Architecture and Planning Journal (APJ)

Volume 23 | Issue 1
ISSN: 2079-4096

Article 3

March 2015

A GIS-BASED APPROACH FOR AUDITING SUSTAINABLE DEVELOPMENT OF NEW INDUSTRIAL COMMUNITIES: THE CASE OF "NEW BORG ELARAB" CITY, EGYPT

Yasser Fouda
Associate Professor, Department of Architectural Engineering, Faculty of Engineering, Tanta University, Tanta, Egypt, fouday@dataxprs.com.eg

Deena ElKhazendar
Architect, Researcher, Department of Architectural Engineering, Faculty of Engineering, Tanta University, Tanta, Egypt, zizo_deeno@yahoo.com

Keywords: Sustainable development; Decision support systems; Geographic information systems; New industrial communities; Urban indicators

A GIS-BASED APPROACH FOR AUDITING SUSTAINABLE DEVELOPMENT OF NEW INDUSTRIAL COMMUNITIES: THE CASE OF “NEW BORG ELARAB” CITY, EGYPT

Abstract

As till the present time most of the industrial cities in Egypt have not achieved the necessary objectives aimed for them, they need different strategic auditing plans to ensure that the city urban area is developed in a sustainable manner.

Keywords

Sustainable development; Decision support systems; Geographic information systems; New industrial communities; Urban indicators

A GIS-BASED APPROACH FOR AUDITING SUSTAINABLE DEVELOPMENT OF NEW INDUSTRIAL COMMUNITIES: THE CASE OF "NEW BORG ELARAB" CITY, EGYPT

Fouda, Yasser E.[1]
ElKhazendar, Deena M.[2]

Abstract

As till the present time most of the industrial cities in Egypt have not achieved the necessary objectives aimed for them, they need different strategic auditing plans to ensure that the city urban area is developed in a sustainable manner.

The research applies an integrated approach to auditing sustainable development in "New Borg ElArab" City, Egypt. The approach which was erected on a Decision Support Systems (DSS) based on a geographic information system (GIS), involved the evaluation of the sustainable development dimensions addressed by the planning process and land use activities resulting from physical planning and functional activation of the city.

Auditing framework went through identification of vision, analyzing sustainability themes, and finally developed a set of core/sub-indicators which managed to illustrate the city's current and future performance towards sustainability.

Sustainability appraisal results concluded that some aspects of sustainable development were not tackled by the planning process. The planning process addressed economic sustainability issues more than that of social and environmental issues. A set of recommended measures was advanced in the form of main tasks covering all selected indicators outcome to ensure the city strategic master plan success towards sustainable development on both, the long and the short run.

KEYWORDS:

Sustainable development; Decision support systems; Geographic information systems; New industrial communities; Urban indicators

INTRODUCTION

Most of the industrial cities around the world are facing persisting problems, and their difficulties seem to be intensifying. The future seems uncertain and threatening, with the industrial revolution thrust kicking into high gear, and more people were moving into the cities.

Population growth began to expand one year after another and led to enormous environmental deterioration. The impact of urbanization all over the world in terms of mass poverty, major inequality, high unemployment, under employment, over-crowded housing and the proliferation of slum areas and squatters and general deteriorations in overall environmental conditions; all have become the major concerns of policy issues (Perloff: 1980).

The main problem that leads to the decay of metropolitan cities was based on the idea "Economic versus Environmental Protection" as most cities found themselves in a gap between demands for faster economic development and demands for protection of urban environment and natural heritage (Agueda: 2010). Consequently, it can be said that the challenge now is shifted to redirect people to new satellite cities that possess a transit enabling density, a unique, exciting environment, a quality infrastructure, and a settlement pattern that enables sustainable growth (Kriken, Enquist, and Rapaport: 2010).

[1] Associate Professor, Department of Architectural Engineering, Faculty of Engineering, Tanta University, Tanta, Egypt

[2] Architect, Researcher, Department of Architectural Engineering, Faculty of Engineering, Tanta University, Tanta, Egypt

If new satellite cities act like magnet to citizens in metropolitan ones, this will eventually help to guide future population growth. The new city will have to have adequate resources and good quality of life to be able to sustain and attract people. The term "Sustainable Development" is used to bridge the knowledge gap and revitalize these cities to act as magnets to metropolitan ones (Cho et al.: 2000); (Williams: 2000); (Harris: 2007); (Plöger: 2007).

The research aims to develop an appropriate model scenario for industrial communities in Egypt. Other new industrial communities like the "Sixth of October" new city and the "Tenth of Ramadan" new city would benefit from this experience of assessing the extent of urban development and comparing it to the original plans and aims.

"New Borg ElArab City" (A New Industrial City in Egypt) is chosen as an empirical study. The framework criteria is based on the decision support system method (DSS) as the DSS enables the user to view the impacts on different pillars in a view aggregate, for example economic - physical environment - transportation …etc. (Pecham: 1997); (Johnson and Lachman: 2001).

Appropriate sustainability indicators are introduced and are utilized to audit the performance of the city and its trends towards sustainability. Indicators are chosen according to the industrial city characteristics and adaptations, vulnerability, validity and the availability of data (Hart: 2010).

A GIS will assist the decision support system by providing an excellent medium for data integration and a basis for the spatial decision support system. It draws on many sources for input as it captures stores, analyzes, manages, and presents data that refers to or is linked to location and affects many different parts of society (USGS: n.d.); (Federal Geographic Data Committee: 1996).

METHODOLOGY

The study involves three major parts, namely, a theoretical background the illustrates the national and international codes, regulations and ethics of practicing architecture, the second part is a case study that exhibits the alterations and modifications made to the award winning Library of Alexandria. The last part is a thorough analysis of merited values of award winning buildings to draw final conclusions and answer initial research question.

