DEMOGRAPHIC ANALYSIS OF THE MAKKAH PROVINCE FOR THE PURPOSE OF EVALUATING THE BALANCE OF THE URBAN SYSTEM

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Abstract: Reaching a well-adjusted population distribution is a major challenge for urban settlements. Various research works have been focusing on evaluating the demographic balance of urban systems worldwide. Regularities in population distribution among urban settlements have been noticed and confirmed by empirical studies in the contemporary era. These studies assert that both rank of a city in the demographic hierarchy and its population size are proportionally correlated in a balanced urban system. It has been proved that this correlation is established according to mathematical theories that have been scientifically identified and proved through in-depth research. This article aims to check the conformity of the population distribution of the Makkah Province to two main demographic, organisational theories. In this article, there will be an attempt to measure the variations, evaluate and assess the deviations, interpret the result thereof, and then compare the outcomes of the two methods applied on the Makkah Province.

Keywords: urban system, urban hierarchy, Zipf's law, law of Beckmann, demographic macrocephaly, demographic hypertrophy, holy city of Makkah

JEL Codes: R23, P23, Q56

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Introduction

The French demographer Jean-Claude Chesnais (1987) defines demography as "one of the major components of what used to be called political arithmetic". It is also "moral statistics because it allows measuring a society's degree of integration or disintegration. It is the biology of nations; it measures the potential for growth or decline, expansion or recession of human groups, civilizations or religions" (Buhler 2003). Demography, a statistical study of human populations, has always been a fascinating topic of projections, interpretations of researchers, as it occupies an essential part in all the major contemporary social issues, namely resources, climate, conflicts, migrations, urbanisation, growth, education, employment, pensions, health, and so on.

In urban planning and development, the number and distribution of people over space comprise primary data of the analysis of territories. In this field, researchers have devoted their studies

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to evaluating the demographic hierarchies of urban systems to support their hypotheses of the balance or imbalance of such systems. This article focuses on the demography of the holy city of Makkah, one of the most important cities in the Islamic world. The objective is to measure the size of this primate city for the demographic distribution of all human settlements in the Makkah Province, a micro-regional area governed by Jeddah, its capital (Fig. 2). The size of this holy city grows in a particular way.

Today, Makkah is experiencing an exponential rise in its inhabitants and visitors, both annual Muslim pilgrims (Hajjis) and seasonal Umrah performers. Every year, the number of Hajjis continues to increase, and Makkah, which in 2015 welcomed about seven million visitors per year, would reach, according to the Ministry of Hajj (Islamic Pilgrimage) and Umrah, 20 million visitors by 2022, which means that the number of Hajjis has tripled over seven years. This generates new needs to which the holy city of Makkah should respond by accommodating the requirements of the resident population and the visitors. The latter has pushed the local authorities to carry out a prompt urbanisation strategy aiming to improve both quantitatively and qualitatively the conditions of the Hajj. Unfortunately, this strategy has triggered a severe urban crisis experienced by visitors and residents, especially regarding access to facilities and traffic congestion.

This research aims to demonstrate that one of the main problems that contributed to this urban crisis is the demographic overload. This multiform urban crisis goes beyond the local framework of the holy city, and the solution should be in its hinterland. It is assumed that the demographic distribution in the villages and cities of the Makkah Province is unbalanced and this urban system suffers from urban pathologies. For this reason, there is no fear of the isolation of the city of Makkah from its micro-regional context. It would rather be more appropriate to spread this analytical perspective to the whole Province of Makkah, which would be the main topic of this study.

Literature review

In this paper, it is not feasible to make the review of a massive body of research, investigations and tests on the hierarchical distribution of cities and their importance in complex urban systems. So instead, we will try to introduce the most famous researchers who have initiated this track of studies and cite some recent cases of theoretical scrutiny and practical application.

As regards primacy, Mark Jefferson (1939) first defined primate cities of a different order of magnitude and the significance of other towns in a national urban hierarchy. As an example, he investigated the case of London (1931), which had a population seven times larger than the second city in Britain, then Vienna (1934), which had 12 times the people of the second city in Austria and finally Copenhagen (1935), which had nine times the population of the second city in Denmark.

Since the classic work of the German geographer Walter Christaller (1933), who introduced the central place theory, there has been an increasing interest in the size and frequency distribution of centres in urban systems. In addition, numerous empirical studies have displayed evidence of a functional hierarchy.

For the hierarchal distribution of cities in urban systems, Zipf's rank-size law (1949) is one of the most striking empirical laws in urban economics, describing a remarkably stable regularity in the spatial structure of market economies (Krugman 1996). His studies in the United States imply a unique rank-size relationship according to which the area's largest city (New York) is twice as large as the second-largest city (Los Angeles), three times as large as the third-largest city (Chicago), and so on. On the other hand, Beckmann's work was the first attempt to estimate city size hierarchies in the central place theory. Moreover, Beckmann's analysis is the first initiative to introduce the rank-size law in the existing spatial economic ideas. In the 1950s, the works of Beckmann explore the emergence of rank-size law from the 'Lösch' construction to the recent comparisons of ranking coefficients of different distributions. The latter allows the description of the hierarchical organisation of systems of cities. Parr (1969) was also an early pioneer of the theoretical discussion of city size hierarchy.

These theories of hierarchal regularities in urban systems have also been the focus of many critical recent contributions. For instance, Pumain (2004) explained the hierarchical fact by the existence of several levels of service defined

by spatial ranges (a distance that the consumer agrees to travel to obtain the service, determined by the additional cost of transport added to the purchase of the product.

The theoretical explanation and practical testing of these rules, especially that of Zipf, have also come to life again, theoretically and empirically. The principal theoretical insight has been the understanding of the extent to which the rank–size rule is simply a statistical phenomenon with virtually no empirical (or economic, or regional science) content. In particular, Reed (2002) and Gabaix (1999) have suggested that the rank-size rule is the natural result of a growth process that is independent of the size of the city. Reed (2002) has also found that the rank-size relationship could vary with different signs, depending on which tail of the distribution one is examining. Fujita (1999) has argued that the rank-size rule approximates the long-run spatial distribution of a mature spatial system. Giesen and Suedekum (2009) have claimed that it is not only appropriate for Germany's national urban hierarchy, but also for the city size distributions in single German regions.

Yanguang (2010) has integrated Zipf's law to allometric scaling and fractal relations framework based on a hierarchy of cities in China, and then proposed a model of playing cards to explain the Zipf distribution and hierarchical scaling.

Jefferson (1939) has identified in his later research the conditions under which Urban Primacy, the direct consequence of an unbalanced hierarchy in urban systems, might occur.

Many other researchers have also conducted investigations into the factors underlying these urban irregularities in many cities worldwide. For instance, Mehta (1964) found that urban primacy resulted from the small area and population size of countries, while Linsky (1965) argued that high urban primacy was most often correlated to a small extent but high density, low per capita income, export-oriented and agricultural economies, a colonial history, and rapid population growth rates (Short, Pinet-Peralta 2009). Ades and Glaeser (1995) explained urban primacy by political factors such as instability and high levels of centralised political power. Moomaw and Alwosabi (2004), who restricted their investigations to Asian and American cities, showed that primacy was associated with economics and population size, economic development, population density, level of industrialisation and capital city status. Krugman's (1996) general model suggests that primacy decreases with the openness of a national economy, but this has not been supported in the literature.

In our current investigation, we refer to both Zipf's and Beckmann's theories as they are the most common methods used globally to investigate the hierarchical balance in complex urban systems.

