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Quantifying the Driving Forces of Informal Urbanization in the Western Part of the Greater Cairo Metropolitan Region

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Academic Editor: Teiji Watanabe
Received: 17 February 2016; Accepted: 19 May 2016; Published: 2 June 2016

Abstract: This paper discusses the driving forces (DFs) of informal urbanization (IU) in the greater Cairo metropolitan region (GCMR) using the Analytic Hierarchy Process (AHP). The IU patterns in the GCMR have been extremely influenced by seven DFs: geographical characteristics, availability of life facilities, economic incentives, land demand and supply, population increase, administrative function, and development plans. This research found that these forces vary significantly in how they influence urban growth in the three study sectors, namely, the middle, north, and south areas in the western part of the GCMR. The forces with the highest influence were economic incentives in the middle sector, population increase in the north sector, and the administrative function in the south sector. Due to the lower availability of buildable land in the middle sector, the land demand and supply force had a lesser influence in this sector compared to in the north and south sectors. The development plans force had medium influence in all sectors. The geographical characteristics force had little influence in both the middle and the north sectors, but higher influence than economic incentives, availability of life facilities, and development plans in the south sector. Because of the spatial variances in life facilities organizations in the GCMR, the life facilities availability force had little effect on IU in the south sector.

Keywords: informal urbanization; AHP; driving forces; slums; urban development; Egypt

1. Introduction

More than 50% of the world's population is expected to live in urban areas by 2020 [1,2]. In addition, the world population is expected to rise from 3.6 billion in 2011 to 6.3 billion in 2050. Presently, there are 23 megacities globally hosting 9.9% of the world's urban population, and they will increase to 37 by 2050, hosting 13.6% of the world's urban population [1,2]. As urban surfaces cover 3%–5% of Earth's total land surface [3], the environmental impacts of urbanization have become a major concern around the world [2]. Urbanization is a widespread anthropogenic cause of loss of arable land [4], habitat destruction [5], and decline in natural vegetation cover. It has severe effects on local ecosystems [6], causes the urban heat island phenomenon [7], consumes valuable productive arable land [4], results in loss of habitat and biodiversity [8], and also causes global effects such as climate change [9–11].

Urbanization is often characterized by severe changes that directly affect the human environment and are accompanied by highly negative influences on the global carbon cycle, such as an increase in atmospheric CO_2 [12,13]. Moreover, the absence of proper urban plans in developing countries to deal with this dilemma has caused several additional problems such as inadequate housing supply, haphazard development, urban poverty, and inequity of land supply, which lead to the rapid emergence of slums and unplanned urban areas [13].

In Egypt, rapid urbanization had been witnessed over the past three decades, notwithstanding governmental attempts to reduce it. The urban population in Egypt had increased from less than 10% at the onset of the 20th century to more than 45% by the end of the 20th century. The annual growth rate of the urban population is estimated to be 2.2% until 2050—surpassing the existing 1.8% annual growth rate of the rural and urban population [14,15]. The current population of the greater Cairo metropolitan region (GCMR) is estimated at 17 million inhabitants, which corresponds to nearly a quarter of Egypt's population of 72,798 million inhabitants in 2006, and about half of the country's population lives in cities. Currently, the population of the GCMR (Figure 1) is estimated to grow at nearly 2.0% per annum. However, the labor force will grow by over 3.0% annually, because 33% of the total population in the GCMR is under 15 years old and expected to reach working age during the current decade. The sex ratio for Cairo is precisely the same as that of the entire country (48.8% of inhabitants are female).

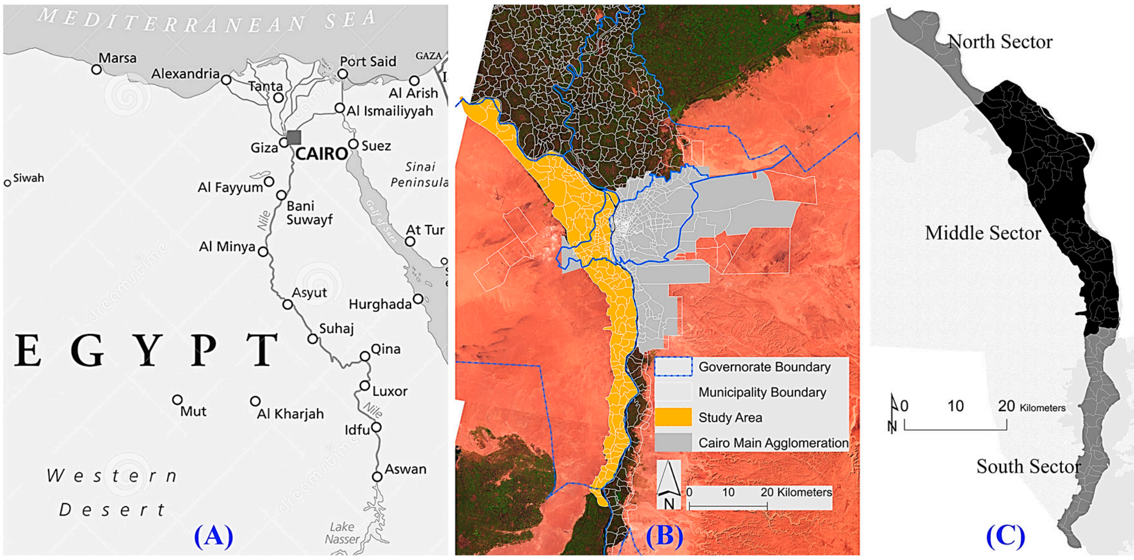

Figure 1. Location of study area. (**A**) Location of Cairo within Egypt; (**B**) location of study sectors within Cairo; and (**C**) study sectors.

The population of today's GCMR has grown since 1950 to be 2.4 million in 1975, 6.4 million in 1986, 12.5 million in 1996, and 17 million in 2006 [16]. The metropolis's informal urbanization (IU) is supported by a natural increase and the amalgamation of rural populations. In the GCMR, more than seven million inhabitants dwell in informal areas; 80% are living on privately owned arable land [14–17]. The informal urbanized areas have expanded particularly on private arable land and, less customarily, on publicly owned desert land. By 2025, around 50% of Egypt's urban population is anticipated to dwell in informal areas [14–17]. During the mid-1980s, the region's population grew at a rate of 2.6% annually [18]. A study using satellite images detected that the surface area covered by IU in the GCMR between 1991 and 1998 grew by 3.4% per annum, while the population living in the informal areas grew by 3.2% per annum (200,000 people per annum). On the other hand, between 1986 and 1996, the population growth rate of IU areas was 3.4% per year compared to the official estimate of 0.3% annually [19,20]. Moreover, it has been estimated that more than 1.5 million acres of arable lands have been wasted in Egypt because of the IU activities over the last 30 years [19,20].

In order to mitigate the detrimental effects of informal urbanization on the environment and to maintain the ecosystem functioning [21], it is essential to identify the factors influencing IU in order to support urban planners, resource managers, economists, and environmentalists in solving the problems associated with this phenomenon [2,22–24]. Therefore, this paper seeks to investigate the driving forces (DFs) of IU in the western part of the GCMR from 2004 to 2013 using the Analytic Hierarchy Process (AHP). It is crucial to study and understand the nature of the IU phenomenon to stop its negative consequences on land resources and on quality of life in the GCMR, which shelters half of Egypt's urban population. The GCMR greatly needs precautions against IU to maintain its role as a capital, major political center, tourist attraction point, and major economic hub [16,25].

Modeling DFs, which comprise urban planners' observations, and deriving a structural concept of IU procedures have been difficult for many years [26], as various forces execute various functions at various scales in a specific place. DFs are usually integrated, and it is reasonable that one force can influence diverse forces in the IU process [27], while these forces are working as indicators to grasp and quantify the nature of relationships between the IU phenomenon and its causes, which physically alter land use over urban areas. Although various methods, from probabilistic to econometric, are used to grasp the driving forces in different major highly urbanized regions such as Kathmandu, Nepal [26,28,29], the AHP method [28,30] was applied in this research to grasp the process of IU as it can be used to model municipal planners' observations identified through a questionnaire, and it identifies accurate indices to describe the correlations amongst forces.

Urban sprawl is considered the physical outcome of the IU phenomenon, and is often the commonly used term. The IU phenomenon represents the expansion of urban areas occurring outside of the authorized urban plans [31,32]. This outgrowth, seen along the periphery of cities, along highways, and along roads connecting a city, lacks basic amenities like sewage, potable water supply, and major health services [2].

A comprehensive literature review carried out for this paper found that previous researchers have categorized DFs into two main classes, physical and socioeconomic. Physical DFs are determined by biophysical characteristics of the environment such as topography, spatial configuration, climate, soil type, and natural disturbances [33,34]. Socioeconomic DFs can be determined by the human utilization of land resources to meet life needs [33], which could be divided into four categories: political, economic, cultural, and technological DFs [34]. Typically these DF categories are not clearly separable; for example, political and economic DFs are closely interrelated with political steering of economic mechanisms. However, previous studies have identified the main DFs of IU in developing countries based on several case studies [22,35]. Several DFs such as land market and landholder speculation, local government's willingness to lease land as a result of new tax revenue regulations, decentralization process after economic reforms in developing countries, population growth, increase in demand for housing space, construction demand for new development zones, demographic changes, foreign direct investment, transition of land-use regulations, rise in urban residents' income, the gradual monetization of housing distribution, rapid economic development, and shortcomings of land management system [35–38] can be observed in multiple studies.

On the other hand, AHP is widely used in the area of urban planning studies; for example, AHP is widely applied in landscape planning and assessment research [39,40], and site suitability analysis research [41–44]. In recent studies, AHP was applied to identify land-use suitability and to deal with the problems of preference acquisition [45], synthesis, and inconsistent diagnosis that were not completely solved by the Saaty's AHP method. AHP has also been used in the following studies: a demonstration of the use of a PLUS method for a greenway suitability analysis in central Arizona was performed by AHP [46], applying AHP in developing a multi-criteria decision-making method to define parameter values for CA simulation empirically [47], applying AHP methodology as a combined cost-benefits analysis and environmental assessment for a petroleum pipeline project [48], and creating a development-suitability map for the geo-environment around megacities [49,50]. Therefore, we applied the AHP method in this research to identify the weights of DFs in the GCMR.

2. Informal Urbanization in the Greater Cairo Region

As shown in Figure 2 which was prepared by the authors using Landsat satellite data, the urban area influenced by IU in our study area has increased by 135.34% between 1984 and 2013. During the period 2004–2013, the IU-influenced area increased by 44.47% while the rate of formal urbanization in the GCMR was only 13%. Informal areas, as a physical outcome of IU, were manifested in the GCMR and other major Egyptian cities during the 1960s. Land development has been out of control and the land used for construction has kept growing rapidly, particularly in peripheral areas. In the past three decades, IU has had serious impacts on agricultural lands. Scattered development and sprawling growth were persistent during that period, which hindered the Egyptian development process, and it was difficult to keep urbanization under control [14,17,51,52]. Lately, the unfavorable influences of informal areas have become more visible, and the concerned government has started to research solutions to IU. The estimated amount of arable land lost to IU since 1980 is around 1.5 million acres [15,52]. This is equal to an annual decline of 0.6% of Egypt's total arable lands, which are considered among the world's most productive lands. This tendency is estimated to continue for the next 50 years. Between 1980 and 2025, around 50% of Egypt's arable lands will be converted into informal urban areas [53]. The value of arable land converted to informal areas was estimated at $46.2 billion, in addition to $63.1 billion as costs for the informal buildings [53].

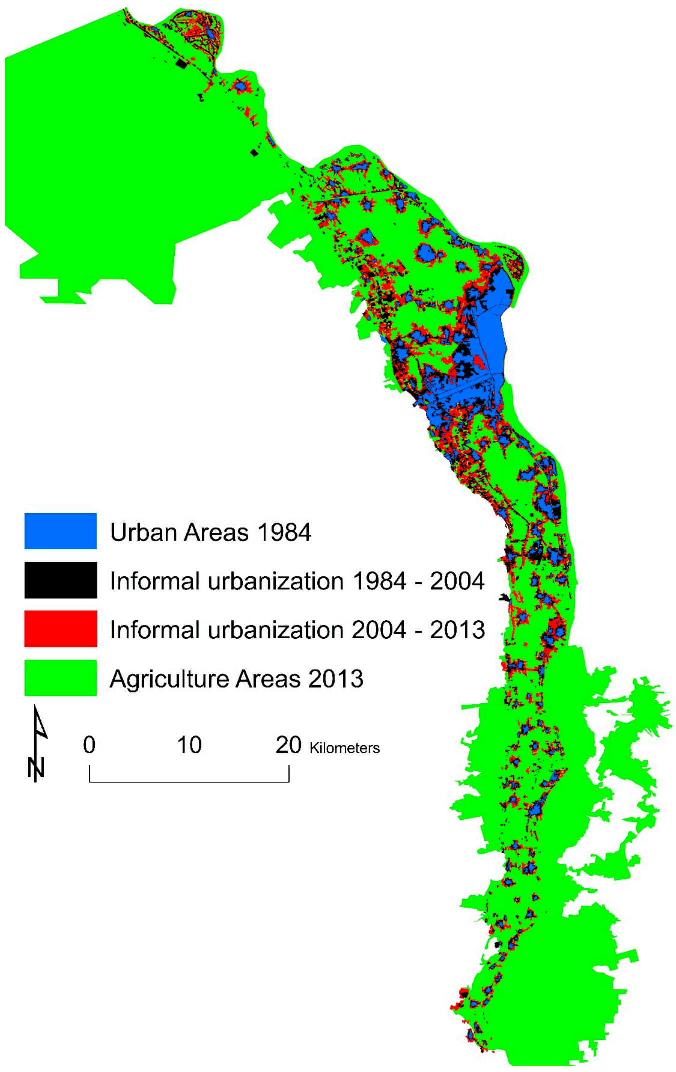

Figure 2. Informal urbanization in the study area, 1984–2013.

3. Methods

3.1. Research Area

Cairo is surrounded by desert hills to both the east and west, and agricultural lands to the north and south (Figure 1). Historic Cairo (*i.e.*, pre-1860) was limited to the higher ground near the eastern hills. The GCMR consists of the entire Cairo Governorate and the urban areas of Giza Governorate (west of the Nile) and Qaliubia Governorate (north of Cairo Governorate). Governorates are the major areas of municipal administration in Egypt, and there are no macro-administrative divisions in the GCMR administrative structure. There are public service authorities (e.g., public transport, water, and wastewater) that cover the whole GCMR. For urban planning purposes, the "Cairo region" has been placed in the national-level General Organization for Physical Planning (GOPP). The GCMR is not only the political capital of Egypt but also its service, social, economic, and administrative hub. For most business and day-to-day governance, administration in the GCMR is controlled by the three governorates and their executive districts accordingly: Cairo is the urban governorate with 26 districts, Giza is the rural governorate with five districts in addition to outer administrative villages, and Qaliubia is the rural governorate with two districts in the Shubra El Kheima area, in addition to outer administrative villages. In this paper, the western part of the GCMR is selected as a case study due to its sub-spatial sprawl in the last three decades (Figure 2). To improve the analysis outputs, we divided the study area into more specific sub-sectors based on their unique internal and homogenous characteristics. Based on urban density, population numbers, connectivity to the GCMR metropolitan transportation network, and rate of IU during the last 30 years, we used three urban sectors (north, middle, and south) in this study, as shown in Figure 1.

3.2. Identifying Driving Forces (DF)

Generally, IU that leads to land-use alterations is an outcome of the synthesis of structural forces related to the needs, technological assimilation, social interactions influencing needs and assimilation, and eventually depletion of the environment. There is no global set of DFs for consideration. Although identical DFs have been identified in diverse studies, the degree to which they share in terrain change varies [27].

Residents, government plans, land patterns, terrain, and availability often cause variances in the DFs' influence on IU. In the study area, similarity between these DFs was observed. Residents' attitudes and interactions with the neighboring environment over time have led to prominent alterations in the region's terrain. Consequently, the researcher interviewed local residents, researchers, urban and regional planners, and academics working in various knowledge backgrounds as they may be familiar with the changing urban environment and be able to provide reasons for the change from various perspectives. Discussion groups, interviews, and investigation of previous studies conducted during the fieldwork (April–August 2012) provided the key data for understanding the DFs of IU in the previous decade. The structure of these data was studied for the extraction of seven exemplary forces, extending from physical to socioeconomic DFs (Table 1).

A group of questionnaires within the AHP settings was developed. In that questionnaire, the respondents assigned the relative significance of each force with regard to the others; for instance, the significance of geographical characteristics with respect to the availability of facilities, economic incentives, land demand and supply, population increase, the administrative function in Egypt, and development plans. An extra choice (other) was included in the questionnaires to allow respondents to enter an additional DF that may be significant. Three sets of the same questionnaires were distributed to each respondent, so as to obtain answers for each study area. The three study areas were introduced to the participating residents by maps. The participating residents were requested to assess the DFs for each sector.

Table 1. Sample of responses to the informal urbanization driving forces in Cairo.

Driving Factors	Descrition
Administrative function	Cairo, as a capital of Egypt, is the head of the administrative and political system in Egypt. In previously socialist countries like Egypt, high administrative function means more facilities, jobs, business opportunities, and an easier life. A higher administrative rank leads to more facilities, so the capital is the best place to live, the city is more attractive than native villages, and small villages are the worst place to live.
Population increase	High population growth (2.2%/year) in the region puts more pressure on finite potentials by asking for more life facilities, eventually resulting in land use alterations.
Economic incentives	Cairo, as a prime economic center of Egypt, identifies diverse high-paying business and job opportunities in the medical, educational, tourism, financial, manufacture, and commercial sectors.
Availability of life facilities	The facilities and services obtainable in the region are potable water, medical services, electricity, transportation, entertainment facilities, commercial, waste disposal, and education. The concentration of these facilities may vary by place.
Development plans	The efficaciousness of zoning, land improvements, land integration, pilot land projects, economic and exploitation plans of the government was investigated.
Geographical characteristics	Geographical location characteristics as nearest to centers, regional roads, the Nile river, *etc.*; soils and topography are executing a role in IU and land use alterations.
Land demand and supply	Land speculators, real estate contractors, and local residents in Cairo are very active in acquiring undeveloped land, then developing the land and offering it on the real estate market.

The potential respondents were identified based on several criteria: have at least a bachelor's degree, be a long-term resident with interactions in the region, and have awareness about land-use changes. A large number of interviewees from various localities in the study area with a wide range of expertise and academic backgrounds responded to the questionnaires (Figures 3 and 4).

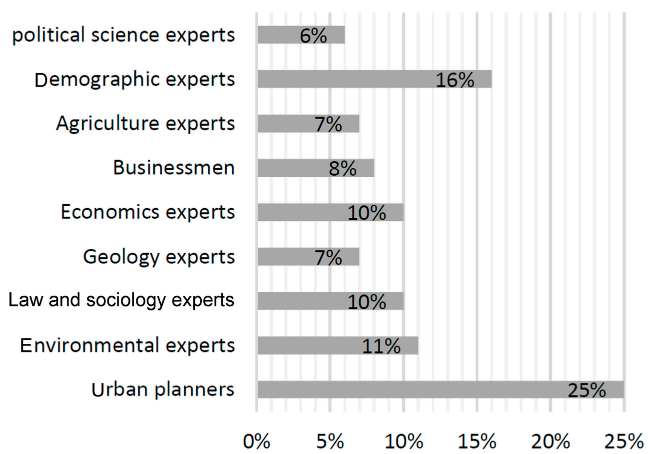

Figure 3. Respondents' specializations.

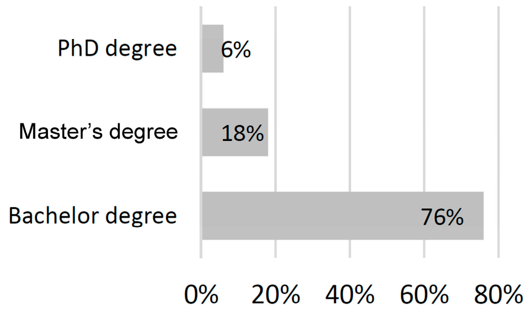

Figure 4. Respondents' academic degrees.

Educated people represent 22% of the total population in our study area [54], belonging to all strata of society. The original citizens of the area were all less educated than the newer inhabitants. Immigrants are mostly educated people who are searching for a good job suitable to their competitive skills in the capital city. Less educated people cannot be permanent residents because they cannot get permanent jobs. They mainly come to the city as temporary workers and they leave their families in their original urban areas. Thus, this questionnaire is focusing mainly on educated residents. By applying a similar study method to [28,55], we investigated 94 respondents in each study sector. As shown in Figure 4, 18% of the investigated residents had a master's degree, while the others had a PhD (6%) or a bachelor's degree (76%). The information identified by these residents who have various specializations is analyzed to identify DFs. This method has enabled us to identify hidden and real DFs of IU with their accurate weights, as judged by local experts, who have enough experience of living in such informal urbanized areas and specialized knowledge of a discipline.

The following provides samples of the answers received to our questionnaire: How did you know about this place? (relatives, friends, land broker, the media, others), Why did you choose this place? (inherited land, urban facilities, business, employment, land value, public safety, other), current land-use (residential, commercial, industrial, other), state of the land before the present use was built (agricultural land, desert, old house, other), and Please choose one or more from the following indicators as land-use change forces and then write between brackets the strength of each selected force (equal, moderate, strong, very strong, extreme): (administrative Function, population increase, economic incentives, availability of facilities, development plans, geographical characteristics, land demand and supply, other).

3.3. Modeling the Driving Forces: The AHP Framework

3.3.1. Analytic Hierarchy Process (AHP)

The AHP is a resilient yet organized methodology for examining and resolving complex issues by organizing criteria into a hierarchical framework [30]. The AHP procedure is applied for rating a set of choices or for identifying the best in a set of choices. The rating is carried out with regard to an inclusive aim, which was distributed into a set of standards. The AHP procedure includes four major steps: evolving the AHP hierarchy, specifying pairwise differentiation module, counting consistency ratio, and calculating the definitive significance.

3.3.2. Evolving the AHP Hierarchy

The first step in the AHP system is to analyze the set of choices into a hierarchy that comprises the most significant components among the choices. In evolving a hierarchy, the top scale is the definitive aim of the resolution at hand. The hierarchy then inclines from the common aim to the most specific components of the problem until a scale of attributes is extended. Despite the fact that a hierarchical structure usually comprises aim, objectives, attributes, and choices, a set of components related to a specific problem and various synthesis of these components can be utilized to understand the problem [30]. In this research, an exemplary four-level hierarchy of aim, objectives, attributes, and choices has been investigated to depict the spatial AHP system.

The set of m choices is indicated here by A_i for I = 1, 2, . . . , m. The choices are to be assessed with regard to a set of p goals O_k for q = 1, 2, . . . , p. The goals are gauged in terms of the attributes. Consequently, there is a set of n features, C_j for j = 1, 2, . . . , n, related to the p goals. A subset of features related to q, the objective, is indicated by $C_{k(q)}$ for k = 1, 2, ... , l; $l \leqslant n$. To refer to the significance of the standards, two sets of significance, W_q = (w_1, w_2, w_p) and $W_{k(q)}$ ¼ ($w1_{(q)}$, $w2_{(q)}$, ... , $wi_{(q)}$), are allocated to the goals and features, respectively.

3.3.3. Specifying the Pairwise Differentiation Module

In AHP, the significance of the standards is gauged severally for each hierarchical scale. The AHP specifies a pairwise differentiation module for each hierarchical scale. Rating the standards of the identical scales over each other outlines these differentiation modules. Experts define the rating for standards by evaluating each standard over the other after investigating their significance to the problem [30,56]. First, the research developed a method to summarize unstructured verbal responses into categories to help decision-makers in determining the rates of the standards (Table 1). The assessment extends from equality to extreme significance of one force over another. These rates are identical to the odd-numbered numerical assessments between 1 and 9 with some moderate even-numbered rates in between [57]. If the components of the pairwise differentiation ratios are identified with a_{ij}, which refers to the significance of ith force over jth, then a_{ji} can be gauged as 1 = a_{ij} [58].

3.3.4. Counting Consistency Ratio

In order to identify the consistency of the subjective rating, a consistency ratio is counted for each pairwise differentiation module. A module is called consistent if and only if $a_{ik} \times a_{kj} = a_{ij}$, where a_{ij} is the i_j th element of the module [59]. In problems with a considerable number of criteria, introducing subjective assessments commonly leads to modules that are not perfectly consistent. A gauge of the consistency of a module is calculated by the consistency ratio (CR). The definitive consistency ratio is evaluated by matching the CI with a random index (RI) relying on the number of components being assessed, CR = CI/RI (Table 2). RI is the consistency index of an indiscriminately produced pairwise differentiation module [43]. The proportion refers to a sensible scale of consistency in the pairwise differentiation if CR < 0.10. If CR $\geqslant$ 0.10, the rates of the ratio refer to incompatible assessments.

Table 2. Scales in pairwise differentiations [30].

Intensity of Significance	Verbal Assessment of Preference
1	Equal significance
3	Moderate significance
5	Strong significance
7	Very strong significance
9	Extreme significance
2, 4, 6, 8	Moderate rates between adjacent scale rates

3.3.5. Calculating the Definitive Weights

A large set of methods could be applied to compute the definitive correlative significance of each criterion. In this study, we applied the lambda max and the geometric mean mechanisms due to their high efficiency in such case studies [60]. In order to obtain the definitive significance by the lambda max mechanism, a vector of significance is outlined as the standardized eigenvector identical to the greatest eigenvalue. To facilitate computing eigenvectors in the lambda max mechanism, and evolving the approximation of the eigenvector related to the maximum eigenvalue [60]. In this system, standardized pairwise significance is gauged by separating each pairwise weight by the sum of pairwise significance in each column. Then the arithmetic average of each row of the standardized module submits the correlative weight of the identical standard or choice. The accuracy of this approximation is escalated when the pairwise differentiation module has a small consistency ratio.

In the geometric mean mechanism, the geometric average of each row of the pairwise differentiation module is first calculated as:

$$r_j = \prod_{j=1}^{n} (\mathrm{a_{ij}})^{1/n}$$

where a_{ij} are the differentiation ratios and n is a number of the standards. Then, by using the subsequent formula, the significance of each standard is gauged:

$$w_i = \frac{r_i}{\sum_j r_j}$$

Previous related papers [61] have contained some studies about the advantages of utilizing the lambda max or the geometric mean mechanisms. Moreover, measuring the eigenvector is problematic every so often in the lambda max method, and a solution cannot be made by choosing one criterion over another. Crawford & Williams, 1985 [62] prioritized utilizing the geometric mean instead of the lambda max, while J. Barzilai, 1997 [63] believed that the geometric mean is the only reasonable method for the problem of deriving significance from pairwise differentiations in the AHP. In the case of a consistent pairwise differentiation module, the geometric mean method consistently generates the same significance as the lambda max mechanism. Also, if n = 3 (n is a number of standards), then both processes produce the same significance; and when n > 3 the outcomes for the significance in both processes are relative [59].

AHP-based fieldwork data modeling settings (Figure 5) were evolved to assess the DFs of IU in the region for the previous decade.

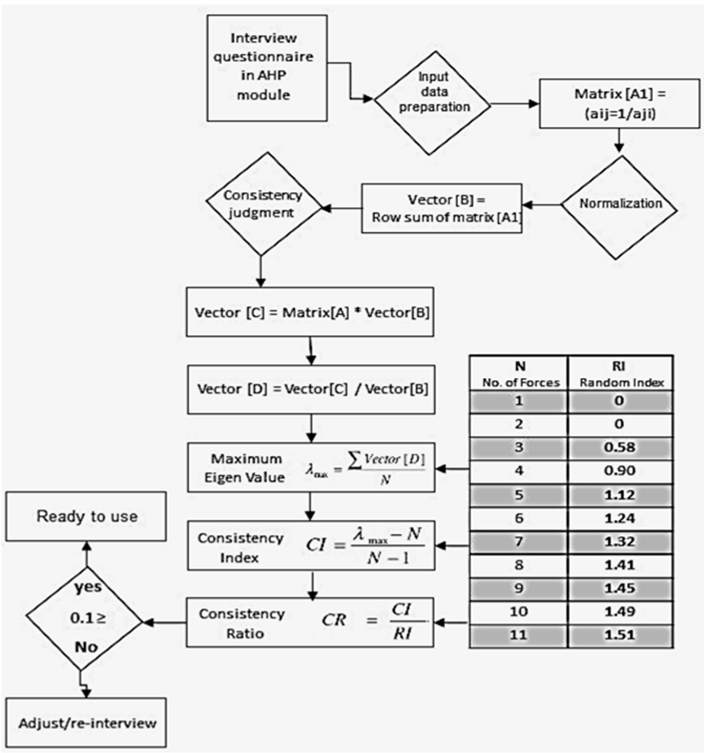

Figure 5. Model of the driving forces in the AHP method.

A total of 94 samples were evolved for each study sector. The samples from each urban area were linearly integrated using a geometric mean. The geometric mean is utilized for the data in this stage, which are obtained from correlative assessments. As per the AHP model, mutual calculation, rate equalization, major vector significance calculation, and consistency assessments were implemented for each study sector. The forecasting outputs in all study structural sectors are accomplished by a consistency ratio (CR) of 0.007–0.009, which is better than the maximum reasonable (⩽0.1) domain [30]. The definitive scores of the DFs were scaled to 0–100 for simpler preformation. The outputs are explained by structural urban areas. Moreover, the DFs are sorted from 1st to 7th (from the lowest to the highest influence) and submitted in a radar chart to explain the correlations among the forces for IU in the Cairo region.

4. Results

4.1. Driving Forces in Middle Sector

Figure 6 presents the weight of each driving force influencing IU in the middle sector. The economic incentives force, with a weight of 28.2, has the highest influence on the IU process in the area because major commercial and governmental foundations are restricted to the middle sector [20,64]. Therefore, most of the land in this area is usually converted into these types of uses. These foundations have generated various types of jobs that attract considerable population numbers, which is indirectly related to the population increase force, which is the second major force in the sector (2.17). Nearly equal functions are observed in availability of life facilities (18.4) and the administrative function (14.1). Roads, hospitals, parks, educational institutions, and head offices of the major governmental establishments are established in this sector. The middle sector is congested and the land is comparatively expensive. Land for development is only available for businesspeople or for commercial organizations. Consequently, in the middle sector, the land demand and supply force (8.5) is not as significant in altering the terrain as the aforesaid forces. The development plans force has a weight of (5.7) for the previous decade because the terrain in the middle sector is already well developed or limited to renovation schemes. The geographical characteristics of the land showed a feeble effect compared to all other forces. This is because most of the land in the middle sector is flat and was transformed into built-up surfaces previously or by other DFs.

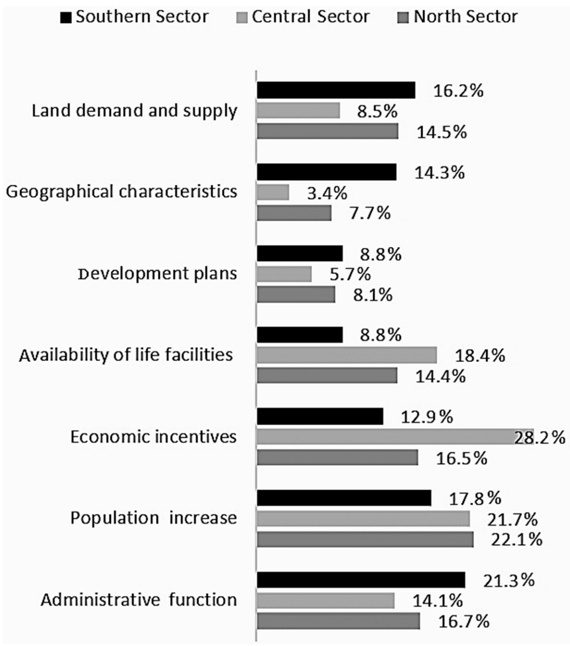

Figure 6. Driving forces influences in the study sectors.

4.2. Driving Forces in the North Sector

Figure 6 shows the quantified outputs of the DFs for alteration in terrain in the north sector. Interestingly, the population increase force has a weight of 22.1, which is the highest in all the study sectors. The north sector has both urban and rural lifestyles. Consequently, it might be a good place for residents from both groups. Firstly, the north sector comprises a plurality of residents who have transformed their land. Secondly, the land is relatively moderate compared to that in the middle sector [64,65]. Diverse investors and workers choose the north sector area to host their business sites [25,65]. That has promoted a significant population increase by accelerating the demand for urban services that eventually change the terrain.

The land demand and supply force, with a weight of 14.5, is the second major IU force in this area. The fieldwork detected that local residents, land speculators, and real estate developers are very active in the land development process. First, real estate contractors acquire the land from one or more local residents based on the land plot size and availability for sale, and construct housing or sell the land to clients at a relatively higher price. The administrative function recorded 16.7 points and economic incentives recorded 16.5 points, making them the third and fourth major functions, with only a small variance in their significance, while the availability of life facilities achieved only 14.4 points. Correlatively few educational institutions and economic incentives, and small medical centers and shops are found in the north sector. The development plans and geographical characteristics of the land received fewer than 10 points.

4.3. Driving Forces in the South Sector

Figure 6 presents the importance of the DFs in altering the rural terrain in the south sector. The administrative function scored 21.3 points, which indicates that it has a higher influence on altering the terrain than the other forces. Diverse residents who had migrated from rural areas were identified as living in the area [65]. Population increase with 17.8 points and land demand and supply with 16.2 points are the second and third most effective forces. Because of cheaper land prices in this sector compared to the north sector and middle sector, new residents have identified that there is more low-cost land in the area.

The geographical characteristics force with 14.3 points is the fourth most significant DF of rural terrain alteration in the sector. The lush soils and availability of water have attracted numerous mercantile producers, and are helpful for brick manufacture. These features may explain why the geographical characteristics force is higher than the following three forces. The economic incentives, availableness of life facilities, and development plans forces rated badly as compared with the other two sectors. Besides mining and brick-making, few major economic activities have been established in the south sector. Residents living in the south sector have minimal access to education, public transportation, and other facilities [25,65]. To use these facilities, most residents would need to go to the middle sector. There are low numbers of facilities with influence on the alteration of urbanization procedures in the sector. Currently, some planned residential zones are being evolved as private projects of local contractors, but their impact is small. Consequently, the residents who participated in this study felt that the development plans force has a low influence on land use changes.

5. Discussion

The alterations in the spatial patterns due to IU in the study area during the last three decades were supported by improvements in transportation networks and the accomplishment of several governmental development plans [66,67]. With the growth in residents' knowledge and public culture, diverse DF has led to alterations to the terrain in the previous decades. Many of these forces, in various proportions, have been identified as significant in other studies. For instance, economic incentives and population growth were identified as significant DFs by [68]. Moreover, public community issues, diversity of transportation modes, neighborhood relations, municipal plans, and political, economic, cultural, technological, and structural affairs were identified to be DFs with various influences in similar studies [27,69]. Comparing our findings with similar developing countries case studies such as in the Dhaka region in Bangladesh, we noticed that the main driving forces for urbanization procedures in Dhaka were land speculation, land prices, growing demand for housing, topography, land use, transportation, economic activities, and population growth [10,11]. These drivers are similar to our findings in the GCMR, with small differences in the order of drivers' importance.

5.1. Comparing the Driving Forces by Structural Areas

When comparing the DF outcomes by study sector in Figure 7, it is clear that the influence of the geographical characteristics force is higher in the south sector than other sectors. Considerable numbers of brick manufacturers are located in the south sector because of the suitable soil properties [25]. The geographical characteristics force is not that significant in the middle sector because of the high rate of yield. Businesspeople and investors are progressively interested in exploiting the land despite physiographic restrictions. Furthermore, other effective forces often disguise this force. For instance, due to the higher availability of facilities and the functional intricacy, the availability of facilities force had the highest influence on the south sector compared to other sectors, where most of the services are limited. Moreover, the setting up of new commercial projects was observed in neighborhoods closer to the facilities, which is a new tendency.

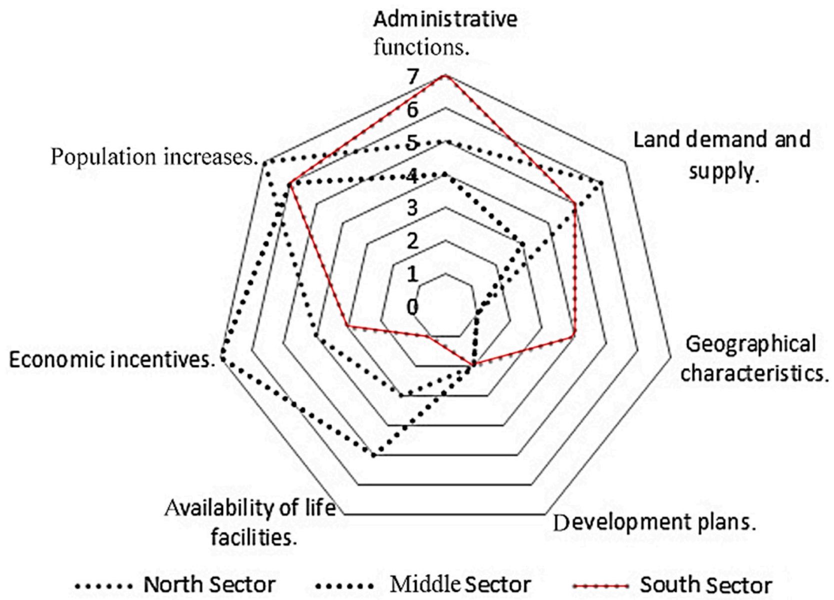

Figure 7. Driving forces impact ranking.

The impact of economic incentives in the south sector is less than half that in the middle sector. The land demand and supply force has the highest influence in the south sector, closely followed by the north sector. Land in the south sector is obtained at a lesser cost for new developments or land trades, while land speculators and local people are very active in land trade in the north sector. These characteristics may describe why the land demand and supply force is relatively higher in these areas than in the middle sector.

The population increase force is more influential in altering the north sector terrain than in the middle and south sectors. Some of the native residents are active in maintaining their ancestral land. Consequently, population increase persists. Moreover, investors are attracted to the north sector areas in the GCMR for developing residential buildings. Some of the new top-class residential areas are in these north sector areas. As the population increases, demand for housing escalates. The population increase force was rated lower in the middle and south sectors.

The administrative function force in the south sector has a higher function in altering the rural terrain than in the middle and north sectors. The development plans force has the least influence in the south sector, due to the poor accomplishment of government development plans in the last three decades, as has been asserted by other studies [15,17,20].

5.2. Rating of Driving Forces by Study Sector

Figure 7 shows the DFs ranked from 1st order to 7th order. Administrative function force is the highest-ranked DF in the south sector, but it was only 5th and 4th in the north and middle sectors, respectively. This has been a significant theme for a few decades in Egypt. Through the previous three decades, considerable numbers of people in Egypt moved to the Cairo region, as it was found to be the most affordable place to work and live in Egypt. Some of the newcomers became the source of labor for the manufacturing and real estate sectors. The influence of population increase force is the 2nd most crucial DF in both the middle and south sectors with a rating of 6, and is rated 7th in the north sector. This indicates that population increase has a higher influence on terrain alteration in the north sector. The land demand and supply force looks to have the lowest rating, at 6th, 5th, and 3rd in the north, south, and middle sectors, respectively.

The geographical characteristics force had the smallest influence in the middle and north sectors, but it was rated 4th in the south sector. The economic incentives force had the top rate in the middle sector, but it was 4th and 3rd in the north and south sectors, respectively. This is because there are more business and employment opportunities in the middle sector as diverse classical residential areas in the middle sector are being converted to businesses. In contrast, this force has a lesser function in rural areas because there are fewer opportunities for investment and work.

The function of development plans is not as considerable in the study area. It is the 2nd least influential force in all of the three sectors in the study area. Residents state that government development plans have been implemented imperfectly, with no effect in altering the terrain. Because of the lack of availability of facilities in the south sector, it ranked the lowest in this sector, and with growing accessibility to the middle sector, its influence decreased, from the 3rd order in the north sector to the 5th in the middle sector.

Ultimately, economic incentives, population increase, and administrative function forces are the highest-rated forces influencing IU in the middle, north, and south sectors, respectively. As shown in Figure 7, two forces, population increase and land demand and supply, extended the 6th order. The geographical characteristics force seems to be the least influential force in the middle and north sectors, while the availability of facilities force is the least influential in the south sector.

6. Conclusions

The most important result in this paper is finding the variations in DF influences over the three study sectors of the western part of the GCMR terrain. These variations proved the need for local and separate development plans to decrease the rates of IU for each study sector. Moreover, the finding concerning the low importance of development plans over all the study sectors is significant because this force should have a highly important role in directing urbanization and hindering IU in such case studies. This might explain how IU continued at high rates between 1984 and 2013, even with the existence of several authorized development plans to manage urbanization in the GCMR. This result is not only important for the Cairo context but also for such cases in developing countries, which witness rapid IU rates although several studies and development policies work to address this dilemma. The urban policies force has lost its major role in managing urban growth by managing and directing related tools such as life facilities, economic incentives, population growth, land market, and the administration role. Based on this study's results, the development policies force has lost its role as a tool that directs other growth forces, and has become useless since there is no relationship between the real needs of the community and the suggested governmental urban plans.

Taking into consideration municipal planners' notes over the involvement of the local community in the procedure of assessing DFs reduced the likelihood of faults. The estimation of DFs' functions in directing IU is a significant part of the information that will share in modeling IU to understand the likely IU process. This experimental analysis detected DFs of IU in the western part of the GCMR, which is significant for regional and urban planners in Egypt and other developing countries.

For future research, the findings of this paper about DF order will be useful in building detailed indicators for measuring and assessing the driving forces that will help decision-makers to enforce urban development plans in the GCMR.

Acknowledgments: We thank all of the urban and regional experts in the General Organization of Physical Planning in the Greater Cairo Metropolitan Region who participated in this study.

Author Contributions: Taher Osman conceived the survey, and developed the model, Taher Osman and Prasanna Divigalpitiya conducted analyzes, model runs, and wrote the paper, Taher Osman, Prasanna Divigalpitiya, and Takafumi Arima revised the paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. United Nations Department of Economic and Social Affairs. *World Population Prospects: The 2010 Revision*; UNDESA: New York, NY, USA, 2012; Volume 1.
2. Central Intelligence Agency World Factbook. Available online: https://www.cia.gov/index.html (accessed on 14 December 2015).
3. Schneider, A.; Friedl, M.A.; Potere, D. A new map of global urban extent from MODIS satellite data. *Environ. Res. Lett.* **2009**, *4*, 044003. [CrossRef]
4. Lopez, T.D.M.; Aide, T.M.; Thomlinson, J.R. urban expansion and the loss of prime agricultural lands in Puerto Rico. *Ambio* **2001**, *30*, 49–54. [CrossRef] [PubMed]
5. Alphan, H. Land use change and urbanization in Adana, Turkey. *Land Degrad. Dev.* **2003**, *14*, 575–586. [CrossRef]
6. Turner, B.L., II. Local faces, global flows: The role of land use and land cover in global environmental change. *Land Degrad. Dev.* **1994**, *5*, 71–78. [CrossRef]
7. Li, Y.Y.; Zhang, H.; Kainz, W. Monitoring patterns of urban heat islands of the fast-growing Shanghai metropolis, China: Using time-series of Landsat TM/ETM+ data. *Int. J. Earth Observ. Geoinf.* **2012**, *19*, 127–138. [CrossRef]
8. McKinney, M.L. Urbanization, biodiversity, and conservation. *Bioscience* **2002**, *52*, 883–890. [CrossRef]
9. Herold, M.; Goldstein, N.C.; Clarke, K.C. The spatiotemporal form of urban growth: Measurement, analysis and modeling. *Remote Sens. Environ.* **2003**, *86*, 286–302.
10. Dewan, A.M.; Yamaguchi, Y. Land use and land cover change in Greater Dhaka, Bangladesh: Using remote sensing to promote sustainable urbanization. *Appl. Geogr.* **2009**, *29*, 390–401. [CrossRef]
11. Dewan, A.M.; Kabir, H.; Nahar, K.; Rahman, Z. Urbanisation and environmental degradation in Dhaka Metropolitan Area of Bangladesh. *Int. J. Environ. Sustain. Dev.* **2012**, *11*, 118–147. [CrossRef]
12. Alves, D.S.; Skole, D.L. Characterizing land cover dynamics using multi-temporal imagery. *Int. J. Remote Sens.* **1996**, *17*, 835–839. [CrossRef]
13. Dewan, A.M.; Yamaguchi, Y. Using remote sensing and GIS to detect and monitor land use and land cover change in Dhaka Metropolitan of Bangladesh during 1960–2005. *Environ. Monit. Assess.* **2009**, *150*, 237–249. [CrossRef] [PubMed]
14. Osman, T.; Arima, T.; Divigalpitiya, P. Measuring Urban Sprawl Patterns in Greater Cairo Metropolitan Region. *J. Indian Soc. Remote Sens.* **2016**, *44*, 287–295. [CrossRef]
15. Osman, T.; Divigalpitiya, P.; Arima, T. Modeling urban growth scenarios in Cairo metropolitan region 2035. In Proceedings of the 14th International Conference on Computers in Urban Planning and Urban Management, Cambridge, MA, USA, 7–10 July 2015.
16. Sims, D.; Sejoume, M.; Shorbagi, M. *Understanding Slums, Case Studies for the Global Report 2003*; German Technical and Financial Cooperation (GTZ): Cairo, Egypt, 2003.

17. UNDP/INP. *Egypt Human Development Report 2004: Choosing Decentralization for Good Governance Cairo*; UNDP/Institute of National Planning: Cairo, Egypt, 2004.
18. Denis, E. *Urban Planning and Growth in Cairo*; Middle East Report; Centre de Research et de Documentation Economique, Juridique, et Social (CEDEJ): Cairo, Egypt, 1997; Volume 27.
19. Denis, E.; Sejourne, M. *ISIS: Information System for Informal Settlements*; Ministry of Planning: Cairo, Egypt, 2002.
20. Osman, T.; Divigalpitiya, P.; Arima, T. Effect of Governmental Housing Regulations on the Egyptian Housing Market: Focusing on Greater Cairo Metropolitan Region. *J. Archit. Urban Des.* **2015**, *28*, 1–9.
21. Fang, S.; Gertner, G.Z.; Sun, Z.; Anderson, A.A. The impact of interactions in spatial distribution of the dynamics of urban sprawl. *Landsc. Urban Plan.* **2005**, *73*, 294–306. [CrossRef]
22. Seto, K.C.; Sánchez-Rodríguez, R.; Fragkias, M. The new geography of contemporary urbanization and the environment. *Ann. Rev. Environ. Resour.* **2010**, *35*, 167–194. [CrossRef]
23. Dewan, A.M.; Corner, R.J. *Dhaka Megacity: Geospatial Perspectives on Urbanisation, Environment and Health*; Springer: Dordrecht, The Netherlands, 2014; pp. 99–121.
24. Stewart, D.J.; Yin, Z.Y.; Bullard, S.M.; MacLachlan, J.T. Assessing the spatial structure of urban and population growth in the Greater Cairo Area, Egypt: A GIS and imagery analysis approach. *Urban Stud.* **2004**, *41*, 95–116. [CrossRef]
25. Japanese International Cooperation Agency (JICA). *The Strategic Urban Development Master Plan Study for Sustainable Development of the Greater Cairo Region in the Arabic Republic of Egypt*; Ministry of Housing and Urban Development: Cairo, Egypt, 2008; Volume 1.
26. Tian, G.; Liu, J.; Xie, Y.; Yang, Z.; Zhuang, D.; Niu, Z. Analysis of spatiotemporal dynamic pattern and driving forces of urban land in China in the 1990s using TM images and GIS. *Cities* **2005**, *22*, 400–410. [CrossRef]
27. Verburg, P.H.; Ritsema van Eck, J.; de Nijs, T.; Schot, P.; Dijst, M. Determinants of land-use change patterns in the Netherlands. *Environ. Plan. B* **2004**, *31*, 125–150. [CrossRef]
28. Thapa, R.B.; Murayama, Y. Drivers of urban growth in the Kathmandu valley, Nepal: Examining the efficacy of the analytic hierarchy process. *Appl. Geogr.* **2010**, *30*, 70–83. [CrossRef]
29. Mottet, A.; Ladet, S.; Coque, N.; Gibon, A. Agricultural land-use change and its drivers in mountain landscapes: A case study in the Pyrenees Agriculture. *Ecosyst. Environ.* **2006**, *114*, 296–310. [CrossRef]
30. Saaty, T.L. *The Analytic Hierarchy Process*; McGraw-Hill: New York, NY, USA, 1980.
31. Sudhira, H.S.; Ramachandra, T.V. Characterizing urban sprawl from remote sensing data and using landscape metrics. In Proceedings of the 10th International Conference on Computers in Urban Planning and Urban Management, Iguassu Falls, Brazil, 11–13 July 2007.
32. Osman, T.; Arima, T.; Divigalpitiya, P. Tale of Slums in Cairo Region: Describing the actual gap between the unplanned and planned urban growth in the greater Cairo Metropolitan Region. *J. Habitat Eng. Urban Des.* **2014**, *6*, 83–93.
33. Briassoulis, H. Analysis of land use change: Theoretical and modeling approaches. In *The Web-Book of Regional Science*; Jackson, W.R., Ed.; Regional Research Institute, West Virginia University: Morgantown, WV, USA, 2000.
34. Hersperger, A.M.; Bürgi, M. Going beyond Landscape Change Description: Quantifying the Importance of Driving Forces of Landscape Change in a Central Europe Case Study. *Land Use Policy* **2009**, *26*, 640–648. [CrossRef]
35. Zhang, T.W. Community features and urban sprawl: The case of the Chicago metropolitan region. *Land Use Policy* **2001**, *18*, S221–S232. [CrossRef]
36. Wang, Z.Y.; Gao, H.Y. An Important Problem: Urban Sprawl. *J. Northeast. Univ.* **2005**, *7*, S391–S394.
37. Deng, X.Z.; Zhan, J.Y.; Chen, R. The patterns and driving forces of urban sprawl in China. In Proceedings of the 2005 IEEE International Geoscience and Remote Sensing Symposium, Seoul, Korea, 25–29 July 2005.
38. Li, Q.; Yang, K.Z. *Urban Sprawl*; Machinery Industry Press: Beijing, China, 2006.
39. Nieman, T.J.; Meshako, D.S. *An Analytical Approach to Weighting Attributes for Landscape Planning*; University of Kentucky, Department of Horticulture and Landscape Architecture: Lexington, KY, USA, 1983.
40. McDonald, G.T.; Brown, A.L. The land suitability approach to strategic land use planning in urban fringe areas. *Landsc. Plan.* **1984**, *11*, 125–150. [CrossRef]
41. Banai, R. Fuzziness in geographical information systems: Contributions from the analytic hierarchy process. *Int. J. Geogr. Inf. Syst.* **1993**, *7*, 315–329. [CrossRef]

42. Banai-Kashani, R. A new method for site suitability analysis: The analytic hierarchy process. *Environ. Manag.* **1989**, *13*, 685–693. [CrossRef]
43. Miller, W.; Collins, M.G.; Steiner, F.R.; Cook, E. An Land-Use Suitability Analysis 619approach for greenway suitability analysis. *Landsc. Urban Plan.* **1998**, *42*, 91–105. [CrossRef]
44. Malczewski, J. A GIS-based approach to multiple criteria group decision-making. *Int. J. Geogr. Inf. Syst.* **1996**, *10*, 955–971. [CrossRef]
45. Xiang, W.N.; Whitley, D.L. Weighting land suitability factors by the PLUS method. *Environ. Plan. B Plan. Des.* **1994**, *21*, 273–304. [CrossRef]
46. Collins, M. An Integrative Approach to Multi-objective Greenway Suitability Analysis. Master's Thesis, Arizona State University, Tempe, AZ, USA, 1996.
47. Wu, F. SimLand: A prototype to simulate land conversion through the integrated GIS and CA with AHP-derived transition rules. *Int. J. Geogr. Inf. Sci.* **1998**, *12*, 63–82. [CrossRef]
48. Dey, P.K.; Gupta, S.S. Quantitative approach to impact assessment: A case study on cross-country petroleum pipeline project in India. In Proceedings of the 20th Annual Meeting of the International Association for Impact Assessment, Hong Kong, China, 19–23 June 2000.
49. Dai, F.C.; Lee, C.F.; Zhang, X.H. GIS-based geo-environmental evaluation for urban land-use planning: A case study. *Eng. Geol.* **2001**, *61*, 257–271. [CrossRef]
50. Uy, P.D.; Nakagoshi, N. Application of land suitability analysis and landscape ecology to urban greenspace planning in Hanoi, Vietnam. *Urban For. Urban Green.* **2008**, *7*, 25–40. [CrossRef]
51. Sims, D. *The Case of Cairo, Egypt UN Habitat, Global Report on Human Settlements 2003, the Challenge of Slums*; Earthscan: London, UK, 2003.
52. MOP and GTZ, (Ministry of Planning—German Technical and Financial Cooperation). *New Practice of Participatory Local—Development in Egypt's Urban Areas*; Participatory Development Programme in Urban Areas (PDP): Cairo, Egypt, 2004.
53. El-Hefnawi, A. Protecting agricultural land from urbanization or managing the conflict between informal urban growth while meeting the demands of the communities. In Proceedings of the 3rd Urban Research Symposium on Land Development, Urban Policy and Poverty Reduction, Brasilia, Brazil, 4–6 April 2005.
54. Central Agency for Population, Mobilization and Statistics (CAPMAS). *Census of Egypt, The Final Results: Population and Housing Census of the Year 2006*; CAPMAS: Cairo, Egypt, 2008.
55. Taylor, I. Survey Sample Sizes e How Many Respondents Do You Really Need? 2012. Available online: http://blog.questionpro.com/author/thirdforce/ (accessed on 26 April 2012).
56. Saaty, T.L. A scaling method for priorities in hierarchical structures. *J. Math. Psychol.* **1977**, *15*, 234–281. [CrossRef]
57. Saaty, T.L. How to make a decision: The analytic hierarchy process. *Eur. J. Oper. Res.* **1990**, *48*, 9–26. [CrossRef]
58. Boroushaki, S.; Malczewski, J. Implementing an extension of the analytical hierarchy process using ordered weighted averaging operators with fuzzy quantifiers in ArcGIS. *Comput. Geosci.* **2008**, *34*, 399–410. [CrossRef]
59. Buckley, J.J. Fuzzy hierarchical analysis. *Fuzzy Sets Syst.* **1985**, *17*, 233–247. [CrossRef]
60. Malczewski, J. *GIS and Multicriteria Decision Analysis*; John Wiley & Sons: New York, NY, USA, 1999.
61. Buckley, J.J.; Feuring, T.; Hayashi, Y. Fuzzy hierarchical analysis revisited. *Eur. J. Oper. Res.* **2001**, *129*, 48–64. [CrossRef]
62. Gordon, C.; Cindy, W. A note on the analysis of subjective judgment matrices. *J. Math. Psychol.* **1985**, *29*, 387–405.
63. Barzilai, J. Deriving weights from pairwise comparison matrices. *J. Oper. Res. Soc.* **1997**, *48*, 1226–1232. [CrossRef]
64. Osman, T.; Arima, T.; Divigalpitiya, P. Dynamism generated by alternative use of space in the unplanned settlements of Greater Cairo Metropolitan Region. In Proceedings of the 2013 International Symposium on City Planning, Sendai, Japan, 23 August 2013.
65. General Organization of Physical Planning (GOPP). *Project of Development Plans for Egyptian Villages*; Ministry of Housing: Cairo, Egypt, 2005.
66. General Organization of Physical Planning (GOPP). *The National Urban Development Plans in the Arab Republic of Egypt, Ministry of Housing*; GOPP: Cairo, Egypt, 2009.

67. Osman, T.; Divigalpitiya, P.; Arima, T. Driving Factors of Urban Sprawl in Giza Governorate of the Greater Cairo Metropolitan Region Using a Logistic Regression Model. *Int. J. Urban Sci.* **2016**. in press. [CrossRef]
68. Marc, A. Why landscapes of the past are important for the future. *Landsc. Urban Plan.* **2005**, *70*, 21–34.
69. Hersperger, A.M.; Burgi, M. Driving forces of landscape change in the urbanizing Limmat valley, Switzerland. In *Modelling Land-Use Change*; Koomen, E., Stillwell, J., Bakema, A., Scholten, H.J., Eds.; Springer Netherlands: Berlin, Germany, 2007; pp. 45–60.