The Library of Alexandria can be considered as a modern heritage resource, since it is listed on Egypt's Tentative List, of the properties that might be nominated for the inscription on the World Heritage List. Consequently, the library's qualities that should be considered while evaluating the appropriateness of the modern alterations made to it should also involve heritage values. Therefore, the analysis of the merited values of the library also involved the analysis of the property's heritage values. To undertake a heritage value analysis, a typology of values was first adopted. The adopted value typology was based on Feilden's typology. According to Feilden's typology, heritage value can be classified into three major groups, which are the emotional values, the cultural values and the functional values. The emotional values might involve values; such as religious values, the identity value, and the respect and veneration values. The cultural values might involve value; such as the architectural value, the historic value, the townscape value, the artistic value, and the newness value. Finally, the functional values might include values; such as the use value, the social value and the political value.[i] The analysis also focused on another influential factor, which are the criteria that might be used to justify the inscription of the Library of Alexandria on the World Heritage List.

PROBLEMS AND DEFECTS OF SUSTAINABILITY ISSUES

Problem background of sustainable development

The onset of the 21st century signalled the birth of the urban era. Half of the world's population now lives in cities, and that number is growing rapidly. This rapid urbanization presents staggering challenges for the region's city governments. Up until now, most cities have not developed in a sustainable way to circumscribe the urban development negative impacts.

Economic development, land use planning, urban infrastructure, sewers, potable water systems, solid waste handling, and transportation systems are all inadequate to meet current needs. To meet this challenge, cities have to be organized and managed as efficiently as possible, from here came the term "Sustainable Development" which is considered to be a primary goal for the achievement of availability of the long-term future needs (Harris: 2007). The concept of sustainable development has been widely accepted as a laudable goal to be achieved by different nations. In order to reach an optimum solution for a sustainable development issue, the final outcome must reflect the tension among three main competing interests: social-equity, economy and the environment. The issues that are addressed by the dimensions of sustainable development are integral parts of human quality of life, ensuring a better quality of life that could be maintained through it, (cGIT: 2007); (AxXiom: 2010).

The context of new industrial communities in Egypt

The origins of the proposition of developing new communities outside the populated areas of Egypt; dates back to the late 1960s. The conception, policy, and related plans and actions of developing of new communities outside the densely populated Nile Valley and its Delta gathered momentum in the second half of the 1970s. The new cities are divided into three generations prioritized by their establishment dates. By going through the literature review for the context of new Egyptian communities, we find that these communities need to be revitalized by auditing the current situation together with its strategic master plan to gauge its sustainable directions, efficiency and success. (Abdel-Kader & ElTouney: 2009); (Helaly: 2006).

Study Area: "New Borg ElArab" Industrial City

New Borg ElArab city will be chosen as a study case, and a conceptual model for the city's sustainability will be developed covering all issues of current and potential concerns to guide its sustainable development on the long and short run. New Borg ElArab is considered the fourth pioneering of the first generation of Egyptian new cities, and was established by the presidential decree 506/1979. The master plan and detailed studies were executed between 1977-1982, by a joint Dutch (ILACO) and Egyptian (Hassan Ismail and partners) consulting groups (Abdel-Kader and ElTouney: 2009); (Helaly: 2006).

The development policies and stipulations included to help in solving Alexandria and Behera governorates congestion, overcrowding, and lack of developable lands, to protect the threatened agricultural land, and to provide a major urban magnet in the region. New Borg ElArab city was planned as an independent satellite city, on the regional coastal road some 60 km to the southwest of Alexandria and about 7-8 km from the Mediterranean coast line, as shown in Figure 1, and on a plateau 30-60 m above sea level, and having location coordinates of 30o51'37"N 29o34'29"E (Abdel-Kader and ElTouney: 2009); (Helaly: 2006).

Figure 1: "New Borg ElArab" industrial city site plan, (Google: 2014).

Characteristics and features for "New Borg ElArab" City

New Borg ElArab city has the following characteristics and features, as shown in Table 1.

Total Surface Area	=	199.50 Square Kilometres (47.5 x 1000 Feddan[1])
Total Urban Mass	=	110.46 Square Kilometres (26.3 x 1000 Feddan)
Residential Areas	=	28.98 Square Kilometres (6.9 x 1000 Feddan)
Non Residential Areas	=	40.74 Square Kilometres (9.7 x 1000 Feddan)
Economic and Industrial Areas	=	26.46 Square Kilometres (6.3 x 1000 Feddan)
Number of Residential Units (by the Year 2022)	=	122,000 units

Table 1: New Borg ElArab city's characteristics and features. (Ministry of Construction and New Housing Communities: 2002)

1 Feddan: A unit of area used in Egypt, and is not an SI unit. In Egypt the Feddan is the only non-metric unit which remained in use following the switch to the metric system.

1 Feddan = 4200 Square Meters (m2) = 24 Carats (175 m2/Carat) = 0.42 Hectares = 1.0378 Acres

- It is comprised of ten residential and five industrial districts, each residential district containing eight to nine neighborhoods.

- The industrial zone of the city has been located to its east and south, downwind, so that it will have no environmental impact on the city.
- The central hub of the city is situated in the heart of the city, in which located and concentrated the main city services: commercial, recreational, administrative … and others.
- The city is planned to absorb 570,000 inhabitants at its fullest extent and provide approximately 160,000 employment opportunities, with 122,000 housing units, by the year 2022.
- It has a mixed economic base comprised of industry, agriculture, services, construction, and tourism.
- The site is characterized by a flexible urban form, with a linear development possibility.
- The city is connected with other cities through:

  - Public transport authority commuter bus lines with Alexandria - Amereya - North Coast.

  - Service cars to Alexandria and Amereya.
- The city is connected locally through buses connecting the industrial and residential zones and city districts.
- 700 million pounds have been planned to be funded to start construction of a railway line to connect the city of New Borg ElArab with Alexandria city (The gate to Egyptian cities: 2002); (M.H.U.U.D.: 2012).
- Population growth of the city could be analyzed briefly in (Table 2) as follows:

New Borg ElArab City	Starting Date	Years of Development	No. of Population x 1000					
	1980	20 Years	1987	1996	2006	Estimated 2012 (By the Ministry of Housing, Utilities, and Urban Development)	Goal/Actual No./ year 2000	2022 Fullest extent
			0.4	7.051	41.661	115 : 120	500	570

Table 2: Population growth of the city (APMS: 2006).

