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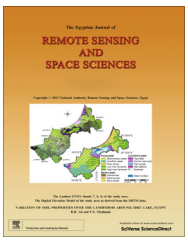

RESEARCH PAPER

A GIS-based approach to breakdown the TeleDensity indicator and estimate the occupied fixed lines at different administrative levels: A case study in Alexandria Governorate, Egypt

Hesham A. Baraka [a,*], Mohamed H. Elwany [b], Islam H. EL-Gamily [a], Hamdy I. EL-Gamily [c,d]

[a] *National Telecom Regulatory Authority, Egypt*
[b] *Faculty of Engineering, Alexandria University, Egypt*
[c] *National Authority for Remote Sensing and Space Sciences, Egypt*
[d] *Kuwait Institute for Scientific Research, KISR, Kuwait*

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Abstract TeleDensity is a very important tool to show the trend of economic development at the country level. There is a big gap in the value of TeleDensity between the Least Developed Countries and developed countries. In general, TeleDensity is usually measured at the National level. The calculated TeleDensity value of Egypt in 2010 is more than the world average value and less than the average value of Europe.

This study aims at introducing a new approach to breakdown TeleDensity from the National to Sector level, and estimates the occupied fixed lines (OFL) at both Sector and Shiyakha levels.

Alexandria Governorate that is located at the northern coast of Egypt was selected as a case study in this research. Detailed analysis was applied at the Shiyakha level inside the El-Montazah sector. The proposed GIS-based approach is used to project the Exchanges and their spatial coverage extent at the Shiyakha level. TeleDensity was calculated at the Governorate and Sector levels. The resultant TeleDensity was used to estimate the OFL at the Sector and Shiyakha levels.

The results indicated that the TeleDensity of Alexandria Governorate (24.1%) is considered among the highest values, whereas El-Fayoum Governorate is considered as having the lowest

* Corresponding author. Address Tel.: +20 1006042190; fax: +20 235344155.
E-mail address: hbaraka@tra.gov.eg (H.A. Baraka).

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TeleDensity value in Egypt. In general, the lowest TeleDensity values were observed at the Governorates of Upper Egypt. It is noticed that the highest OFL values were concentrated on the northern sectors of the Alexandria Governorate study area. It is concluded that the GIS plays an important role in visualizing and analyzing the telecom infrastructure.

1. Introduction

Telecommunications is considered as one of the most capital-intensive industries worldwide. The development of an effective telecommunications infrastructure is considered one of the main prerequisites of economic integration in modern society (Mbarika et al., 2003). Such a modern, reliable and expanded telecommunications infrastructure is a driving force to the promotion of a variety of economic activities (World Bank, 1991; Uysal, 2010). TeleDensity refers to the number of main telephone lines per hundred inhabitants (Gille, 1986; Mbarika et al., 2001, 2003; Fernandez-Maklonado, 2009; ITU, 2010). According to the International Telecommunications Union ITU (1994), national TeleDensity refers to the relationship between the population and the number of main telephone lines in the country. Data from the ITU helped conclude that the average TeleDensity of the Least Developed Countries (LDCs) is 0.29%, which means less than one telephone line for 300 inhabitants. It also indicated that the average of the world TeleDensity indicator is 11.57%. Mbarika et al. (2001) indicated that there is a great difference between the level of TeleDensity of LDCs and that of developed countries. The total number in the 48 LDCs is about 1.5 million lines. It represents about 1% of the total telephone main lines in the USA (Rorissa, 1999).

There is a close relationship between TeleDensity and both of GDP per capita (Mbarika et al., 2003; Saunders et al., 1994) and number of technical telecommunications staff in developing countries (Mbarika et al., 2003). Also, they prove a weak relationship between the level of telecommunications infrastructure investment and TeleDensity.

Negash and Patala (2006), concluded that economically developing countries (EDCs) spending large proportions of their budget on telecommunications investments but are not reaching the needed critical mass to encourage economic development. So, they proposed to change the framework from

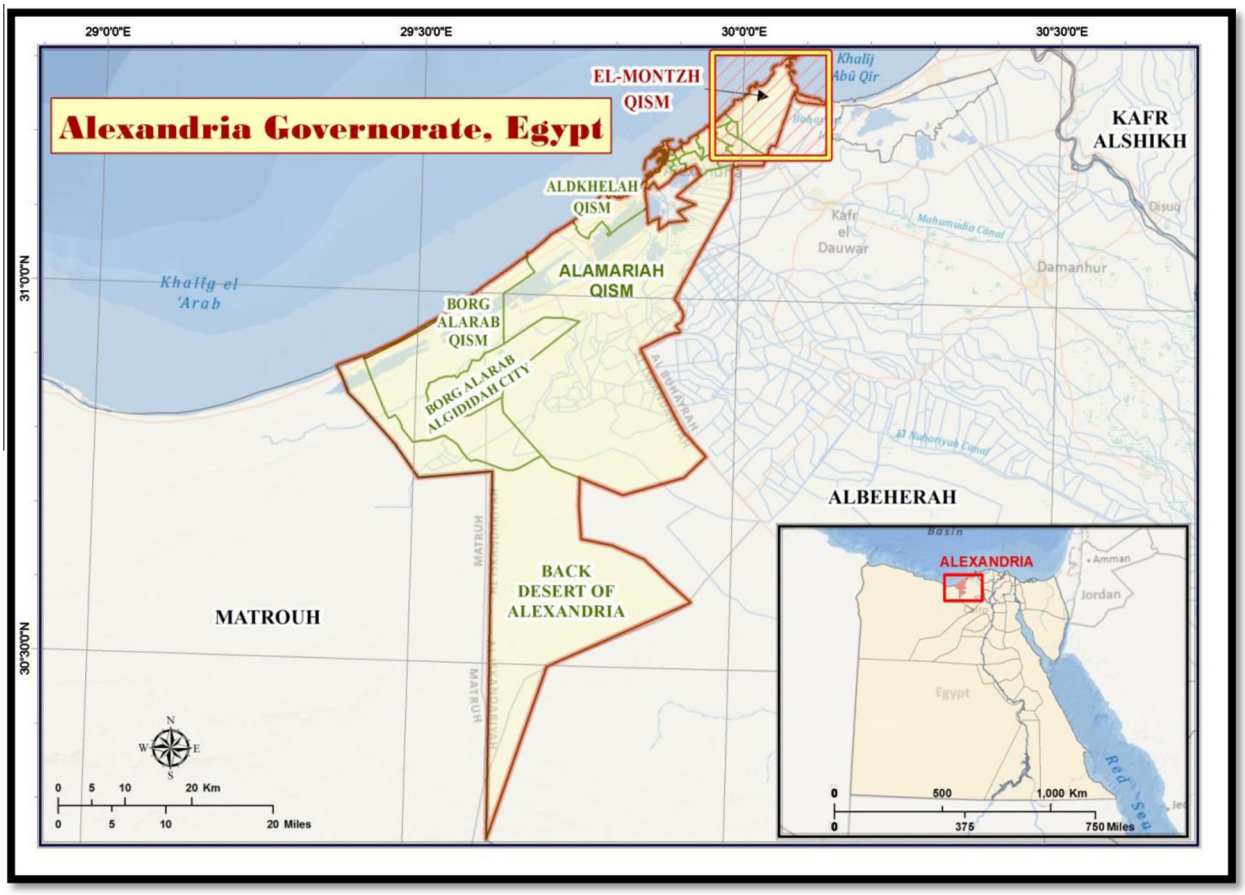

Figure 1 Alexandria Governorate study area, Egypt.

individual focus into community focus to push the economic development in EDCs.