Methodological approach

The main objective of this paper is to highlight the urban primacy (hypertrophy) of the holy city and the macrocephaly of its micro-regional territory through the demographic indicator. The sub-objective would be to identify the role of the other urban centres of the province for evaluating the balance. Quantitative treatment would be taken as a tool for detecting pathologies and not as an end in itself.

The demographic hierarchy of 133 urban centres of the entire Makkah Province is based on the last census of 2015. The hierarchisation of the demographic sizes of all the components of the region's urban system is understood through two great 'classical methods' of spatial analysis: the rank-size law and Beckmann's law. The rank-size law or Zipf's law stipulates a bi-logarithmic relation between the size and rank of each element of the urban system. It has become one of the fundamental laws of urban geography. The bi-logarithmic curve reflects, in terms of demographic distribution, the structural state of the micro-region. It is graphically displayed on the adjustment line. The underlying hypothesis suggests that "the existence of regularities allows the inference of the existence of a structure or identifiable structures. This inference is, undoubtedly, one of the main achievements of contemporary geography" (Charles Hussy 1985). Mathematically, this law is formulated according to a straightforward equation Pn = P1 / Rn, where Pn is the population of the town of n rank, P1 is the population of the city of first rank and Rn is the rank of town **n.**

The Beckmann law stipulates "that a coherent system would require that the size decreases in proportion to the rank and according to a

constant m which must have the value of 1 for the primate city. This model is simplified by a mathematical equation: Yn = X / Zn.m (Yn = population of a center n; X = population of the primate city; Zn = rank of the centre n.) The deficit in number and overpopulation is related to the value of the constant of each centre, whether it is greater or <1 (1)" (Medaregnarou Hana 2015).

The comparison of the results obtained from the use of the two methods of analysis, taking into account the specificity of each process, would make it possible to assess not only the degrees of balance and consistency in the demographic distribution of the fundamental components of the territory of the Makkah Privince but also the coherence of the primate city (Jeddah) and that of the second city (Makkah).

Presentation of the studied corpus

Saudi Arabia is divided into 13 'regions' or 'provinces' (Fig. 1). The Makkah Province is located on the west of the Kingdom, overlooking the Red Sea. Each region has a 'capital' city where the 'Emirate' (Lit: princedom, or a region governed by an Emir) is the centre of urban and administrative management, which contains all the administrative and management sectors. The region is, in turn, divided into several 'Mouhafadhas' (Lit: governorates), and in each 'Mouhafdha' there are urban centres, the size and population of which are generally smaller.

Makkah: Identical administrative names for two different scales

When talking about Makkah, it is important to emphasise two different urban scales attributed to this name. The first is related to the 'region' or the province of Makkah, and the second is associated with the constituency of the city (Fig. 2), where the Haram and the Holy Mosque are located. It is indeed the 'Emirate', as the capital of the region.

The region or the Makkah Province is made up of 17 governorates, including that of Makkah (Fig. 2). The city of Makkah is its administrative capital. Each governorate is assigned centres of different categories (A or B) based on the level of development and the number of facilities they host. This categorisation is also directly linked to the urban area of the centre, the importance of the population residing there and the urban

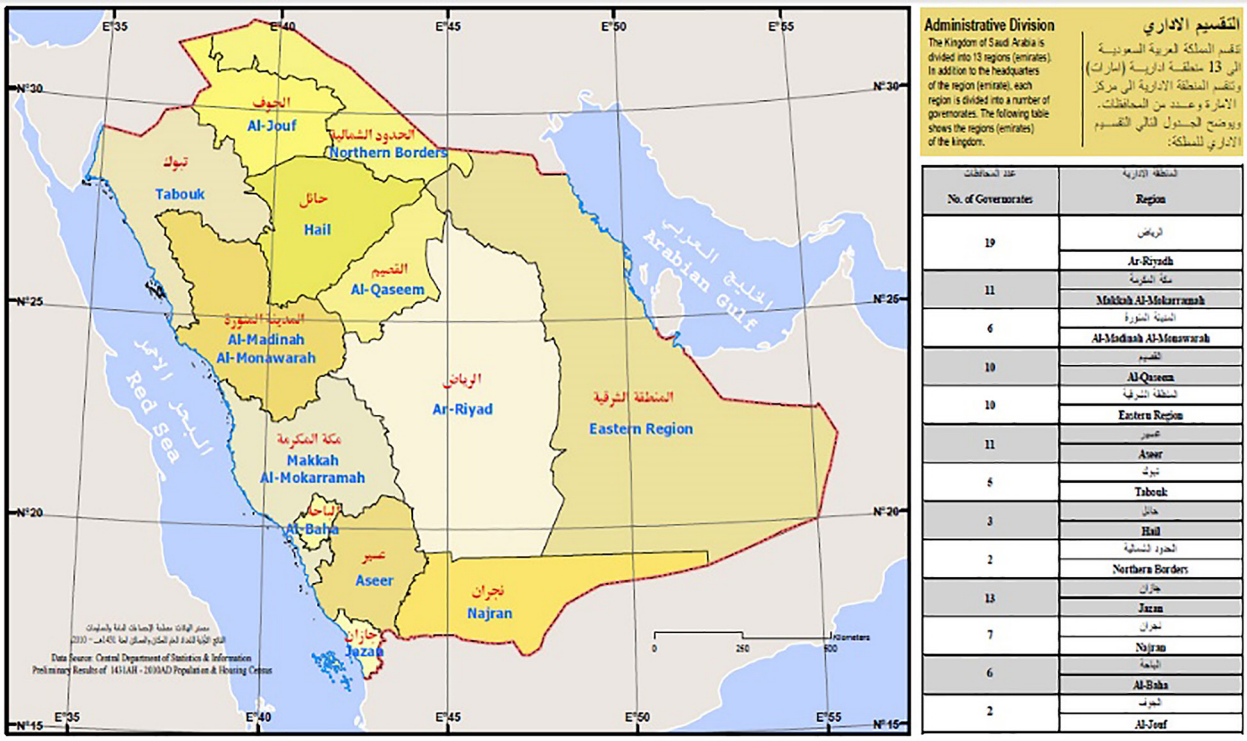

Fig. 1. Map of the regional administrative division of Saudi Arabia.
Source: Makkah Province municipality 2015.

services required. The population of different governorates of the Makkah Province is distributed as shown in Fig. 3.

According to the General Authority for Statistics (GaStat), the population in the region of Makkah includes Saudi citizens representing 59.52% of the total, with the rest being multinational foreign residents with a percentage of 40.48%; their distribution is given in Table 1.

In the governorate of Makkah and since the building of the House of Allah 'the Kaaba' by the prophet Abraham, the inhabitants settled all around it because of its spiritual dimension and the sacred religious connotation which has always

Fig. 2. Map of the Makkah Province.
Source: Ministry of Interior, Makkah Province municipality 2015.

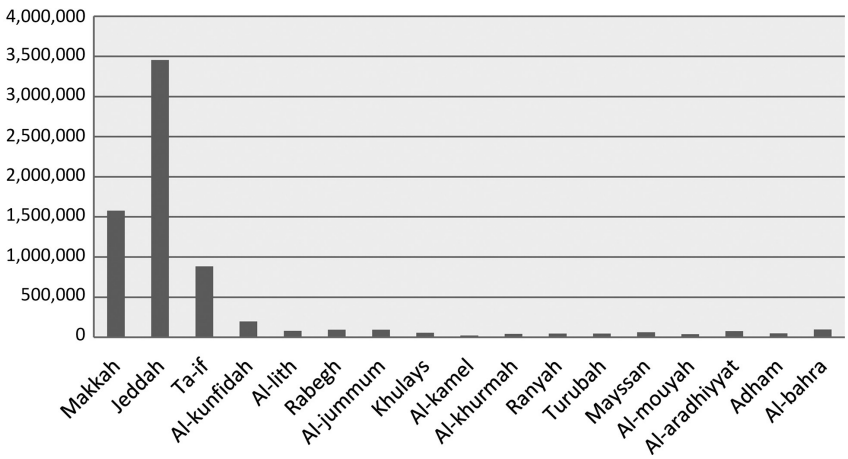

Fig. 3. Geographic distribution of Makkah population.
Source: General Authority for Statistics (GaStat), 2015.

Table 1. Population distribution (Saudi/non-Saudi).

Percentage of population	Jeddah	Makkah	Rest of centres
Saudi	42.002	20.79	37.21
Non-Saudi	61.710	25.82	12.41

Source: GaStat, 2015.

been attributed to this building, as it is considered one of the most attractive places in the holy city, Saudi Arabia and the whole Muslim world (Fig. 4). With the spread of Islam around the world and the development of transport, the importance of the Kaaba increased. It became the destination of millions of worshippers from all over the world.

Table 2. Urban growth of Makkah city between 1990 and 2030.

Year	Area (km^2)	Difference (km^2)	Difference (%)	Annual growth (%)
1990	80.012			
2010	158.583	78.571	98	4.9
2030	690.007	531.424	335	16.8

Source: Dawod et al. (2013).

The urban areas continued to be dense, leading to an ultimate state of urban overload compared to the neighbouring urban centres.

This urban expansion in Makkah city is accelerating over the years with a very ascending frequency (Table 2).

Demographic analysis of the region of Makkah according to the Beckmann model

According to the Beckmann law, the primate city is the reference element of the entire urban system. The evaluation of the coherence and balance in the demographic distribution of all the components of the system being studied must be correlated to the size of the first city, which is taken as a benchmark and the demographic constant of which is assumed to be, in advance, equal to the unit. One should remember that according to this model, a balanced and coherent urban system must have all the demographic constants of

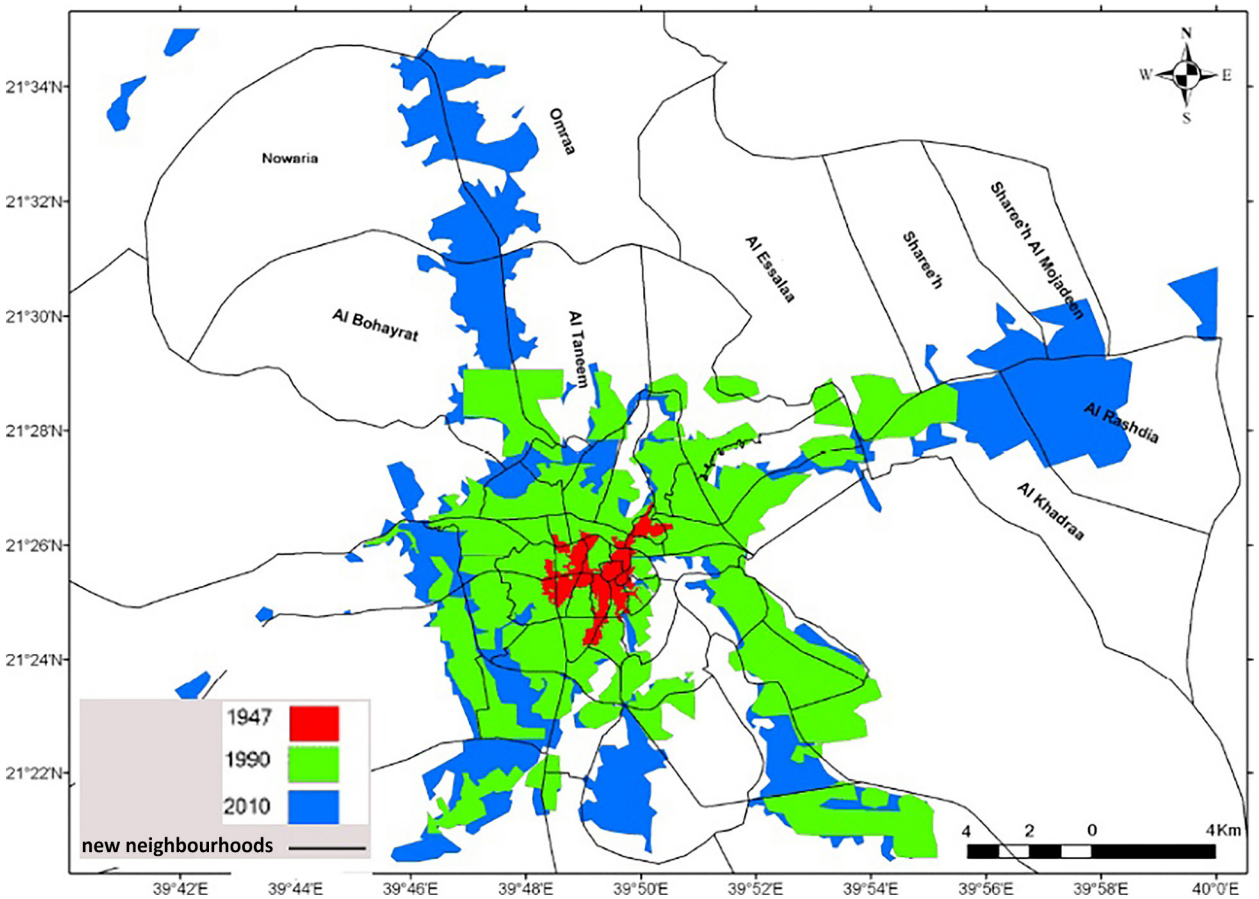

Fig. 4. Concentration of the population around Haram.
Source: Makkah Region Development Authority 2015.

Table 3. Classification of urban centres and their corresponding demographic constants.

Governorate	Population	Rank	μ	Governorate	Population	Rank	μ	Governorate	Population	Rank	μ
Jeddah	3,955,839	1	1	Madrakah	7,705	45	11.40915	Al-Rayan	2,026	89	21.93861
Makkah	1,547,843	2	1.277855	Al-mahani	7,581	46	11.34369	Al-kafif	2,026	90	21.69485
Al-taef	883,870	3	1.491863	Al-Barza	7,400	47	11.37389	Al-SSour	2,020	91	21.52018
Al-Bahra	80,307	4	12.31474	Thaguif	7,363	48	11.19290	AbuMarwa	1,941	92	22.15263
Rabigh	63,147	5	12.52898	Kinanah	7,160	49	11.27534	AlGou'our	1,908	93	22.29345
Al-gouz	54,090	6	12.18906	Al-DhabyawaAl		50	11.27984	AlBaydha'a	1,720	94	24.46709
Al-joumoum	49,340	7	11.45358	SouqAl-Ain	6,898	51	11.24463	Al-faysalia	1,712	95	24.32267
AlAradhiyyaNord	48,638	8	10.16653	Dhoulam	6,860	52	11.08948	Baniamir	1,692	96	24.35382
Almidhilif	43,039	9	10.21254	AbuRakah	6,825	53	10.93604	Al-Khalidiyya	1,646	97	24.77633
Raneyah	39,596	10	9.990502	Al-Ghareef	6,233	54	11.75297	Faydhatalmislah	1,608	98	25.10305
Al-Khurmah	38,303	11	9.388866	Houda-alsham	6,175	55	11.64767	Saaiya	1,583	99	25.24193
AlAradhiyyaSud	37,930	12	8.691095	Al-saadiyah	6,140	56	11.50488	Al-Oulba	1,575	100	25.11644
Turbah	37,318	13	8.154116	Al-shaiba	6,100	57	11.37716	Maran	1,547	101	25.31786
Hala	34,135	14	8.277719	Ainshams	5,855	58	11.64887	Al-ouwila	1,474	102	26.31122
Khaliss	32,236	15	8.180996	Wadygadid	5,757	59	11.64636	Al-farii	1,328	103	28.92033
Al-Kunfudah	27,465	16	9.00200	Albijidi	5,706	60	11.55462	Al-Alawa	1,299	104	29.28169
Al-chawagh	24,372	17	9.547695	Al-Amlah	5,649	61	11.47988	Alghafa	1,219	105	30.9062
Adham	23,845	18	9.216558	OumAl-Rakah	5,574	62	11.44669	Chi'ir	1,141	106	32.70748
Ahadbanizayd	21,806	19	9.547925	Joudhoum	5,178	63	12.12652	Al-Raghiya	1,039	107	35.58273
Al-layth	20,997	20	9.42001	Al-abawaa	5,159	64	11.98100	Al-Gawama	1,016	108	36.05132
Thoul	20,528	21	9.176407	Baniiyaziid	5,108	65	11.91446	Dhaleem	885	109	41.00802
Al-sadira	19,381	22	9.277688	HafrKashab	4,916	66	12.19222	Al-Awali	883	110	40.72726
Mayssan	18,329	23	9.383654	Al-hafayer	4,873	67	12.11623	Al-fawara	882	111	40.40611
Jaaranah	17,539	24	9.397721	Al-madhik	4,826	68	12.05431	Khedan	807	112	43.76703
Kayaa	16,692	25	9.479605	OumAl-Jourm	4,279	69	13.39822	Khamiss Harb	800	113	43.75928
Al-hada	16,406	26	9.273903	Al-Ghareefaltar		70	13.58788	Al-Oussla	776	114	44.71694
Al-Jaiza	15,931	27	9.196695	Thoulathaaalkh		71	13.80819	Al-Hounou	716	115	48.04274
Ghamighah	15,083	28	9.366834	Yalamlam	3,960	72	13.87430	Al-zimah	675	116	50.52157
Achira	14,460	29	9.433488	Hegual	3,938	73	13.76068	Al-Meziraa	658	117	51.38387
Afssan	14,349	30	9.189581	Rehat	3,864	74	13.83470	Al-Raknah	640	118	52.38134
Al-gadhima	14,149	31	9.01885	Chagssan	3,565	75	14.7951	Al-Ruwilia	466	119	71.3355
BaniiSaad	13,625	32	9.073025	Wadyal-kouwar	3,293	76	15.80641	Al-Nasaef	445	120	74.07938
Sabtaljarah	12,990	33	9.228169	Al-newibaa	3,285	77	15.63913	Al-matarifah	441	121	74.13352
HadadBaniMalek	12,850	34	9.054335	Radhwan	3,234	78	15.68209	Al-wid	397	122	81.67484
Doughah	12,763	35	8.855596	Al-atif	3,079	79	16.26304	Hachach	363	123	88.5986
Al-kamel	12,124	36	9.06338	Al-Hachraj	3,039	80	16.27114	Hida	322	124	99.07431
AlGariibenMalek	10,107	37	10.57827	WadyDaguag	2,945	81	16.58320	Al-Rafayaa	320	125	98.89598
Hijr	10,064	38	10.3439	Setara	2,891	82	16.68694	Al-Zarban	271	126	115.8507
Al-MoyahalJadidah	9,777	39	10.37453	Al-Irguin	2,739	83	17.40077	Al-michaan	249	127	125.0937
Al-saylalkabir	9,713	40	10.18182	Al-Murguiban	2,685	84	17.53941	Al-Sahm	212	128	145.7783
UmmAl-Doum	9,440	41	10.22075	Al-sharaa	2,512	85	18.52678	Mashashal-Taref	189	129	162.2509
Al-chafa	9,259	42	10.17244	AlIfiriya	2,332	86	19.72475	Al-Khadiraa	19	130	1601.554
Mastoura	8,815	43	10.43633	Dhaghija	2,173	87	20.92472	Warcha	12	131	2516.437
Majmaaaltourough	7,861	44	11.4369	Al-Mahra	2,092	88	21.48791				

Source: data received from GaStat, 2016.

its components equal to 1. If the constant **'m'** of a given centre is >1, this means that this centre is demographically deficient compared to the size of the primate city. In the case where **'m'** is lower than 1, it is demographically plethoric. Coherence is only shown when the constant 'm' of all the centres is equal to 1. The application of the Beckmann model 'Yn = X / Zn.m' to all the cities and all the villages of the Makkah Province has resulted in the demographic constants shown in Table 3.

Discussion

Apart from the primate city of Jeddah, the demographic constant which is equal to the unit and constitutes a reference concerning the whole province, all the other urban centres of the region of Makkah have constants 'm' >1. This already means that there is a marked urban macrocephaly. The significant disparity in the obtained values highlights a macrocephalus, heterogeneous, and unbalanced structure (Fig. 5).

Owing to the large number of urban centres that make up this system, the significant differences in the values of the demographic constant are not quite discernible. Thus, for a better reading of this curve, we will try to zoom through the levels of points. The objective is to cover and explain the most significant changes in the slope. Seven levels have been identified, four of which are the most revealing of these alterations. These levels are 1, 2, 6 and 7.

Level 1: The value of the demographic constant is between 1 and 2 (1 <m <2)

Only 3 centres among the 131 that make up the region are at this level. These are the primate

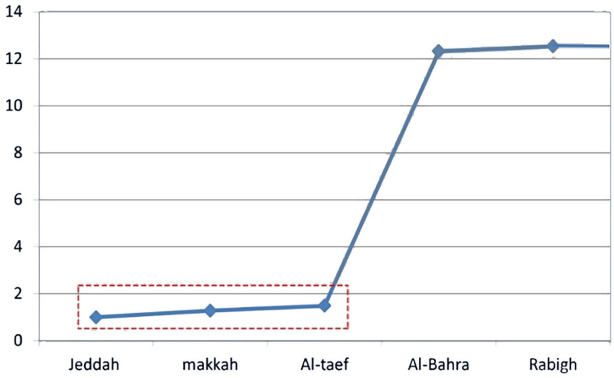

Fig. 6. Zoom shot of level 1 of the curve.
Source: authors 2016.

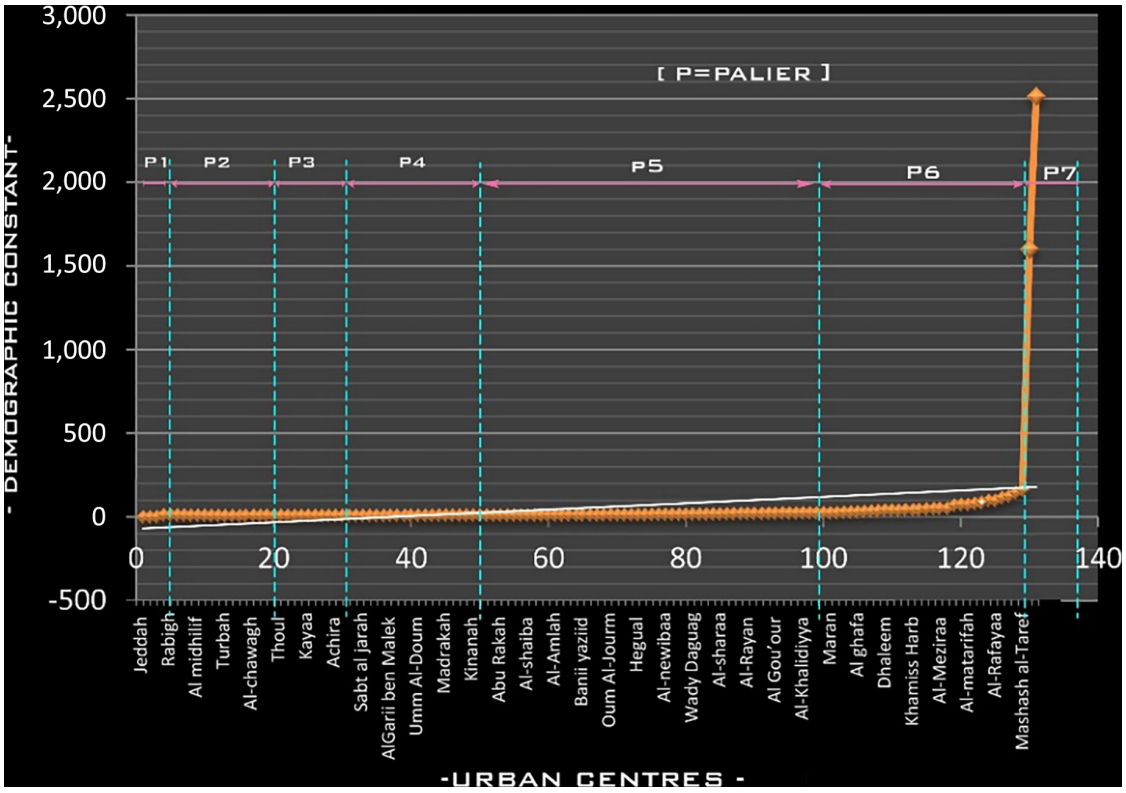

Fig. 5. The curve of demographic constants of urban centres of the Makkah Province.

cities of Jeddah with m = 1, Makkah with m = 1.27, and Al-Taef with m = 1.49 (Fig. 6). In this level, the curve shape is nearly horizontal since the values of the ms are relatively close to the unit. Although the values of the constants of the two second cities are <1, it is essential to emphasise the relative coherence between the elements of this group of centres. However, a global reading of the values and the curve reflects a macrocephaly of the urban system.

Level 2: The value of the demographic constant is between 8 and 20 (8 <m <20)

Compared with this level, it is noted that the values of m deviate considerably from the value of the unit balance. The striking inconsistency means that the slope of the curve takes a very irregular shape compared to that of the previous level (Fig. 7). There is a relatively remarkable demographic deficit relevant to the primate city of Jeddah and the city of Makkah. This level fairly represents the entire system in that it groups the highest number of urban centres in the region (82 centres out of 131). This group displays an unbalance compared to a normal distribution of the population in the system under study.

Level 6: The value of the demographic constant is between 100 and 170 (100 <m <170)

There are four centres with a demographic constant between 100 and 170 (Al-Zarban, Al-Michaan, Al-Sahm, and Mashash al-Taref) (Fig. 8). This value of demographic constant shows a critical shortage in the population. However, there is a relative consistency in the shape of the curve at this level, which is nearly horizontal. The curve seems to reach its peak, which corresponds to the most unpopulated centres that require a proactive correction to achieve as quickly as possible the demographic size corresponding to both their ranks in the demographic hierarchy and their coherence compared to the size of the primate city.

Level 7: The value of the demographic constant is >1,000 (1,000 < m)

After the relative consistency observed in the previous level, it is noted that there is a sharp rise towards another level in only two centres, whose demographic constants are >1,000. The difference between the unit referential value of the primate city and the two last units of Al-Khadiraa and Warcha, which have demographic constants equivalent to 1,601 and 2,516, respectively, shows a chronic deficit in the urban system (Fig. 9).

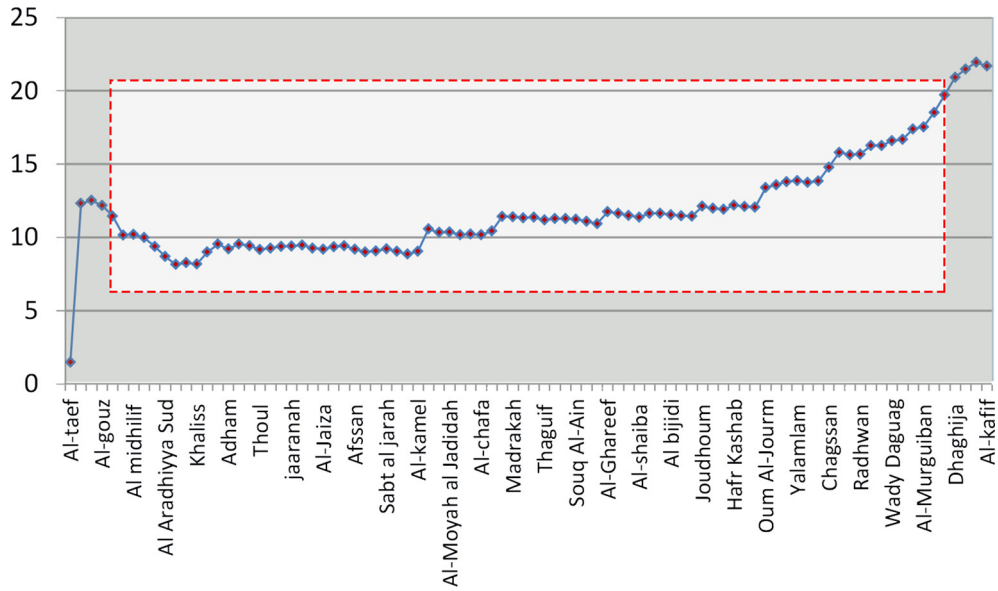

Fig. 7. Zoom shot of level 2 of the curve.
Source: authors 2016.

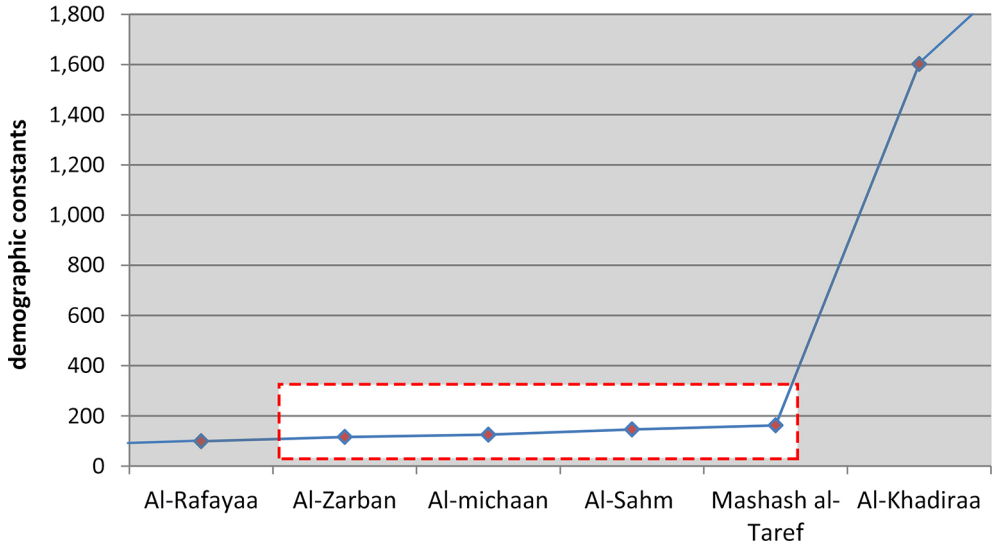

Fig. 8. Zoom shot of level 6 of the curve.
Source: authors 2016.

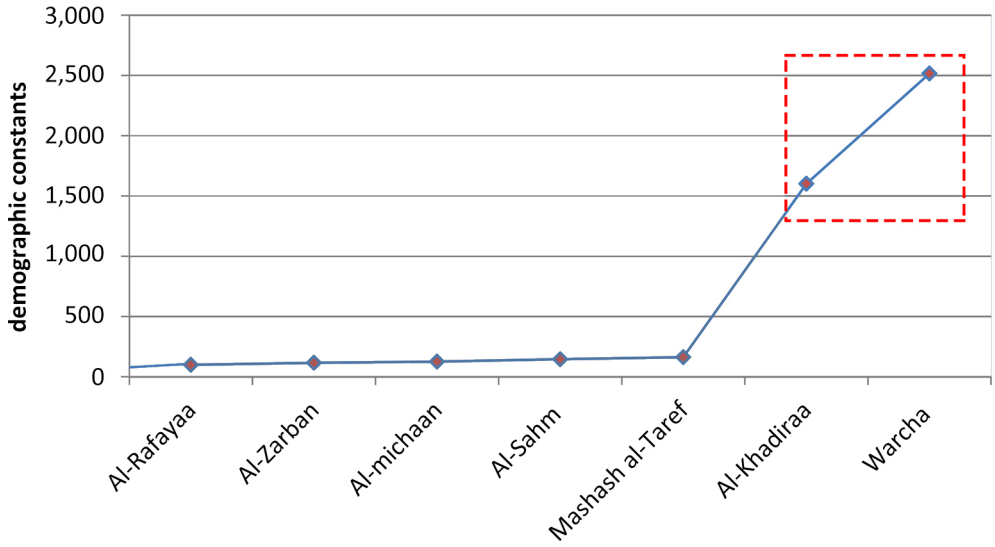

Fig. 9. Zoom shot of level 7 of the curve.
Source: authors 2016.

Demographic analysis of the region of Makkah according to the rank-size model

Unlike Beckmann's theory, Zipf's law does not consider the primate city as a reference unit for the whole system. "The primate city cannot be taken as a reference since Zipf's law is rather a law of internal and hierarchical distribution within the urban system (Belhedi 1992).

The population of the primate city is undoubtedly an essential element of the system, but it cannot be a basis for the distribution effect. On the contrary, considering the total population as a reference base, the first city would be determined like the other cities. Zipf's law highlights a simple relationship between the population of urban centres of the same network and their hierarchical ranks (law/rank-size). It is essential to remember that the law is often presented in its simplified form: Pr = P1/r, where P = population of the primate city, n = urban centre and Pr = Population of centre **n**. In reality, this model defines an ideal hierarchical distribution that a balanced urban system should have. "The regularity is in a way that the second city is half the first and the third city is only a third thereof. The size of cities in a given country follows an arithmetic series: 1, 1/2, 1/3, 1/4¼ 1/n"(Belhadi 1992). To apply

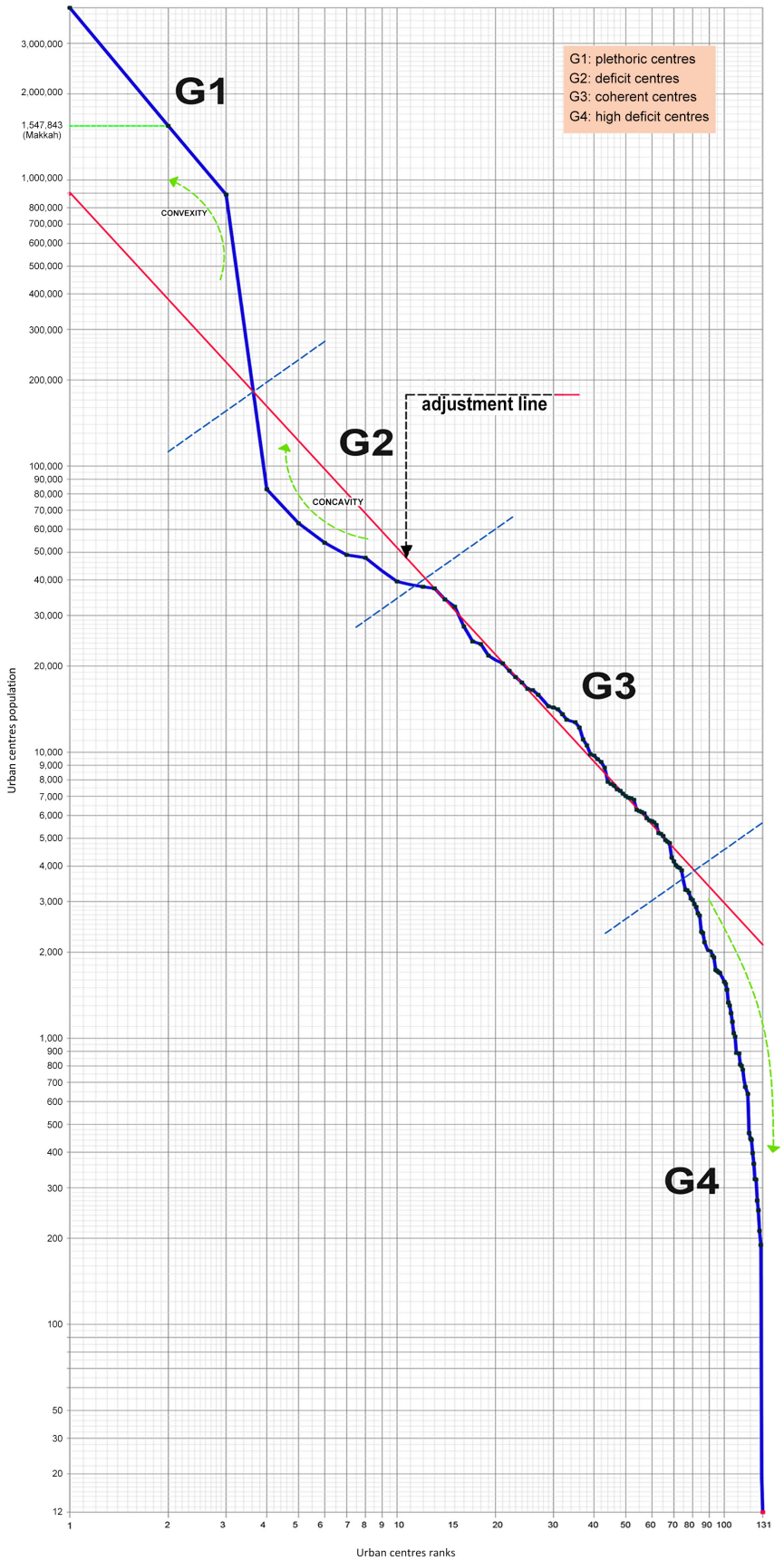

Fig. 10. Curve resulting from applying Zipf's law for the Makkah Province.
Source: authors 2017.

Zipf's law to the region of Makkah, we modelled a bi-logarithmic orthonormal marker that allows covering the large variations and ranges of values in the abscissa, referring to the ranks of urban centres and the ordinate and their populations. The curve obtained displays the actual distribution of the urban centres of the Makkah region based on their growing demographic hierarchy. To evaluate the result based on this model, we have inclusively drawn the adjustment line. This line passes through the majority of the projected points in the curve. It represents the look that the curve should theoretically have, according to Zipf. Comparing the adjustment line with the rank-size curve allows us to read the differences between Zipf's theory and the reality on the ground (Fig. 10).

Discussion

The interpretation of Fig. 10 by comparing the rank-size curve to the adjustment line reveals several facts. First, it is possible to see that very few centres, namely Jeddah, Makkah, and Al-Taef, suffer from an urban plethora that stands above the adjustment line. The majority of urban centres have a low demographic weight according to the ranks they occupy in the hierarchical classification of the Makkah Province. Second, we notice that the bottom of the curve, which takes the form of a half-hyperbola, goes downwards. It is moving away from the adjustment line, affirming the disproportion and inequality at the distribution of the population in the different spatial units. The observation of an individualised set of points allows a relatively precise distinction of the cities on either side of the adjustment line. Thus, it is possible to distinguish four groups of centres. The first group, whose points are located above the adjustment line, indicates the plethora situation concerning the demographic distribution of the total population of the urban system. The second group shows an abrupt deviation in the shape of the curve and displays a set of irregularly distributed points. This group highlights the most critical disharmony in the shape of the curve. The third group presents a relative balance that almost follows the line of adjustment. This group is the most coherent and balanced regarding the urban system. The fourth and last group seems to be the furthest from the adjustment line. Its curve is located below the adjustment line and tends to widen further. Thus, it marks the most significant demographic deficit in the Makkah Province. These are the small centres with the smallest population sizes in the region.

The first group where there is hypertrophy of the first three centres of the urban system

At the top of the curve, three centres are isolated from the rest of the components of the Makkah system. These centres are the cities of Jeddah, Makkah and Al-Taef, which occupy the first three hierarchical ranks and have a population of 3,955,839; 1,547,843 and 883,870 inhabitants, respectively. Their positions in the orthogonal bi-logarithmic coordinate system are largely below the adjustment line, which confirms not only their accentuated demographic plethora but also their hypertrophy. This hypertrophy is justified by the fact that all the rest of the human settlements in the Makkah provincial system are below the adjustment line and are therefore in deficit except for the centres of Group 3, which seem more or less coherent since they are projected on the adjustment line, or they experience a very slight plethora for some centres. The convexity of the first group of centres and the projection of their positions in the ordinate axis makes it possible to precisely determine their plethoric values (Table 4).

Therefore, the first three cities are hypertrophied. However, it is necessary to highlight the importance of the plethora, which exceeds 1,000,000 inhabitants for Makkah and 3,000,000 inhabitants for Jeddah.

In this group, it is possible to note the difference in demographic sizes between the first two cities, which significantly exceeds the limit stipulated by the Zipf model in which, theoretically and in a balanced hierarchical distribution, the

Table 4. Demographic plethora evaluation of the three first centres of Makkah's urban system.

Urban centre	Real population	Population according to Zipf's law	Over-population
Djeddah	3,955,839	830,000	3,125,839
Makkah	1,547,843	415,000	1,132,843
Al-Taef	883,870	276,666	607,203

Source: GaStat, 2016.

ratio between the sizes of the first and second city of the system should barely exceed 2.

$$P1 / P2 = 3,955,839 / 1,547,843 = 2.5 > 2$$

However, the interpretation of the obtained results shows that this ratio is equivalent to 2.55. This indicates that there is not only another internal hypertrophy in Group 1 but also a remarkable macrocephaly of the urban system of the Makkah Province due to the demographic plethora of its primate city compared to the other successive urban units.

When the metropolitan area dominates neighbouring centres: A significant gap between the cities just below group 2

Generally, the centres in Group 2 have smaller demographic sizes than those required by their ranks in the demographic hierarchy. Starting from the fourth rank in the system, we note a move from plethora to deficit. The difference between the first three major cities and the fourth city is more significant than that which results from the application of Zipf's law. Looking at the abrupt change in the curve between the first and the second group, we assume that this is related to an apparent deficiency in urban areas with populations between 100,000 and 800,000 inhabitants. The steepness of the slope and the absence of centres in this hierarchical level translate to the theoretical vacuum, which is proof of the inadequate demographic distribution at the top of the urban system (Fig. 11).

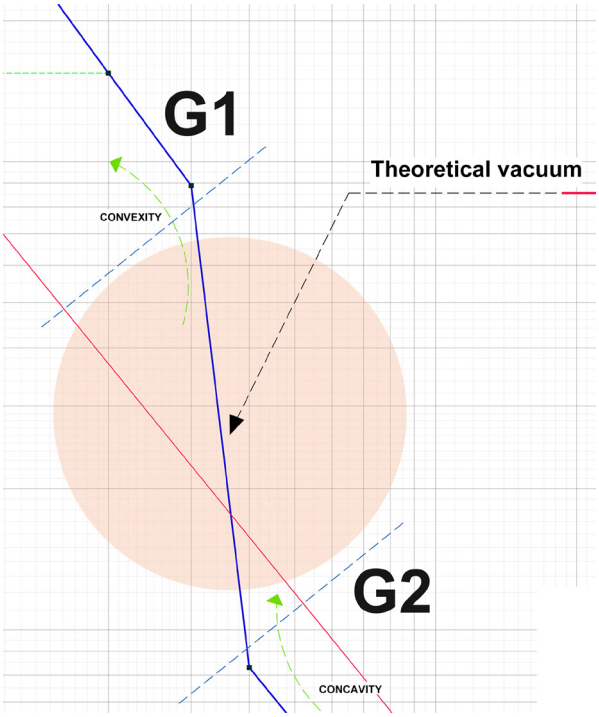

Fig. 11. The gap between the levels of Groups 1 and 2 of the hierarchical distribution of centres.
Source: authors 2017.

We argue that the demographic growth can be explained by the intense competition between the centres with a significant urban presence (Jeddah and Makkah). This competition increasingly diminishes the population of other urban areas that have significantly smaller sizes. Therefore, they do not allow them to reach a demographic threshold that agrees with the theory, which takes into account a uniform space with a rational hierarchy of urban units based on their demographic weights. For example, the fourth-largest city, Bahra, should have a demographic size equivalent to a quarter of the population of the primate city of Jeddah to achieve a regular and consistent demographic size.

By applying the law Pn = P1 / Rn, this means that P4 = 988,959, whereas the actual value of the number of inhabitants in Bahra, fourth in rank at the regional level, is equal to 80,307. The difference is indicative of the hiatus which separates the first two groups. On the other hand, this city occupies a strategic geographic location because it is very close to metropolitan centres with an assertive economic dynamism. It constitutes a central axis of communication between the two major regional metropolitan cities, namely Jeddah and Makkah. The importance of this centre is precisely overshadowed by the juxtaposition to the primate cities that dominate it. It seems that the cities of both immediately higher and lower ranks had probably limited their growth. The city of Jeddah is growing due to its strategic geographic location, and the city of Makkah is growing due to its religious connotation.

Domination of centres of Group 3 whose sizes vary between 4,000 and 40,000 inhabitants

This level groups the centres which are relatively balanced according to Zipf's law with some overall non-significant gaps. Their populations count between 4,000 and 40,000 inhabitants.

Compared to their ranks, they have demographic sizes which are consistent with the requirements of Zipf's law. Although the number of centres in this group represents 42% of the total number of urban units in the system, the percentage of settled populations represents only 9.6% of the total population of the province.

Group 4: A sparse and depopulated demographic base

This level, in which the units clearly show a deficit in terms of the population, includes 47% of the total number of urban centres in the system. This is the largest percentage of all the groups. Given the quantitative importance of the centres in this group, the sum of the demographic sizes of all the centres that compose it does not exceed 1.4% of the total population of the system. The most distressing report which indicates a striking inequality in the distribution of the population and an alarming disproportion between the top and the bottom of the curve is undoubtedly that of the last two centres in the demographic classification, namely Warcha and Al-Khadiraa: these two centres are isolated from the rest of the urban units, including those suffering from underpopulation and belonging to the immediately higher ranks. Regarding the rank-size model used in this analysis, the difference between the two centres and the rest of the components of the urban system is huge. At this level, the imbalance is amplified and the macrocephaly of the provincial system is accentuated.

The anomalies of the general distribution of the population in the Makkah Province

A comparison of the real and theoretical distributions (Fig. 13) shows that the Makkah Province has several weaknesses regarding the distribution of demography over the different urban centres that form it. The variations in the curve show a significant imbalance compared with the theoretical adjustment line. Compared to the primate city, the second city is not developed enough to attract a substantial number of the population. It has only 1.5 million inhabitants, a deficit of around 500,000 for its rank as the second city after Jeddah. It also shows the non-existence of the third and fourth cities in the current distribution

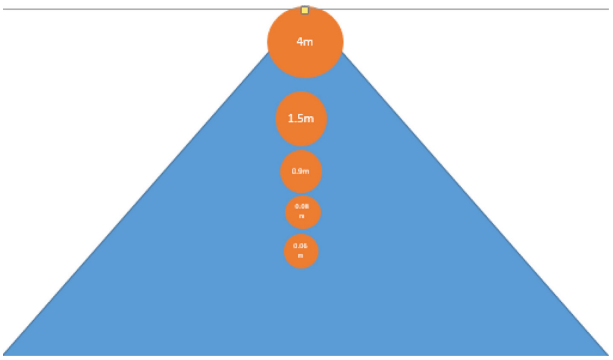

Fig. 12. Diagram representing the real hierarchical distribution of cities and urban areas with their ranks in the Makkah Province.
Source: Ledraa 2016.

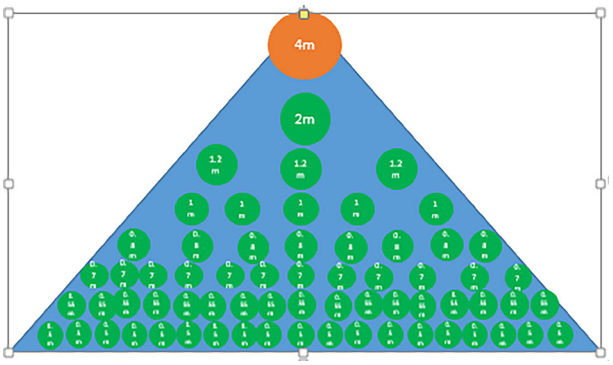

Fig. 13. Diagram of the theoretical hierarchical distribution of cities and urban areas with their ranks in the Makkah Province.
Source: Ledraa 2016.

of the city system in the Makkah Province. This non-existence reflects a hierarchical hiatus and the lack of intermediate centres that meet the Zipf model requirements. At the base of the pyramid, the demographic weight and the number of centres per level are insignificant and far from the values stipulated by the theory (Fig. 12).

Factors of imbalance in the demographic hierarchy

Religious connotation: A demographic magnet that catalyses macrocephaly

The demographic growth of the primate cities of the urban system of the Makkah Province is closely linked to the religious importance that the holy city has, being the first sacred city of Islam. The sacredness of the ritual of 'Hajj' and 'Umrah' makes it an ultimate destination for

faithful Muslims. These rituals attract not only residents of all of Saudi Arabia, who visit the city more frequently and easily, but also visitors from elsewhere whose number, despite the fluctuations, remains considerably significant. The political vision adopted recently by the sovereigns of the Kingdom facilitates access to the holy places and therefore, it amplifies the demographic impetus of the primate cities and consequently the macrocephaly of the whole province previously demonstrated by the two used models of Zipf and Beckmann.

The demographic movement, the main obstacle to a balanced hierarchy between spatial units

After the rapid economic development of Saudi Arabia following the discovery of petroleum, the forts surrounding the urban centres have been destroyed. "The fort of Jeddah was destroyed in 1947 and that of Riyadh in 1950. After that, other operations of the destruction of the fortifications which surrounded the cities and the villages took place because of the sudden and accelerated urbanization" (Al Abyadh 2016). This has contributed to the densification of cities and their transformation into large metropolitan areas. Then, there was an unprecedented migratory flow from rural areas to big cities, mainly Riyadh, Makkah and Jeddah (primate city hypertrophied in this urban system). This rural exodus was accompanied by the external immigration of hajjis and the faithful Muslims, a large part of whom settled in the capital Jeddah because of its proximity to Makkah and for the quality of services that it offers to its residents. These migratory movements give Jeddah an excessive urban image compared to the rest of the centres, which has contributed to making the province a macrocephalus system.

Trade is the main economic activity that stimulates the growth of metropolitan areas and obscures small centres

"Arabia, in the absence of rainfall and fertile agricultural lands, has never been a society the economy of which is primarily based on agricultural activity. Being a harbor city par excellence, the Hejaz region (Jeddah and its region) is much better known for its commercial activities" (Ladraa 2016).

In the Makkah Province, commercial activities are of utmost significance. According to the Saudi GaStat (2017), Jeddah city, the economic and tourism capital of the Kingdom holds nearly half the commercial units of the entire province with 50,365 businesses. Many factors have underlined this pre-eminence, for instance, the wide range of facilities and equipment including transport. This has given Jeddah great influence and radiance over the rest of the urban centres, including that of the religious capital 'Makkah' and enhances tremendously its demographic primacy.

A highly centralised political system

Although theoretically, there is a division of the territory into administrative districts where representatives of the state are appointed in the various centres of the province, we find that this division does not correspond to an efficient political will that provides these urban units with autonomy. The political system gives the central government the power to decide. Although there are equivalents of local governments, in the context of Saudi politics, they are not sovereign and are dependent on the central government. This dependence is often the result of a shortage of local capacity and the lack of resources necessary to apply a self-governing policy. The Makkah Province, like other provinces of Saudi Arabia, remains centralised despite its evolution towards territorialisation. This centralisation affirms this context so that it favours the monopolisation of capitals and, therefore, urban macrocephaly.

Conclusion

The theories of Zipf and Beckmann applied to the Makkah Province reveal a great imbalance in the hierarchical classification over the demographic basis of the urban centres of this system. The weight of the primate city, Jeddah, is explained by its urban population. The distribution of the population by rank in the urban system shows a hiatus which characterises the different theoretical levels. These combined parameters made it possible to assert that the Makkah

Province is a macrocephalus urban system. This urban crisis from which the Makkah system suffers implies that urban planning is not suitable for the rapid growth of large cities which spread to the detriment of small centres. At this level, there is an urban system where there is probably competition between the urban primate unit and the one which supersedes it. To ensure the required balance and that the territory can host the resident population and visitors without compromising the imperatives of sparse management of the territory, first, it is necessary to promote the city of Makkah so that it becomes more attractive in terms of investment and high-quality services. Second, the authorities who are in charge of planning the Makkah Province must take the necessary measures to fill the gaps between the different hierarchical levels. They can promote other cities like Al-Taef, Al Bahra and Rabegh, and the centres which are getting ready to be placed in the non-existing ranks in the current distribution. A balanced distribution means that the further down the level in the pyramid, the larger number of cities in each row. This measure could be taken in urban planning strategies to redevelop and develop the region according to a globalising perspective.

Although the application of these theories to the Makkah Province confirms that the urban system is macrocephalous with Jeddah as a plethoric primate city, this result remains insufficient to confirm the initial hypothesis. Indeed, the form of distribution is only the result of processes that contribute to generated inequalities between these entities. Functional analysis is essential to detect this process to give the results an even more exhaustive and precise character. The demographic perspectives would imply functional questions which will be addressed later.

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