From here we conclude that there is a conflict between the estimated population goals and objectives for New Borg ElArab City in one side, and the current ones in another side, as it was found that about 8.3% of the estimated population has been achieved and the population growth is very slow (The gate to Egyptian cities: 2014); (M.H.U.U.D. : 2012)

METHODOLOGY OF MODELLING SCENARIO

Evolution of sustainable development indicators

Community indicators are not a new concept; they have been introduced since 1910, when the Russell Sage Foundation initiated the development of local surveys for measuring industrial, educational, recreational factors, and others.

The processes used by Sage foundation are similar to those that re-emerged during the 1990s. But the difference today is the use of indicators to consider the full spectrum of a community's well-being, not isolated factors (Al-Shuwaikhat and Aina: 2006). In 1970, indicators of sustainable development were discussed in the environmental economics literature; a renewed form was then formulated in Agenda 21. After the UN guidelines of the conferences held at Rio de Janeiro in 1992, most of the countries in the world adopted the protocol "Agenda 21" which suggests that "indicators of sustainable development should be created in order to ensure a solid base for decision-making on all levels (United Nations: 1993, Ch. 40), (Al-Shuwaikhat and Aina: 2006).

There are many examples for efforts done to characterize and measure sustainable development. The efforts range from global to national to local scales. These are: United Nations Commission on Sustainable Development, Consultative Group on Sustainable Development Indicators, Well-being Index, Environmental Sustainability Index, US Interagency Working Group on Sustainable Development Indicators, Boston Indicators Project, Central Texas, Durban Metro State of the Environment and Development Report. (Atkisson: 2005); (Michigan Government: 2005); (Peck, Peck and Associates, and Dauncey: 2002); (Helsinki City Urban Facts Office: 2007).

Sustainable development indicators: Spatial Dimensions

Increasing number of studies have elaborated on the operation of the principles of sustainable development, especially at the city level, and quite a number of authors have researched aspects of implementing and measuring urban sustainability. Also due to the nature of most development activities (spatially interdependent and hierarchical), the integration of spatial dimension has been explored (Al-Shuwaikhat and Aina: 2006).

For urban planning and development specialties, and since these specialties are often related to spatial manipulation, analysis, and illustration of data, like thematic maps format, it would be most beneficial to include a powerful spatial analytic tool like "Geographic Information Systems" GIS in analyzing these spatial data within the structure of the proposed "Decision Support System" DSS. Spatial analysis of data coverage union, subtraction, subset, buffering, shortest path creation, and many other analytic features, may promote the study precision and reliability to a higher level, with significant assistance to the decision maker clarifying viewing the study issue within different perspectives.

The geographical pattern, scale and spatial hierarchy of developmental processes influence the social, economic and environmental impact of these processes. The integration of spatial dimensions into sustainability auditing through the research has encountered the utilization of geographic information systems (GIS) in assessing the impact of development activities.

GIS has the capability to link location data with attributes and also perform spatial analysis on these data. Thus, and in the research in hand, GIS is an essential tool for evaluating sustainable development. GIS technology will enable city leaders to integrate and visualize enormous amounts of data for better and more realistic decision making (Al-Shuwaikhat and Aina: 2006).

Structure of sustainable development indicators

The number of indicators of sustainability depends on the level of analysis that needs to be carried out as well as the variables and categories which define each case. In general the indicators of sustainable development are numerous and comprise categories of each field of sustainable development disciplines (social, environmental, and economic), but other fields can also be added as cultural, political and institutional.

Selection of indicators must be based on a set of characteristics. To reach an ideal selection, a set of criteria should be addressed to evaluate and revise the indicators, targets and goals. Characteristics of "good" indicator selection have to be relevant, understandable and reflect community values, reliable, timely informative, integral and complex, policy relevant and with reachable data (Communities Committee: 2003); (Hart: 2010).

A frame work for the modeling process

Usually in practice, several individual indicators are organized in a series or groups. In order to measure sustainable development, a general frame work is needed to articulate the process. The process will have to seek certain procedures to ensure an appropriate problem solving process.

The overall procedures for the model Scenario will include consecutive steps that are further detailed in Figure 2, as follows:

Step 1: Conceptual review

Involves a comprehensive search and review for all relevant and concerned topics like literature review and cities which undergone similar experience of sustainable development assessment, and sustainability indicators that may be used for the assessment procedure.

Step 2: Exploration and Analysis of Data

Investigating the available data would be considered the difficult part. Scarcity and criticality of the required date may act as an obscure to get acknowledge to the actual situation of the problems existing in the operating urban system, covering services, economy, environmental issues, infrastructure sufficiency, and the social aspects in the city.

Acquisition of the city master plan, statistical data, planning policies and guidelines, all are essential for examining the city sustainability appraisal, by observation and comparison.

Step 3: Development of sustainability indicators

First, the study goals and objectives are primarily identified. Accordingly, appropriate sustainability core and sub/indicators that are relevant to urban parameters needed to be studied and investigated for assessment, are selected and formatted to the study context.

Step 4: GIS and Spatial Processing

Urban parameters that can be spatially illustrated are prepared as digital maps of segmental and thematic categories, like municipal networks, urban land use. Analysis process is carried out to extract anomalies and faults that contradict the planning flow originally put for the community under study.

Step 5: Process of Policy Formulation and Decision Making

Benchmarking and performance assessment can thus be carried based upon the analytic extractions obtained from the spatial processing, and policy directions and decisions are practically supported.

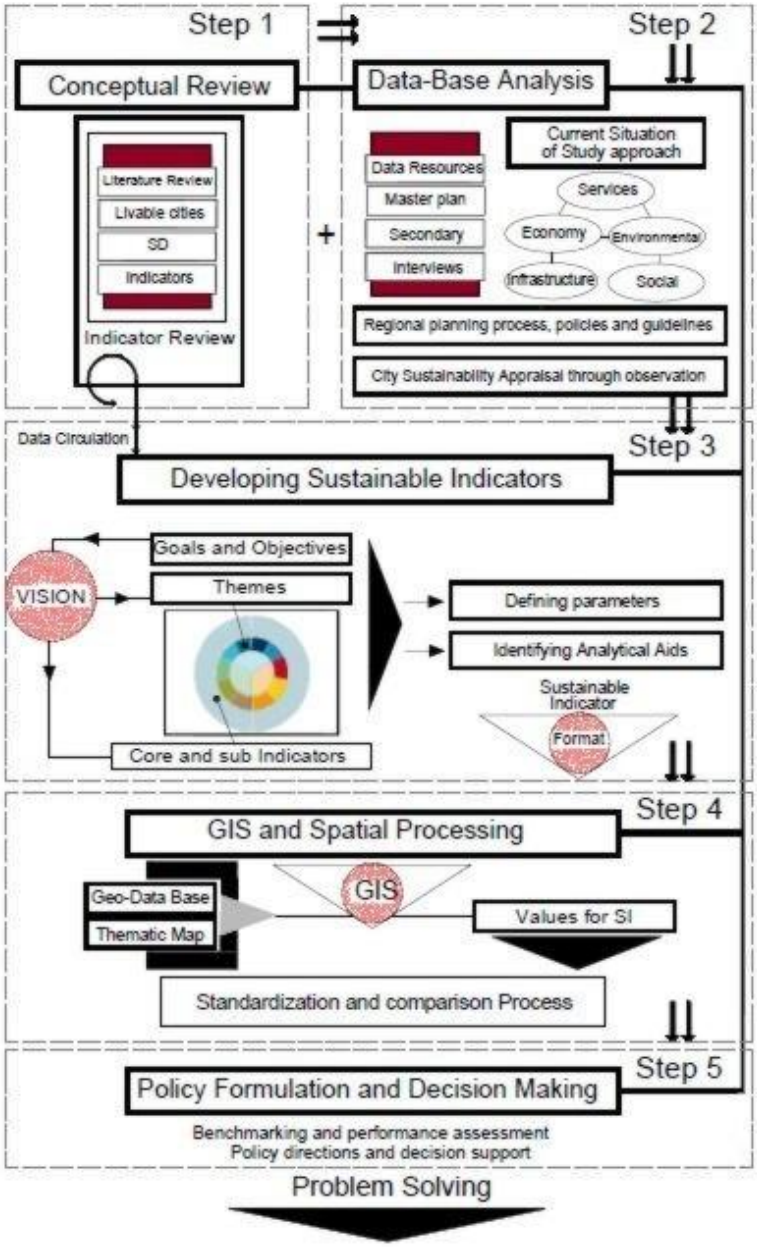


Figure 2: The proposed DSS model scenario.

Study approach of the current situation.

From the previous population growth analysis we found that there is a wide gap between the objectives and the goals already achieved in the city during the current state.

An analysis of data and problem identification of the different development sectors is crucial to know the current state of the city sustainable trends. This includes a detailed analysis for the population and demography sector for the city in comparison to its mother city Alexandria, together with the master strategic plan (Figure 3), infrastructure, and economic and environmental sectors. Consequently, a foundation is developed, from which improvements and monitor progress can be monitored. The study approach for the city relied on miscellaneous data-base resources which are mainly divided into the following:

I: Master Plan Documents. All Master plan documents including maps for current conditions, city vision and strategic master plan were referenced from the document "New Borg ElArab City" Strategic Plan – phase 1 and phase 2 performed by the Ministry of Housing, Utilities and Urban Development/ New Urban Communities' Authority (NUCA)/New Borg Al Arab Development Agency and the General Organization for Physical Planning (GOPP), (Ministry of Housing et al.: 2012).

II: Secondary Resources. As for the secondary resources, the study relied on statistical sources issued by the Central Agency for Public Mobilization and Statistics (CAPMAS), Data support and urban analysis input for UN-"Habitat State of Arab Cities Report" - Chris Horwood - Egypt, World Bank Reports, Egypt's Informational Portal: 2012, population census (2006), the Cabinet Information and Decision Support Center (IDSC), New Urban Community Authority, "CEDARE" Center for Environment and Development for the Arab Region and Europe, "UNDP" The Egyptian Ministry of Trade and Industry, Egypt human resources reports, population and labor force in Egypt, Ministry of Housing, and New Borg ElArab Development Executive System and agency.

III: Questionnaire. A questionnaire was done randomly on a sample of residents and immigrants, as a guide for investigating the core indicators for the city and emphasizing the idea of social equity and public participation.

The questionnaire has summarized answers for the following main three specific issues:

- The problem of day-to-day business trip from Alexandria to New Borg ElArab City (A sample of 4.9% of the population size)
- Job opportunities problem in the city (A sample of 6.4% of total number of employed citizens).
- Residence problems (A sample of 4.9% of population size).

This, consequently, will summarize the problems lagging New Borg ElArab from being an attractive city to citizens and visitors (Hasanein: 2005).

An English version (translated from the used Arabic version) of the used questionnaire is demonstrated in Appendix 1, illustrating the 3 main questioned issues and their various options to be ranked respectively according to their importance.

New Borg ElArab City implementation up to date.

New Borg Al Arab master strategic plan of the city is divided into10 residential districts and 5 industrial zones. As shown in Figure 4, it can be found that although the master plan and detailed studies were executed between 1977 and 1982, only districts 1,2,3,4,6, and 7 are still under construction out of 10 districts, while all industrial zones are almost implemented. From here, it could be analyzed that priority is given more to industrial zones rather than services and residential areas. The sustainability appraisal through observation analysis for the current state (including the city's weakness and strength) was also developed through detailed analysis for sustainability pillars, and it was found that there is a gap between: the original visions, development frameworks, detailed plans and planned actions on the one hand, and the present status of the city on the other (Ministry of Housing et al.: 2012).

Figure 3: Strategic master plan for "New Borg ElArab City", from GIS analysis.

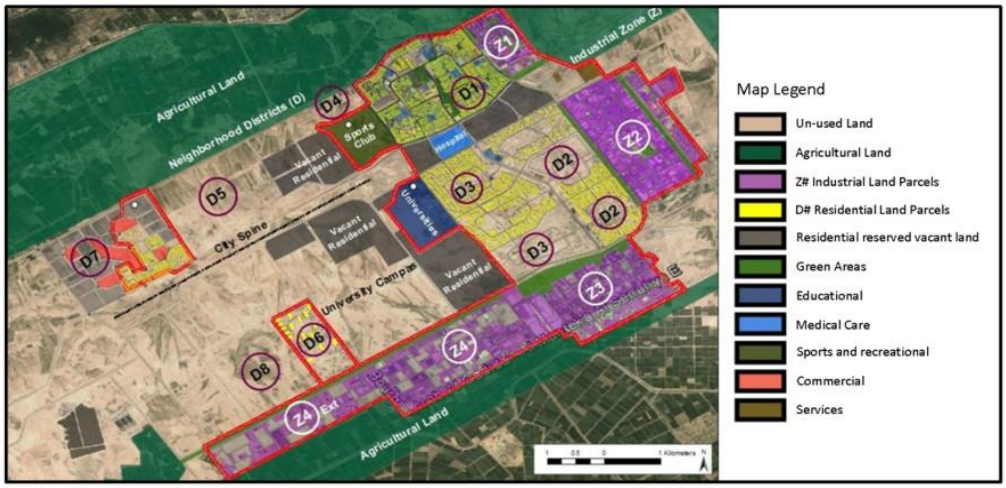


Figure 4: New Borg ElArab City implementation up to date, from GIS analysis.

Setting up the goals, objectives and city vision

As discussed before the concept of sustainable development has been widely accepted as a laudable goal to be achieved by different cities. The concept seeks to give appropriate considerations to social, economic and environmental dimensions of developmental activities. The main goal considered now is to ensure that all sustainable dimensions are maintained through the planning process, the master plan documents and the land use activities resulting from the planning of the city. A GIS-based sustainability assessment of the study area is required to gauge the process. The assessment will be based on the development of a set of sustainable development indicators.

From (Table 3) we could analyze that the policy for the city meanwhile is concerned mainly on industry as an economic base and in order for the city to be sustained on the long run the policy needs to be shifted and boosted to a diversified one. So an outline for the vision was presented to stakeholders, (Ministry of housing, New Urban Communities Authority and General Organization for Physical Planning), and agreed upon and enhanced as follows: *"New Borg ElArab City is a free-standing city, an advanced diversified regional economic hub within Alexandria Metropolitan Region"* (Ministry of Housing et al.: 2012).

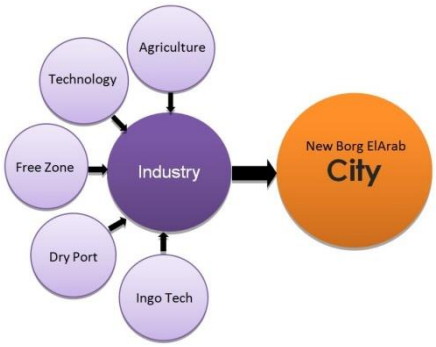
Initial Phase	Long term Position
- Acting as an independent city and main growth pole for neighbouring Alexandria city. - Having an advanced and export-based industrial economic base.	- Acting as an independent city and main growth pole for neighbouring Alexandria city. - Having an advanced and diversified economic base.
	

Table 3: New Borg ElArab city evolution, (New Urban Communities Authority: 2012).

In order for a city to act as a "magnet" for citizens and enhance the preservation of a healthy environment when putting industry and living facilities in the same scheme, a detailed vision together with the main objectives and goals for achieving sustainable development could be listed to articulate thematic policies of the city, as follows:

Within the next 20-30 years the New Borg ElArab City could act like magnet to citizens to (work-live) and could establish reputation as dynamic, vibrant, compact and resourceful city through a shared vision of its citizens and civic leaders. Thus creating a beautiful, livable city region promoting vibrant culture, creation of new employment opportunities, development and delivery of renewable energy; a resilient environment, and a diverse innovation based economy which supports the livelihoods and well- being of its citizens. It will be a city region of communities connected through an integrated transportation network with recreational areas, green spaces,

affordable housing and adequate services. It will protect and improve the natural environment and manage resources efficiently. The vision is for a city region where people will seek to live, work and enjoy as a matter of choice (Grey and Siddal: 2011).

Setting up the indicators of the model

The first step to set up the indicators of the model is to translate the vision into three main categories known as *Headlines*, referring to economic, social and environmental dimensions, as shown in Figure 5, level A.

1. A city region promoting vibrant-incentive culture and a diverse innovation based economy which supports the livelihoods and well- being of its citizens.
2. A city region that protects and improves the natural environment and manages resources efficiently while maximizing energy security and adapting to local and global challenges.
3. A socially inclusive capital city region of resilient communities with a high quality public domain connected through exemplary pedestrian and integrated transport networks (Grey and Siddal: 2011).

The next step is to select the city thematic policies (Suite of "Headline Sustainability Indicators" that resemble the detailing and differential coverage of the previously listed 3 Main Headlines). The indicators selected will be a reflection of a shared vision for "New Borg ElArab Themes" in terms of the progression of the sustainable development agenda. Each concept (category) will be supported by a number of themes that could be used to audit the progress towards the vision. Ten themes are chosen (Figure 5, level B). These were guided by a sample of themes that are included in international, national, regional and local documents (Grey and Siddal: 2011); (Urban Guard: 2005).

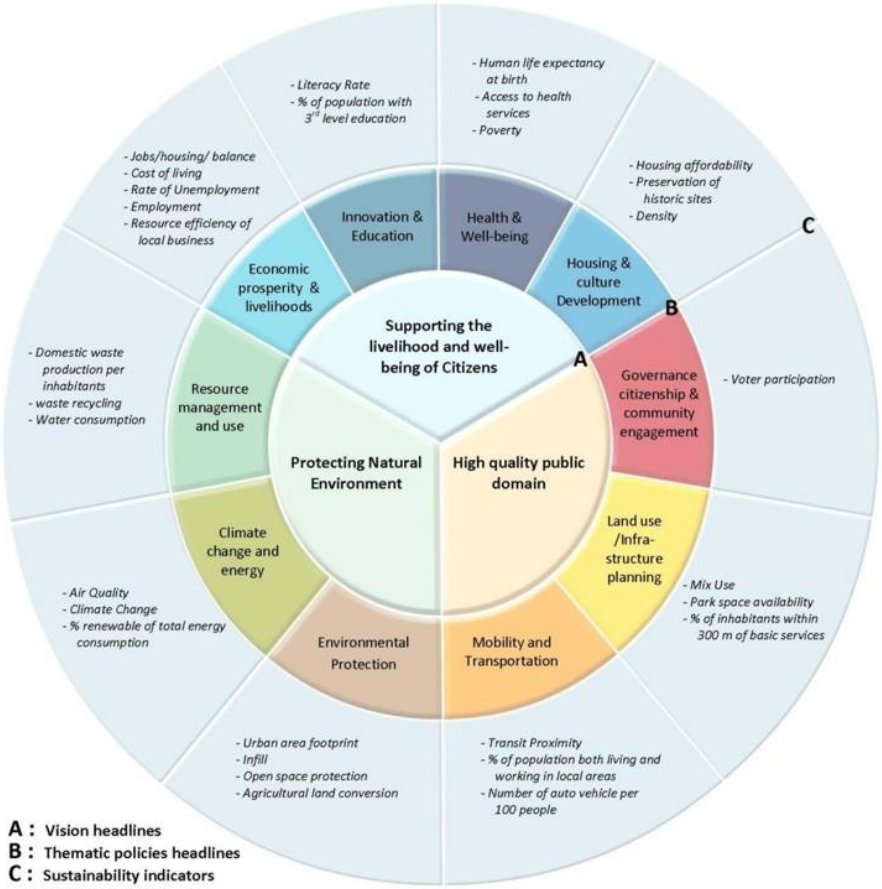


Figure 5: Core and sub-indicators.

Finally a set of indicators (core indicators covering planning policies and sub indicators which evaluate other indicators) is selected for each theme, (Figure 5 level C). The indicators selected are already in use, internationally, nationally, regionally and locally to ensure that the selected indicators were comparable and made the best use of existing measurements. Once the indicators were selected they were grouped according to basic categories (Tanguay et al. 2009). The Chart in Figure 5 (with its 3 levels A, B, and C), summarizes the indicators model scene, used in auditing the study case (Grey and Siddal: 2011); (UN-HABITAT Indicators: 2009).

Indicator review and selection (International – Regional – Local Data resources)

Numerous projects exist world-wide to develop and apply indicators. A survey-based analysis on the use of SDI conducted by Tanguay et al. (2009) extracted 188SDI from a review of 17 studies (for example: United Nations Commission on Human Settlement indicators, The United Nation Development Program, Eurostat……etc.) on the creation of territorial indicators (Moreno: 2010).

These studies covered practices in Canada, the United Nations and Europe and were selected to ensure the compatibility with the socioeconomic context of the city under study and its accessibility of information and data. Scientific studies and articles were another source of indicator. Indicators have been selected for the themes based on how well they:

- Address the issue of the communities carrying capacity relative to the four types of communities capital: natural, human, social and built
- All Data Resources for the city are easy to access
- Highlight the links between the community's economic, social and environmental well being
- Focus on a long range view (Moreno: 2010)

A Goal/Indictor matrix was also developed to ensure the inter-linkages between the indicators and the three dimensions for sustainability. This was done by listing all of the sustainable city indicators and the 10 Themes representing the city goal area across the top. For each indicator, dots are shown for every goal area about which the indicator provides information (Grey and Siddal: 2011).

Coupling "ArcGIS" platform with indicators for steering sustainable development

Indicators simplify complex phenomena into quantifiable measures that can be used for policy and decision making. Therefore, indicators have three functions: to simplify, to quantify and to communicate (Van Delft: 1997). A common frame work is needed in order to benchmark, compare and visualize the state and the future trends of the city in terms of sustainable development.

The previous analysis for the sustainable development tools resulted in 10 themes with an overall 30 core and sub-indicators. By itself, this list does not allow calculations of the indicators and measurement without developing detailed methodological procedures. A table shown in Appendix 2 including all "30" Indicators distributed among "10" selected themes, was developed to summarize each indicator and its relevant characteristics.

A framework for a standard indicator format is also designed to achieve a common understanding of the purpose and definitions of the indicator measurements in the sustainable development indicator set. For each of the 30 indicators, there is one SIF (Sustainable indicator format) containing the following information:

A.(Indicator Sets/Overall Objective) or SD dimension identification. This includes the name and number of the SD dimensions, theme and its indicators as main headlines and a description for each indicator and its relevance to SD.

B.(Individual Core Indicators) or Relevance of the Indicator. The selected indicator must be relevant. In order to ensure its relevancy the indicator must be searched to emphasize its international usage.

C.(Indicator Parameters) This describes the units in which the indicators are expressed by; such as percentage, ratio, km^2…etc. These parameters add a level of precision to the measurements.

D.(Formulas Used for Auditing) or Auditing Formulas, Methodology and Standardization. The equation and methodology describes guidance with operations for producing comparable calculations results. The result is compared afterwards with the international standardization to see whether the values are going upwards or downwards.

GIS would enable city leaders to integrate and visualize enormous amount of data for better decision making. Land use planning, infrastructure operations and maintenance, emergency services, tax assessment, public safety services, economic development, and every other city function – whenever possible to be spatially illustrated - can be monitored and enhanced with the use of a city-wide GIS.

An ArcGIS methodology is used for the visualization of sustainable development indicators and policy scenarios.

A GIS has the potential for operating indicators. While constructing the indicator set it is necessary to organize, quantify, and communicate data. These three functions of indicators coincide with the acknowledged advantage of GIS: data organization, spatial analysis, and visualization.

The spatial dimension of urban inequalities and the area based policies that target deprived areas make decision support for analysis and monitoring with the use.

From the overall 30 core and sub-indicators, 17 were fitting the spatial dimension condition and were conforming to the GIS usage advantage: organization/analysis/visualization possibility for their acquired data. The

visualization in the SIF took the form of thematic maps, graphs and charts to help in the auditing process and the analysis of each indicator (Donlan et al.: 2007).

Appendix 3 shows in details three examples of the selected indicators that have got the spatial dimension, as they can be expressed through graphical maps. For each of the three examples: indicator category, indicator set, individual core indicator, indicator parameters, Formulas Used for Auditing, Data source and GIS analysis, and the GIS final coverage, are shown, clarifying the role played by GIS in indicator analysis.

The result achieved at the end will significantly assist to audit the progress of the city towards sustainable development.

Results and Conclusions

From here the research attempted to develop an auditing framework for evaluating urban sustainable development for the city. Spatial, numerical, and descriptive indicators were needed as an auditing tool to measure the suitability of the city towards progress. A GIS based approach was crucial to guide the indicators as a measuring tool. The auditing process went through a detailed analysis for the city's current performance towards sustainability.

Resulting audit of SD indicators

The study went through a detailed analysis for the city's current performance towards sustainability.

All of the 30 sustainability indicators undergone a detailed analysis for comparing the actual state of the indicator at the functional city, to the standards and levels aimed by the original planning studies carried out by the:

- Ministry of Housing, Utilities and Urban Development
- New Urban Communities Authority
- New "Borg ElArab" Development Agency
- General Organization for Physical Planning

The procedure tackled tabulated data, statistics, and thematic maps, surveying the current actual situation and comparing each to the aimed objectives listed in the original study performed before the city construction.

It was figured at the end that a few indicators achieved sustainable trends, some were irrelevant (not been constructed yet) and a majority of it were going in an unsustainable direction, and that consequently proves the lagging of the city's achievement from being attractive towards its citizens. Table 4 summarizes the 30 indicators and their achievements towards sustainability.

During performing the analytic phase of the study, each selected sustainability indicator was studied through two explicit occurrences: the first was its presence and measurement (according to its nature) in the master plan put by the "Ministry of Construction and New Housing Communities" during the city early phases of planning and designing. While the second was its presence and measurement (according to its nature) in the data surveying during practical phase while carrying out this assessment study, and then the two measurements (readings) were compared to get acknowledged with the positive or negative direction the development process pursues, concerning that particular sustainability indicator.

It was concluded that twelve indicators achieved an acceptable positive trend; two were irrelevant as they are still under construction; while the rest (sixteen indicators) achieved a negative trend. Sustainability trends of Positive and Negative achievement were specified according to the actual trend surveyed for a specific indicator. Even though, some indicators have been covered by policy levels (planned in executive plans), but still, their intended outcome haven't been reached due to technical or administrative obstacles, marking their sustainability trend as unacceptable.

Themes	Indicators	Sustainability Trends	Policy Level Coverage*
1- Economic Prosperity	- Rate of unemployment	Positive	2
	- Jobs/housing Balance	Negative	0
	- Resource efficiency of local business	Negative	2
	- Employment	Negative	2
2- Innovation and Education	- Literacy rate	Negative	1
	- Student/Teacher ratio	Negative	0
	- Access to basic education	Positive	1
3- Health and Well-Being	- Human life expectancy at Birth	Positive	0
	- Access to health services	Positive	1
	- Maternal Mortality Rate	Negative	0
4- Housing and Archaeological Sites Development	- Housing Affordability	Positive	1
	- Preservation of historic sites and buildings	Negative	0

	- Density	Negative	1
5- Efficient Resource Management	- Domestic waste production per inhabitant	Positive	2
	- Waste generation and management	Positive	2
	- Domestic water consumption	Negative	0
	- Water Consumption	Negative	0
6- Climate Change and Energy	- Ambient Air Quality	Positive	2
	- Renewable total energy consumption	Positive	1
	- Noise Pollution	Negative	0
7- Biodiversity and Environmental Protection	- Public access to open space	Positive	1
	- Open space protection	Negative	1
	- Agricultural land conversion	Negative	2
8- Governance, Citizenship and community engagement	- Voter Participation	Negative	0
	- Citizens satisfaction with local community	Negative	0
9- Integrated Land use, spatial and Infrastructure planning	- Min of uses	Positive	2
	- Green Space availability	Negative	1
10- Movement and Transport	- Transit Proximity	Not relevant	1
	- Length of Mass transport network	Positive	2
	- Superior public transport network	Not relevant	1

Policy Level Coverage*
0: No policy level coverage 1: Limited policy level Coverage (covered but not yet implemented) 2: Covered in policy Level

Table 4: Sustainability trends of "New Borg ElArab" City.

Specific guide lines and solutions were deducted and detailed; covering each of the 10 selected themes in order to guide the sustainable development of the city on the short and long run incorporating environmental, social and economic dimensions.

Procedures of strategic solutions

Strategic solutions were needed for the selected thematic policies to guide the strategic master plan success towards achieving the aimed sustainable development. Therefore a set of specific procedures was concluded for the previous selected "thematic policies".

- Economic Prosperity: Promote better employment opportunities and livelihood of residents and vitality and preconditions of a healthy urban economy, which among other advantages enables maintain acceptable service levels. This could be maintained by the development of local resources, and integration of environmental issues with economic aspects.
- Innovation and Education: Promoting a better education for inhabitants and ensuring a highly innovative society. This could be gained by increasing literacy rate; facilitating access to basic education services and strengthening reputation of universities, research centers, and institutes.
- Health and Well-being: Promoting good public health and improving protection against health threats. This could be done by promoting healthcare facilities, and facilitating efficient access to them.
- Housing and Cultural development: Promoting better living conditions through housing and cultural development. This could be done by emphasizing housing affordability, increasing residential density and cultural awareness.
- Efficient Resource Management: Improving resource management and avoiding over exploitation of natural resources and recognizing the values of ecosystem elements. This could be achieved by emphasizing methods of waste generation and management, waste water treatment and the controlled provision of adequate potable water to all districts, with increasing awareness of water saving benefits.
- Climate Change and Energy: Limiting the negative effects of climatic changes to the society and environment. This could be achieved by, enhancing ambient air quality, the efficient use of non-renewable resources, and decreasing pollutants' emission of all forms.
- Biodiversity and Environmental Protection: Limiting environmental deteriorations. This could be achieved by, preservation of agricultural land, enhancing biodiversity, and facilitating access to open space.
- Community Engagement: Encouraging Citizenship activities of individuals to contribute in the decision making process, within expressing the public opinion towards a specific case.
- Integrated Land Use and Infrastructure Planning: Development of city's land use, spatial and infrastructure planning. This could be achieved by ensuring "mix use" planning, green space availability and development of infrastructure and services in different city sectors.
- Mobility and Transport: Ensure that the transportation system meets the society's economic, social, and environmental needs, while minimizing undesirable impacts. This could be achieved by enhancing public transit reliability and increasing access to public transportation facilities in an environmentally friendly manner.

Conclusions review

The study presented in this research focused on the idea of revitalization of new industrial cities; in order to handle the gap formulated by severe problems in current metropolitan cities. The vital term "Sustainable development" was used to bridge the knowledge gap, and revitalize these cities to act as magnets.

The experience of "Egyptian New Communities" was tackled, as initiated in the mid-seventies, as a governmental policy within a general strategy to tackle the multitude of problems burdening Egyptian settlements surrounded by agricultural land in particular. Although belonging to the first generation of new cities in Egypt, New Borg ElArab City was chosen as a study case as being one of the most important industrial cities in Egypt, as till now New Borg ElArab city did not achieve the main objectives and goals required to act as an development attraction pole to Alexandria city, with very low population growth. Based on the details mentioned previously, it was necessary to understand why the city is still lagging behind.

It was figured at the end that economic sustainability issues were addressed more than environmental and social issues through the policy evaluation of the city. The result of the GIS-based sustainability indicator assessment of the study produced similar findings.

At this juncture, it is pertinent to note that some of the results from the analysis have to be interrupted with caution, since only districts 1, 2, & 3 were mainly considered in the study and that is due to the slow construction rate and unavailability of data for other districts. Simple buffer analysis which returns the maximum level of accessibility to services was used by the study due to insufficient local data resources for the detailed number of inhabitants for each district.

A more rigorous buffer analysis might yield slight different results. In addition, some of the data used for the auditing are estimated from the strategic master plan and might be a bit different from the actual situation of the study area. Nevertheless, the sustainability trends deducted by the overall results are valid and were further proved by a questionnaire done at the end of the research analysis.

RECOMMENDATIONS

Recommendations for promoting the city's sustainability were deducted as the following policies and actions:

- Serious regional and national coordination of development rationales and strategies; to avoid fragmentation and conflicts between developmental actions. This defect has been the main anomaly from which the formal governmental and administrative bodies are suffering, especially in the sector of urban development and construction of new communities in Egypt. Coordination between the governorate and the Ministry of Housing, Utilities, and Urban Development, would guarantee the nonreplicable or contradictive decisions taken by each of them towards positively organizing and upgrading the developmental process of the city.
- Priority should always be given to the "limited capability urban areas", and to "lower income groups". This policy would be achieved by encouraging the low cost dwelling units' construction, through the selection of the most appropriate designs, and positing them with affordable units' prices, together with facilitating the basic services in close and reachable locations overcoming the need to transportation vehicles purchase, and with encouraging the reliance on public transportation means.
- Practical encouragement of youth immigration (to the city) for labor and employment, with living settlement benefits. This policy would gain advantage from the previous point, besides the practical advantage of increasing the main attractor of youth immigration which is the availability of job opportunity. The industrial activity and services sectors in New Borg ElArab City would play an inevitable role in attracting the youth category to move in and live in the new city instead of the nearby crowded ones.
- The implementation plan should be improved to solve the problem of slow construction rate, especially in the aspect of the implementation of services, residential units, amenities and public mobility. Encouragement of the private sector, and private land property construction would lead to thrust the slow construction rate. Granting tax advantages, assisting in estate selling and leasing, facilitating construction materials in encouraging costs, all are roles that can be played by the administrative executive system of the city to implement the policy.
- Encouragement of the axis of educational land use adopted by the city, which started by the establishment of the gigantic research centre, would lead to attract and polarize a huge category of residents resembled in undergraduate students that would welcome residing the calm city for university higher education.

The research could be further extended to make a detailed analysis of the measured indicators and aggregate them to create indices and maximize the coverage of social, environmental and economic dimensions of sustainable development. This consequently will aid the rank of city among others world-wide.

The procedures could be done by aggregating the 30 indicators developed in the study among three pillars (Economy, Social, and Environmental) to form three indices. These formulated intermediate indices will then be served to calculate the "Global Livable City Index" and thus calculate the weighted average of the standardization data and present a classification of cities based on their sustainability trends, and their livability attraction towards citizens. Also, GIS could serve as a modeling tool to guide the auditing process through visualizing the aggregation of indicators for different areas, in a powerful illustrative manner.

REFERENCES

Abdel-Kader, N., and ElTouney, S. 2009. "Towards a New Architectural Vision: The Egyptian New Communities, between Objectives and Realization. A Critical Discourse, three Decades Later". ARCHCAIRO, 5th International Conference. Department of Architecture, Cairo University, Cairo, Egypt. Accessed November 11th, 2011.
http://www.cpas-egypt.com/pdf/Ettouney&Nasamat/E&N/ARCHCAIRO%202009,%20New%20Communities%20in%20Egypt,%203%20decades%20later.pdf

Agueda, B.F. 2010. "Shaping the futures of industrial cities in decay: Urban Planning and Memory Retrieval". p. 1-24. Accessed October 10th, 2012. http://oa.upm.es/5978/1/FernandezAgueda_ponencia_2010_02.pdf

Al-Shuwaikhat, H. and Aina, Y. 2006. GIS-Based Urban Sustainability Assessment: The Case of Dammam City, Saudi Arabia. King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

APMS Agency for public Mobilization and Statistics. 2006. Population data base, Census, and social data from Development Reports 1995-2003. Egypt.

Atkisson, A. 2012. Indicators of Sustainable Development. Pittsburgh Publications. Pittsburgh, USA.

AxXiom for liberty. 2010. "Edmond Oklahoma Info for Citizens Planning to Survive Sustainability". December 30, 2010. