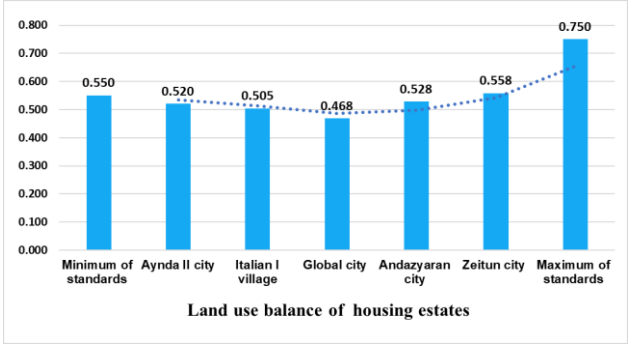

Figure 12. Comparison between land use balance with standards.

Table 7A. Correlation of density indicators and other residential parameters

Correlations							
		Gross Neigh. Area	Population	No. of D.Us	Green Area Size	Open Space Size	Public Facilities Area
Net Pop. Density	Pearson Correlation	-.779**	-.656**	-.687**	-.791**	-.739**	-.758**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
Gross Pop. Density	Pearson Correlation	-.673**	-.533**	-.568**	-.693**	-.635**	-.654**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
Net Acco. Density	Pearson Correlation	-.683**	-.551**	-.580**	-.684**	-.628**	-.647**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
Gross Acco. Density	Pearson Correlation	-.516**	-.364**	-.398**	-.529**	-.466**	-.483**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
land use balance	Pearson Correlation	.724**	.808**	.791**	.685**	.711**	.718**
	Sig. (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000
**. Correlation is significant at the 0.01 level (2-tailed).							
N =179 D.Us							

Table 7B. Correlation of Density indicators and other residential parameters

Correlations							
		Net Pop. Density	Gross Pop. Density	Net Acco. Density	Gross Acco. Density	Land Use Balance	Net Resid. Area
Net Pop. Density	Pearson Correlation	1	.986**	.981**	.934**	-.214**	-.761**
	Sig. (2-tailed)		0.000	0.000	0.000	0.004	0.000
Gross Pop. Density	Pearson Correlation	.986**	1	.979**	.973**	-0.046	-.649**
	Sig. (2-tailed)	0.000		0.000	0.000	0.543	0.000
Net Acco. Density	Pearson Correlation	.981**	.979**	1	.971**	-0.127	-.665**
	Sig. (2-tailed)	0.000	0.000		0.000	0.089	0.000
Gross Acco. Density	Pearson Correlation	.934**	.973**	.971**	1	0.112	-.491**
	Sig. (2-tailed)	0.000	0.000	0.000		0.135	0.000
land use balance	Pearson Correlation	-.214**	-0.046	-0.127	0.112	1	.752**
	Sig. (2-tailed)	0.004	0.543	0.089	0.135		0.000
**. Correlation is significant at the 0.01 level (2-tailed).							
N =179 D.Us							

5. Conclusion

As a spatial concept, housing density with its both dimensions the accommodation and population at both levels of net and gross been witnessed as a highly useful tool in predicting and controlling land use in residential projects in addition to the land use balance indicator. They are controlling elements in determining the capacity available within a defined area in addition to working as controllers for sufficient allocation of land in between all items occupying the neighborhood that are connected with human needs. The approach to sustaining a better life for communities needs careful facilitation of those indicators. The housing density problem is one of the partially but non-obvious and neglected issues in planning neighborhoods in investment projects in the Kurdistan region. The current study focused on five housing projects which are (Zeitun City, Italian I village, Global City, Aynda 2, and Andazyaran) to evaluate the net and gross population density, accommodation density, and land use balance according to Iraqi standards. The study found that:

i. Regarding the size of land and residents among case studies Zeitun city has the largest number of dwelling units, sizing about five neighborhoods while Aynda II city has the lowest one.

ii. It is obvious that housing density increases when the land use balance decreases in standard conditions while additional services are planted in the site to meet nonlocal residents' demands which has not been identified due to a defect in site planning.

iii. Clear two deviations are Italian I and Global City taking into consideration the diversion in terms of surplus of public services and

open areas, both share the ratio of 40% of selected projects that causes the City's deviation from the standard land use balance range.

iv. On the contrary the Andazyaran project had passed the extreme limits of net accommodation density meaning allocating standards plot sizes for dwelling units, gross density also is above moderate approaching multifamily conditions, Aynda II city also shares Andazyaran in the net but has a more balanced gross accommodation density.

v. Overall, it seems that Erbil's investment housing projects were not following well-planned protocols by population density, accommodation density, and land use balance indicators, also no evidence of good relation of density regarding distance from the urban center is maintained in those 5 projects respecting density change with distance to the city center that shows weak planned neighborhood regarding maintaining land value in terms of density.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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Data availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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