The study aims at linking or combining the telecom data such as free telephone lines, occupied fixed lines (commercial, Governmental, household), total capacity of fixed lines, numbering, and waiting lists of each exchange with the administrative boundaries *Geospatial data* to create spatial relationships between them with emphasis on the occupied fixed lines. This study also addresses the idea of spatial representation of Exchanges at the geometric center (*Centroid*) at the third administrative boundary level (Shiyakha) and not necessarily at the exact location of these Exchanges.

In this context, and based on the ITU main indicators list, the telecom indicators are currently calculated only at the country level using the following equation (ITU, 1994):

$$\text{TeleDensity} = \frac{\text{Total occupied fixed lines}}{\text{Total population}} \times 100 \quad (1)$$

The TeleDensity indicator is being used to determine the fixed network services in each country compared to other countries.

2. The statement of the problem

The TeleDensity indicator will not help decision makers in preparing the National Telecom detailed Plan, since this indicator is calculated at the overall country level. For planning purposes, we need to breakdown this indicator to the second administrative level (Sector). The Egyptian Administrative boundary level system is divided into three main levels as follows:

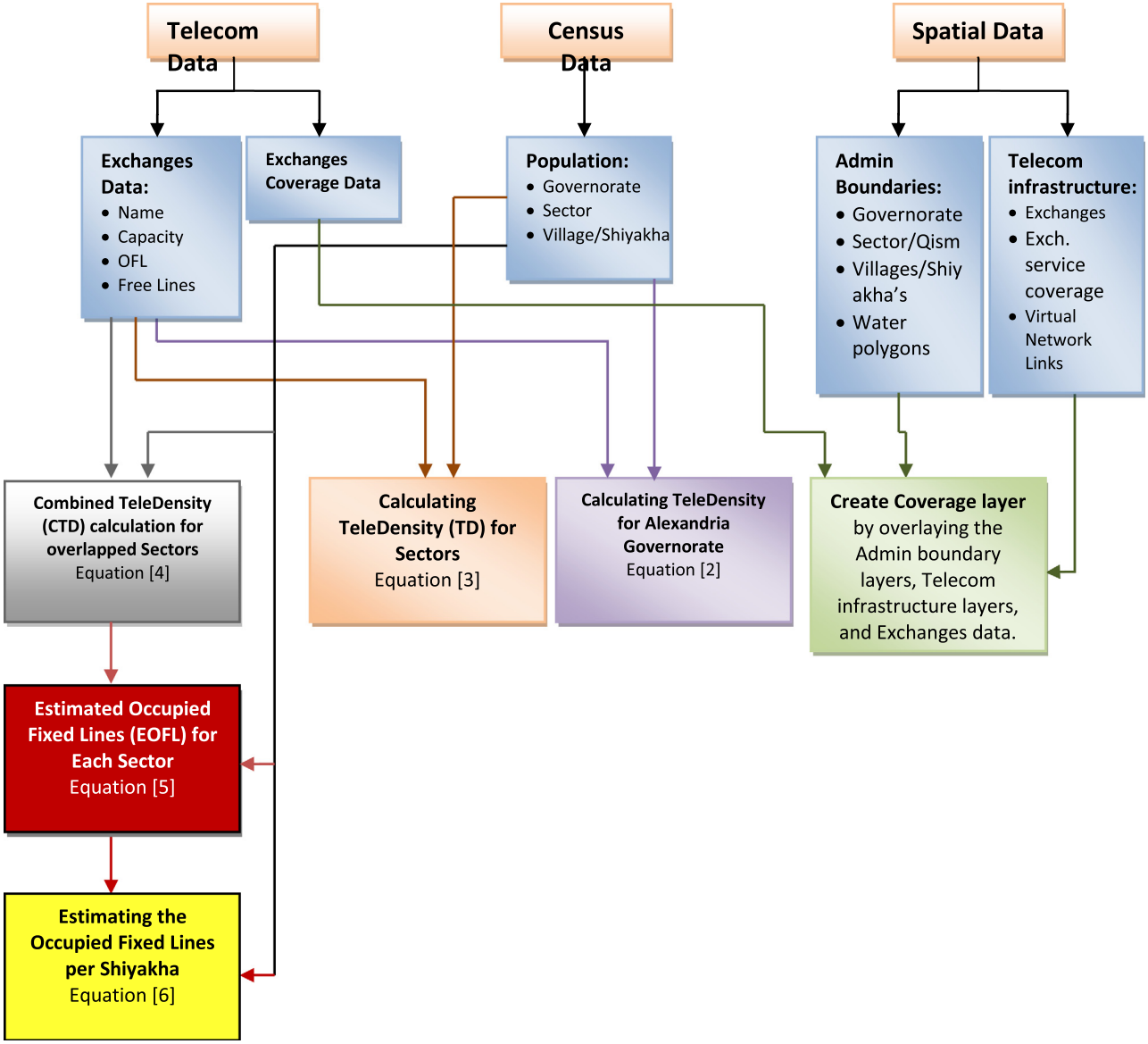

Figure 2 The conceptual process diagram of the breakdown of TeleDensity indicator and estimation of the OFL at the different administrative levels.

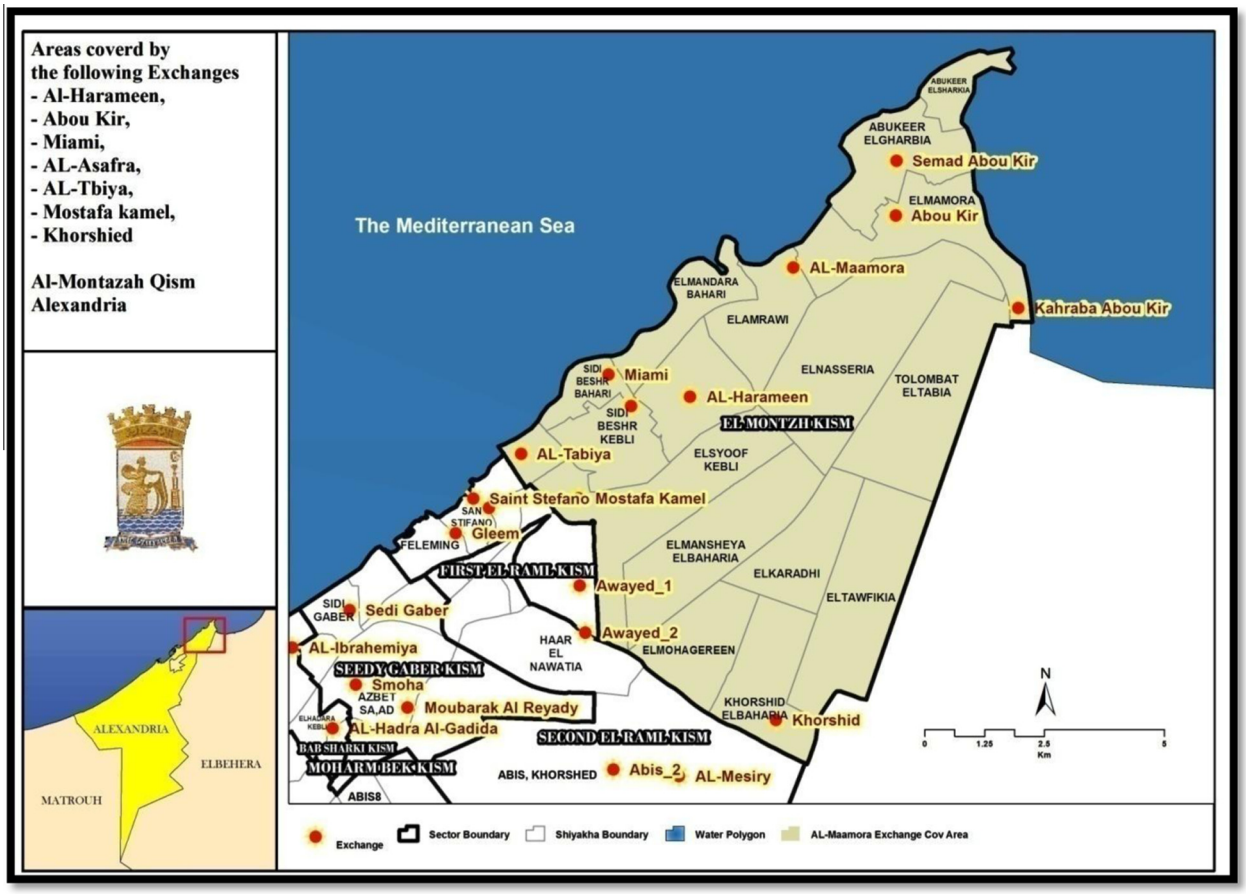

Figure 3 The projected spatial distribution of Exchanges in the EL-Montazah sector, and the spatial extent coverage of AL-Maamora Exchange.

1. *(1st Level):* Governorate;
2. *(2nd Level):* Sector (Qism); and
3. *(3rd Level):* Shiyakha/City/Village.

To calculate and map the occupied fixed telephone lines (OFL) at the Shiyakha level, we need first to determine the spatial coverage of each Exchange. The problem raised in this regard is that there is a coverage overlap, i.e. one Exchange may cover more than one Shiyakha in two or more different sectors. Also, the absence of TeleDensity at the Sector Administrative boundary level is one of the main obstacles to calculate the OFL at the Shiyakha level.

2.1. Objectives

The main objectives of this study are to:

1. Project the spatial location of Exchanges at the Shiyakha Administrative level.
2. Create the Exchanges' coverage layer for the fixed telecom services at the Shiyakha level.
3. Utilize the GIS capabilities to breakdown the TeleDensity indicator value from the country (national) level down to the Sector level, and estimate the OFL at both Sector and Shiyakha levels.

2.2. Study area

Alexandria Governorate is selected as the study area in this research (Figure 1). The El-Montazah sector is selected to apply the proposed approach at the Shiyakha level. This sector is considered the biggest sector in terms of population. Alexandria Governorate is located at the northern coast of Egypt, lying between 29° 23′ 55.336″ **E**, 30° 15′ 24.005″ **N** and 30° 7′ 40.108″ **E**, 31° 19′ 59.229″ **N**. It is considered the second largest city in Egypt, with a population of approximately 4.4 million (CAPMAS, 2012), extending about 32 km along the coast of the Mediterranean Sea in the north central part of the country, and it is one of the oldest resorts in Egypt. In addition, Alexandria Governorate is the largest Egyptian seaport, serving approximately 80% (CAPMAS, 2012) of Egypt's imports and exports. It is also divided into 19 sectors (second administrative level), and 145 Shiyakha (third administrative level) (CAPMAS, 2012).

3. Materials and methods

The TeleDensity indicator is usually calculated at the National level to compare the fixed telecom services between countries. So, it cannot help decision makers to prepare the National Telecom detailed plan down to the lowest administrative level.

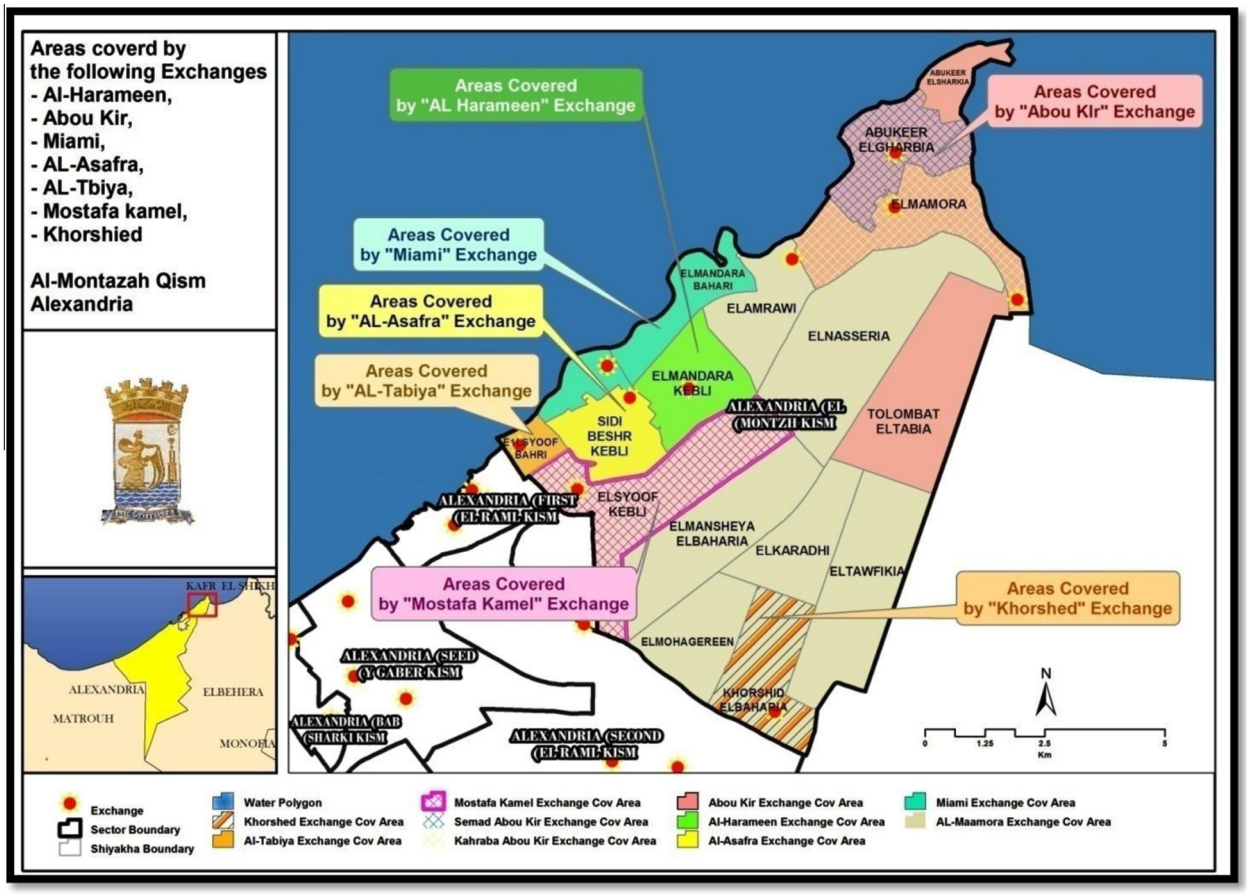

Figure 4 Exchanges' overlapped spatial coverage at the Shiyakha Administrative level at the EL-Montazah sector.

This study addresses a new approach to breakdown and recalculates the TeleDensity indicator at both the Governorate and the Sector (Qism) Administrative levels based on the national TeleDensity indicator. Accordingly, the OFL at both the Sector and Shiyakha Administrative levels will be estimated based on the calculated TeleDensity indicator at the Sector (Qism) level.

3.1. Data collection

The data used in this study include a combination of telecom attribute data, spatial data, and census data. The telecom data are processed and managed as GIS attributes with the relevant GIS layers. The administrative boundaries data are already available while the telecom infrastructure GIS layers are created and used in this study.

3.1.1. Telecom tabular data

- Exchange name, code, and address;
- Governorate name, Sector (Qism) name, and Shiyakha/City/Village names of each Exchange;
- Exchange total capacity;
- Exchange free lines;
- Exchange OFL; and
- Exchange coverage area.

3.1.2. Spatial (Geographic) data

- Administrative boundaries layers:
  - Governorate;
  - Sector/Qism;
  - Shiyakha/City/Village; and
  - Landmarks.
- Telecom infrastructure layers:
  - Exchanges' locations in Alexandria Governorate; and
  - Coverage layer for all Exchanges in Alexandria at the third administrative level.

3.1.3. Census data

- Census data of 2010 produced by CAPMAS at the three administrative levels:
  - Governorate;
  - Sector (Qism); and
  - Shiyakha/City/Village.

3.1.4. Software

The ArcGIS desktop Version 10.0 is used to perform the following functions and analyses:

Table 1 The calculated TeleDensity indicators at the Governorate level based on CAPMAS and Telecom Egypt data of 2010.

Governorate	Population (CAPMAS, 2010)	Occupied fixed lines (Telecom Egypt, 2010)	TeleDensity (%)
El-Fayoum	2,721,478	133,266	4.90
Elmenia	4,481,879	222,771	5.00
Bani Swif	2,470,960	140,479	5.70
Asyuit	3,701,392	234,863	6.30
Qina	2,679,527	182,652	6.80
Suhaj	4,004,613	291,344	7.30
El-Behira	5,071,346	380,717	7.50
Luxor	1,014,587	80,400	7.90
6^{th} of October	2,780,921	242,980	8.70
North Sinai	374,071	33,336	8.90
Aswan	1,258,882	119,667	9.50
Kafr El-Sheikh	2,798,942	267,389	9.60
Matrouh	352,885	38,832	11.00
Ismailia	1,029,136	115,425	11.20
El-Sharqia	5,736,644	643,507	11.20
El-Monoufia	3,496,380	411,080	11.80
El-Qalyoubia	4,546,564	570,036	12.50
El-Gharbia	4,262,200	568,106	13.30
El-Dakahlia	5,338,831	743,389	13.90
South Sinai	154,941	22,315	14.40
El-Suez	549,759	90,100	16.40
Red Sea	306,722	51,890	16.90
El-Wadi El-Gadid	199,810	33,801	16.90
Domietta	1,180,991	208,369	17.60
Portsaied	604,451	138,592	22.90
Alexandria	4,362,168	1,049,073	24.10
Cairo	7,137,218	1,839,474	25.80
Helwan	1,831,505	483,089	26.40
El-Giza	3,326,444	886,559	26.70
TOTAL	77,775,247	10,223,501	13.10

Note: Data used here are not necessarily representing the exact figures of both telecom and Census data. However, they are only representing the distribution pattern of telecom and Census data as a proof of concept of the TeleDensity calculation technique.

- Overlay and proximity analysis (spatial relationship).
- Create, manage, and organize the spatial and non-spatial datasets (telecom infrastructure, and Census data).
- Using the analytical tools to calculate the TeleDensity value at the Sector level in Alexandria Governorate.
- Estimating the OFL at the Sector level and in detail at the Shiyakha level of the EL-Montazah sector using the spatial relationship between the administrative boundary layer, census data, and telecom data.

3.2. Methodology

The GIS technology is a powerful tool to study and mange the telecom infrastructure. It is mainly used in this study to project the Exchanges at the Shiyakha level, calculate the TeleDensity indicator at both the Governorate and the Sector (Qism) levels, and estimate the OFL at the Sector and Shiyakha levels.

3.2.1. Projecting Exchanges at the Shiyakha level

The projection of Exchanges at the Shiyakha level is one of the main steps toward the calculation of the TeleDensity indicator at the different administrative levels. The telecom attribute data are used to locate the Exchanges by using the available addresses and landmarks. However, there are missed addresses for some Exchanges at the Shiyakha level. To solve this issue in this study, the location of those exchanges is projected at the center of the geometric polygon (Centroid) that represents the spatial extent of the Shiyakha. This step is necessary to estimate the OFL at the Sector and Shiyakha levels.

3.2.2. Exchanges' coverage Areas

They are mapped out based on the locations of the known and projected Exchanges. During the mapping out of the Exchanges' coverage areas, the possible spatial relationships between the Exchanges and the related covered areas are:

- *One-to-one and many-to-one relationship:* it means that one or more Exchanges cover a specific Shiyakha only; and
- *One-to-many relationship:* it means that a certain Exchange covers more than one Shiyakha. These covered Shiyakha could be belonging to one or more sectors. In case that they are belonging to one sector, then there is no problem to estimate the OFL at the Shiyakha level inside this Sector similar to the one-to-one and many-to-one cases. However, if the Exchange serves more than one Shiyakha in two or more different sectors, then these sectors should be treated as one unit (combined sectors) to calculate the Combined TeleDensity (CTD) for that group of sectors. Consequently, the CTD will be used to estimate the OFL at the Shiyakha level in the combined sectors. Similarly, the CTD can be used to estimate the OFL at the Sector level as well.

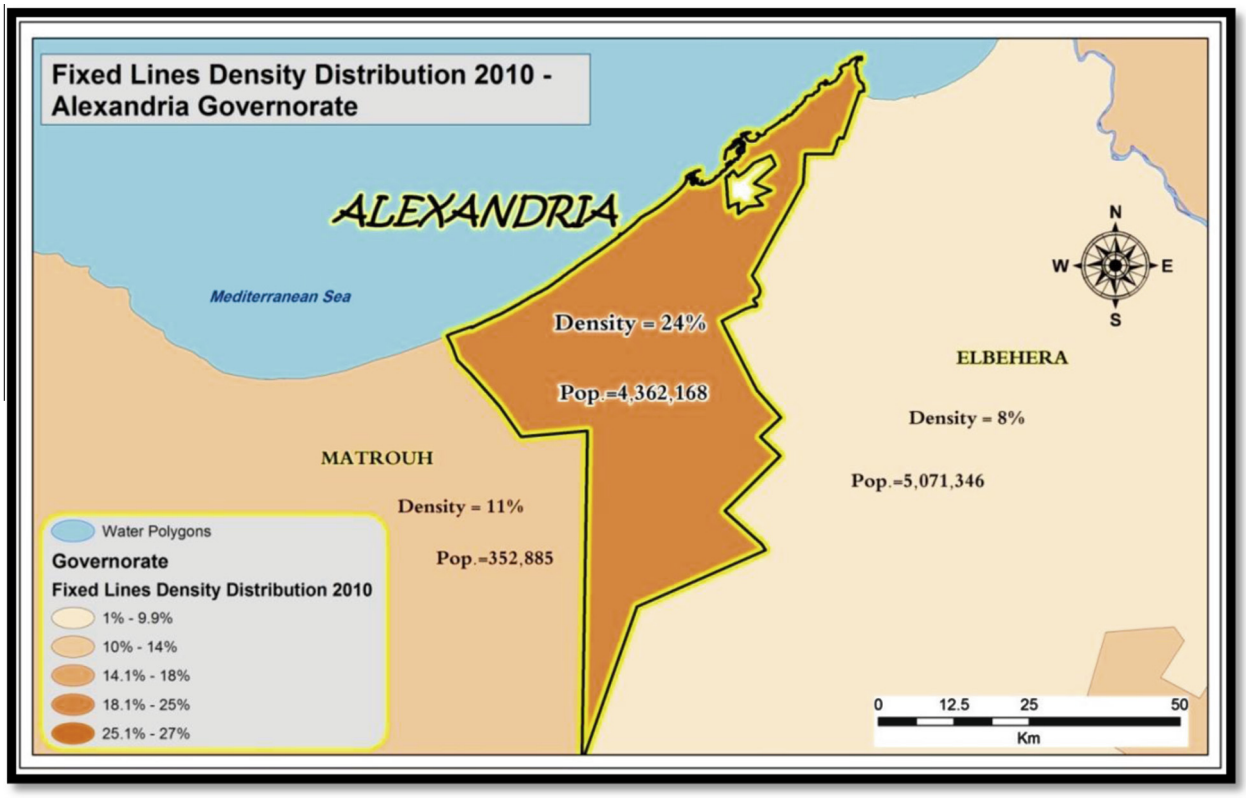

Figure 5 The TeleDensity indicator on the Alexandria Governorate, and its adjacent Governorates using, telecom data (Telecom Egypt data of 2010), and Census data (CAPMAS data of 2010).

3.2.3. TeleDensity breakdown

The breakdown of the TeleDensity from National level to the second administrative level (Sector) is used to estimate the OFL at the Shiyakha level. The TeleDensity indicator at the Alexandria Governorate is calculated using Eq. (1) as follows:

$$\text{TD(Alex.Gov.)} = \frac{\text{OFL(Gov.)}}{\text{Pop(Gov.)}} \times 100 \tag{2}$$

where TD = TeleDensity indicator, OFL = occupied fixed lines, Pop = population.

Similarly, the TeleDensity indicator at the Sector (Qism) level is calculated as follows:

1. **One-to-one and many-to-one relationship:** It means that, one or more Exchanges serving only one sector (Qism). The TeleDensity per sector is calculated as follows:

$$\text{TD(Sector)} = \frac{\text{OFL(Sector)}}{\text{Pop(Sector)}} \times 100 \tag{3}$$

1. **One-to-many relationship:** It means that, one Exchange may serve two or more Shiyakha on two or more sectors (Qism) resulting in the CTD at the Sector level. It is calculated as follows:

$$\text{CTD(Sector 1} + \text{Sector 2} + \cdots \text{Sector } n) = \frac{\Sigma(\text{OFL 1} + \text{OFL 2} + \cdots \text{OFL } n)}{\Sigma(\text{Pop 1} + \text{Pop 2} + \cdots \textit{Pop } n)} \times 100 \tag{4}$$

where CTD is the Combined TeleDensity indicator, OFL n is the occupied fixed lines in sector number (n) and Pop n is the population number in sector number (n).

3.2.4. Estimating the OFL at the Sector level (one-to-many relationship)

The OFL for each sector that belongs to combined sectors (one-to-many relationship) is estimated based on the result of the CTD in Eq. (4) as follows:

$$\text{Estimated OFL(Sector } n) = \text{CTD(Sector 1} + \text{Sector 2} + \cdots \text{Sector } n) \times \text{Pop(Sector } n) \tag{5}$$

where Estimated OFL (Sector n) = estimated occupied fixed lines in sector number (n).

Similarly, the OFL at the Shiyakha level is estimated based on the result of the calculated or estimated TeleDensity values at the Sector level as follows:

$$\text{Estimated OFL(Shiyakha)} = \text{TD(Sector)} \times \text{Pop(Shiyakha)} = \text{CTD(Sector)} \times \text{Pop(Shiyakha)} \tag{6}$$

where TD represents the calculated TeleDensity at the Sector level (Eq. (3)); and CTD represents the Combined TeleDensity at the Sector level (Eq. (4)).

Figure 2 illustrates the process diagram that used to achieve the different objectives of this study.

Table 2 The calculated TeleDensity at the Sector level.

Gov. name	Sector (Qism)_Name	No. of (Shiyakha)	No. of Exchan ges	Total occupied fixed lines	Pop_Sector (2010)	calculated *TeleDensity* per sector (%)	Type of coverage
Alexandria	Second El Raml	1	2	4779	393,656	1	Non-Overlapped
	Borg El Arab	4	4	7602	98,678	8	
	Madinet Borg EL-Arab EL-Gedida	1	1	8329	41,661	20	
	El Amaria	10	16	53,565	519,767	10	
	El Monatzah	17	10	380,261	1,241,631	30.63	
	El Dkhela	5	7	130,560	363,705	36	
	First El Raml	4	5	181,817	402,190	45	
	Seedy Gaber	6	3	136,202	239,381	57	
	El Sahil Elshamaly – part	1	4	5901	2702	218	
					Pop_Sector (2010)	Combined_Pop Sector_2010	Combined TeleDensity (%)
Alexandria	Mina El Bassl	17	1	30,403	269,720	396,720	7.664	Overlapped
	Krmoz				127,000		
	Moharm Bek	6	5	66,221	316,702	506,817	13.066	
	Bab Sharki				190,115		
	El Lban	3	2	62,202	38,874	81,825	76.018	
	El Atarin				42,951		
	El Manshia	1	1	60,080	24,981	115,096	52.20	
	El Gomrok				90,115		

4. Results and discussions

Figure 3 illustrates the projected locations of different Exchanges in the EL-Montazah sector. Some of these Exchanges such as Al-Maamora, Sidi Beshr Bahari, Sidi Beshr Kebli, and Khorshid Exchanges are located at their exact locations. However, some other Exchanges such as AbuKeer ELGharbiya, and AL-Harameen are projected at the geometric center of Shiyakha polygons (Centroid). As an exceptional case in the EL-Montazah sector, Al-Maamora Exchange serves the whole area of this sector. This may be due to the high capacity of this Exchange compared to other Exchanges serving this sector.

4.1. The Exchanges' coverage areas in the El-Montazah sector

The telecom coverage raw data were processed and manipulated to create an attribute data table that linked with the lowest administrative boundary layer at the EL-Montazah sector, to produce the Exchanges' coverage layer at the Shiyakha level. Figure 4 illustrates Exchanges' coverage areas in the EL-Montazah sector. The mapping of the covered areas was carried out based on one-to-one and many-to-one relationships (i.e. an Exchange or more cover only one Shiyakha) at the same sector. EL-Harameen Exchange covers EL-Mandara Kebli Shiyakha only (one-to-one relationship) and Mostafa Kamel and AL-Maamora Exchanges cover ElSyoof Kebli shiyakha (many-to-one relationship) (Figure 3). However, the one-to-many relationship (i.e. an Exchange covers more than one Shiyakha) in two or more different sectors is not existed in this case.

4.2. TeleDensity breakdown from national level to Sector level

The Telecom Egypt data of (2010) in terms of total OFL and the census data in terms of total population of (2010) are processed and manipulated to calculate the TeleDensity indicator of Egypt as follows:

$$\text{TeleDensity(Egypt)} = \frac{\text{OFL(Egypt)}}{\text{Pop(Egypt)}} \times 100 = \frac{10,223,501}{77,775,247} \times 100 = 13.1\%$$

According to Mbarika et al. (2001), the calculated TeleDensity of Egypt (13.1%) is considered to be higher than the world average TeleDensity value (11.57%), and less than the European TeleDensity value (31.95%).

The TeleDensity figure at the National level is calculated at the Governorate level using Eq. (2) as follows:

$$\text{TD(Alex. Gov.)} = \frac{\text{OFL(Alex. Gov.)}}{\text{Pop(Alex. Gov.)}} \times 100 = \frac{1,049,073}{4,362,168} \times 100 = 24.1\%$$

Table 1 lists the TeleDensity indicator for the Governorates of Egypt. The TeleDensity indicator at the Governorate level was calculated given the fact that the Exchanges within a certain Governorate serve only this specific Governorate (Table 1). Figure 5 shows the TeleDensity indicator value of Alexandria Governorate (24.1%) and its adjacent Governorates. This indicates that the TeleDensity of Alexandria

Table 3 The estimated OFL per sector using the calculated CTD at the Sector level.

Sector (Qism) Name	Total No. of (Shiyakha)	Total No. of Exchanges	Total OFL	Pop_Sector (2010)	Combined TD (Sector) (%)	Estimated OFL (Sector)
Mina El Bassl	17	1	30,403	269,720	7.664	20,670
Krmoz				127,000		9,733
Moharm Bek	6	5	66,221	316,702	13.066	41,381
Bab Sharki				190,115		24,841
El Lban	3	2	62,202	38,874	76.018	29,551
El Atarin				42,951		32,651
El Manshia	1	1	60,080	24,981	52.20	13,040
El Gomrok				90,115		47,040

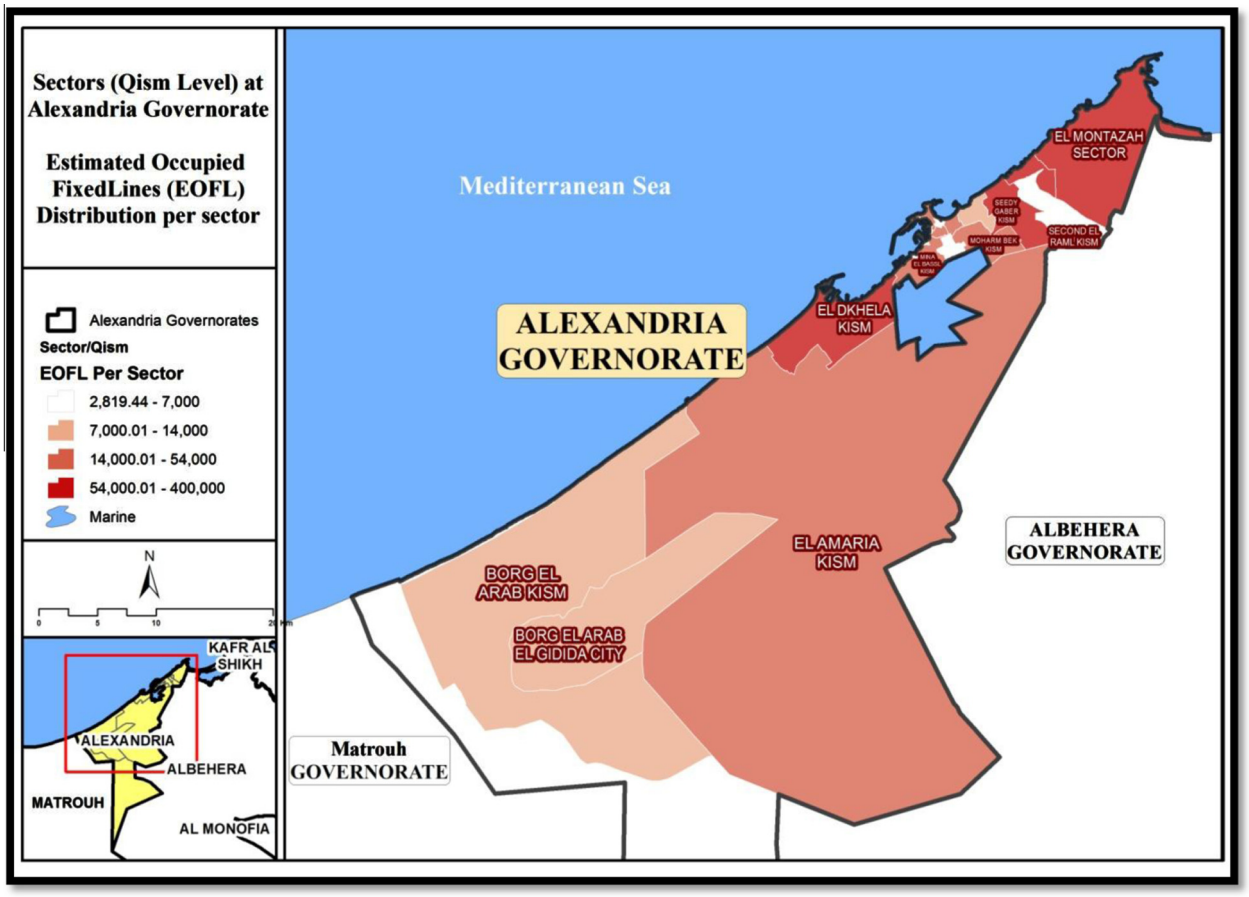

Figure 6 Color coded representation of the estimated OFL at the Sector (Qism) level.

Governorate is considered to be of the highest value when compared with the rest of the Egyptian Governorates. Table 1 indicates that the highest TeleDensity value is found in El-Giza Governorate (26.7%), whereas the lowest value is found in El-Fayoum Governorate (4.9%). In general, the lowest TeleDensity values are concentrated in the Upper Egypt Governorates.

The calculation of the TeleDensity indicator at the Sector level inside the Alexandria Governorate was carried out using Eqs. (3) and (4). Eq. (3) is only used to calculate the TeleDensity of the sectors that belong to the one-to-one and many-to-one relationships. Eq. (4) is used to estimate the TeleDensity at the Sector level where Exchange may serve more than one Shiyakha in two or more different sectors (one-to-many relationship).

Table 2 illustrates the results of the calculated TeleDensity indicator at the Sector level. Unlike the fixed telecom services coverage of the Governorate, the fixed telecom services coverage of the sectors was divided into two cases, the one-to-one coverage (non-overlapped), and the one-to-many coverage (overlapped). The former case illustrates that each sector is totally covered by its Exchanges without overlapping with other sectors. This enabled us to calculate the TeleDensity for each sector individually, where the latter case illustrates that more than one sector is covered by the same Exchanges, i.e. there is a coverage overlapping with other sectors. In this case, the CTD is calculated for these sectors using Eq. (4) (Table 2).

It was noticed that the breaking down of the TeleDensity indicator of Alexandria Governorate (24.1%) at the Sector

Table 4 The estimated OFL at the Shiyakha level using the calculated TeleDensity of the EL-Montazah sector.

Gov_Name	Sector_Name	3rd Admin level (Shiykha)	Shiyakha_Pop	Sector_TeleDensity (%)	Estimated OFL_Per Shiyakha
Alexandria	AL-Montazah	Eltawfikia	12,902	30.63	3952
		Elsyoof Bahri	47,825		14,649
		Elsyoof Kebli	171,840		52,635
		Elamrawi	33,433		10,241
		ELkerdahi	9131		2797
		Elmamora	46,747		14,319
		Elmandara Bahari	63,433		19,430
		Elmandara Kebli	285,043		87,309
		Elmansheya Elbaharia	59,654		18,272
		Elmohagereen	41,604		12,743
		Elnasseria	13,082		4007
		Abukeer Elsharkia	16,064		4920
		Abukeer Elgharbia	26,998		8269
		Khorshid Elbaharia	83,431		25,555
		Sidi Beshr Bahari	60,008		18,380
		Sidi Beshr Kebli	266,234		81,547
		Tolombat Eltabia	15,046		4609

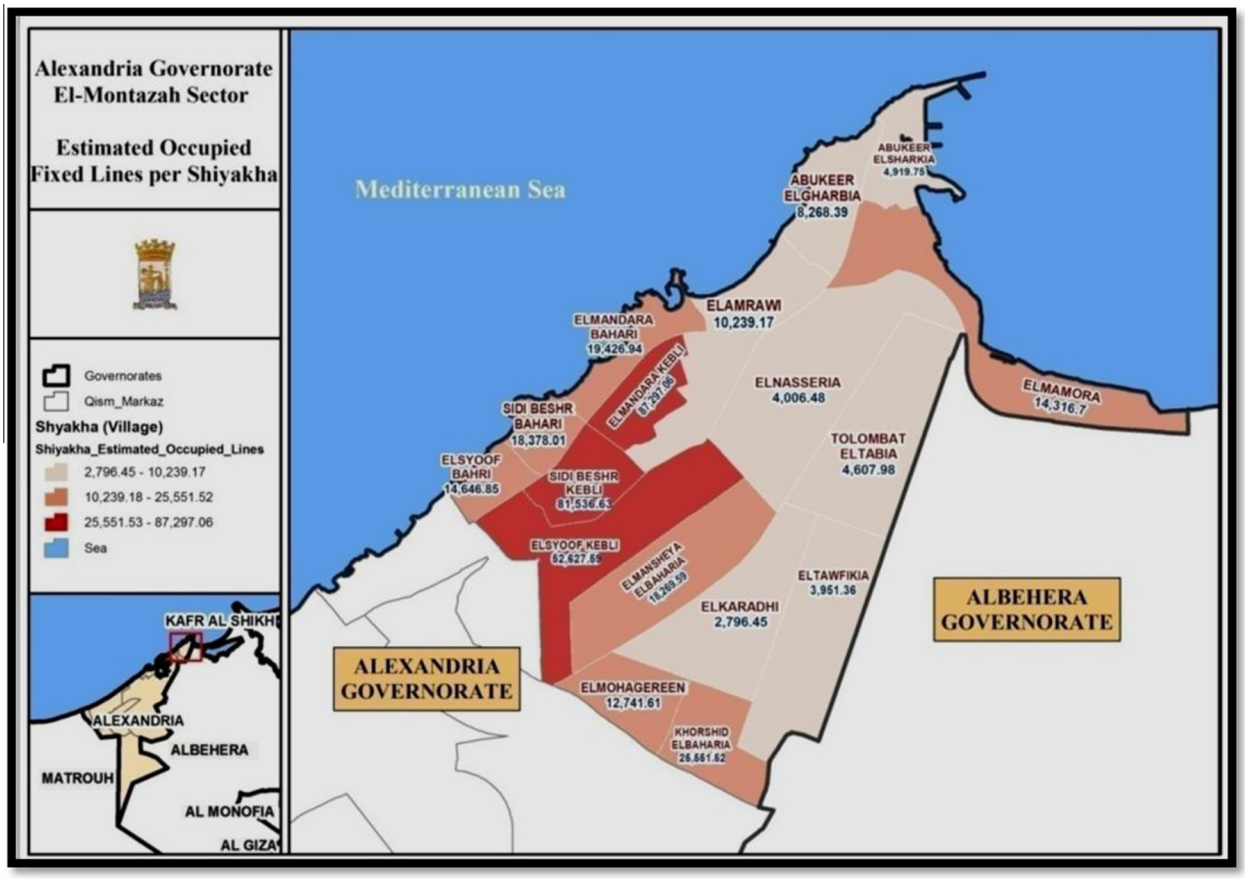

Figure 7 Color coded representation of the estimated occupied fixed lines (EOFL) per Shiyakha.

level resulted in TeleDensity values varying from 1% (Second El-Raml sector) to 218% (EL Sahil ELshamaly – part sector). The abnormally high TeleDensity value in El Sahil Elshamaly – part (218%) might be due to the fact that this sector is considered one of the important summer resorts in Egypt. It is usually inhabited by high class families, which most probably own more than one telephone line per household.

4.3. The estimated occupied fixed lines at Sector and Shiyakha levels

Table 3 illustrates the estimated OFL for each sector using the calculated CTD indicator that belongs to the one-to-many relationship (overlapped sectors) using Eq. (5). The result of the estimated OFL at the Sector level in Table 3 is processed

and manipulated using the GIS layout technique to produce the color coded representation of the estimated OFL at the Sector level in Alexandria Governorate. The dark red represents the highest estimated OFL values, whereas, the light red represents the lowest estimated value. It appears clearly from Figure 6 that the highest estimated OFL value is concentrated at the northern sectors of Alexandria Governorate. This might be due to the high population, and urbanization density on these sectors.

The calculated and estimated TeleDensity indicator values (Table 2) at the Sector level are used to estimate the OFL at the Shiyakha level using Eq. (6). During the calculation of the estimated OFL at the Shiyakha level, we assumed that the TeleDensity of any Shiyakha inside the EL-Montazah sector is equal to 30.63% (same as the TeleDensity of EL-Montazah sector). The estimated OFL at the Shiyakha level in the EL-Montazah sector is listed in Table 4. It illustrates that the highest number of the estimated OFL is found in Elmandara Kebli Shiyakha. Whereas, the lowest number of the estimated OFL is observed in ELkerdahi shiyakha. In general, Figure 7 illustrates the color representation of the estimated OFL at the Shiyakha level in the EL-Montazah sector where, the dark red color represents the highest estimated OFL values, and the light color represents the lowest values.

It is noticed also that the highest three Shiyakha, in terms of estimated OFL, are adjacent to each other namely, EL-Mandara Kebli, Sedi Beshr Kebli, and ELSyoof Kebli. They also have the highest number of population at the Shiyakha level in the EL-Montazah sector.

5. Conclusion and recommendations

TeleDensity is a very important indicator to measure the trend of economic growth at the National level. It is concluded that the developing countries spend a huge amount of money in the telecom infrastructure without reaching the critical mass needed to enhance, encourage, and accelerate the economic development rate. The proposed GIS-based breakdown approach of the TeleDensity from the National level to the Sector level is crucial in estimating the OFL at both Sector (Qism) and Shiyakha Administrative levels. This will support the decision makers and planners to accurately plan the future spatial distribution and guarantee the equity of distributing the different fixed telecom services down to the lowest administrative levels.

The GIS capabilities are very important to visualize the spatial distribution of different telecom infrastructure and identify the Exchanges' services overlap at different administrative levels. The GIS advanced analytical capabilities are essential also to calculate and represent the spatial distribution of different indicators such as TeleDensity.

It is recommended that the telecom official concerned entities should apply the proposed approach to breakdown the TeleDensity indicator from the National level down to the Sector (Qism) level, and estimate the OFL down to the Shiyakha level all over Egypt.

References

CAPMAS, 2012. Central Agency for Public Mobilization and Statistics. Statistical Yearbook, Egypt. <http://www.hrdiscussion.com/ext.php?ref=http://www.capmas.gov.eg/>.

Fernandez-Maklonado, A. M., 2009. Between market principles and equity concerns – the provision of basic services in cities of Latin America. In: The fourth International Conference of the International Forum on Urbanism, Amsterdam.

Gille, L., 1986. Growth and telecommunications. In: Information, Telecommunications and Development. ITU, Geneva, pp. 25–61.

ITU, 1994. World Telecommunications Development Report. International Telecommunications Union, Geneva.

ITU, 2010. Core ICT Indicators. <http://www.itu.int/dms_pub/itu-d/opb/ind/D-IND-ICT_CORE-2010-PDF-E.pdf>.

Mbarika, V.W., McMullen, P.R., Warren, J., 2001. TeleDensity technological growth strategy for Africa's LDCs: viagra development strategy or sustainable development strategy? The African Telecommunications Stakeholders Speak. In: Proceedings of the 34th Hawaii International Conference on System Sciences – 2001.

Mbarika, V.W., Kah, M.O., Musa, P.F., Meso, P., Warren, J., 2003. Predictors of growth of TeleDensity in developing countries: a focus on middle and low-income countries. The Electronic Journal on Information Systems in Developing Countries 12 (1), 1–16.

Negash, S., Patala, L., 2006. Telecommunication investment in economically developing countries. In: Proceedings of the 2006 Southern Association for Information Systems Conference.

Rorissa, A., 1999. The impact of introduction of electronic communication in Ethiopia: a survey. In: Ethiopian Scientific Society Conference.

Saunders, R.J., Warfbrd, J.I., Welienius, B., 1994. Telecommunications and Economics Development, second ed. John Hopkins University Press, Baltimore, MD.

Uysal, A.H., 2010. ICT Development and Economic Growth: An Analysis of Cointegrating and Causal Relationships with a Panel Data Approach. Master's Thesis in economics of Innovations and Growth, School of Architecture and the Built Environment, Royal Institute of Technology, Sweden.

World Bank, 1991. World Bank Telecommunications Sector Report. World Bank, Washington, DC.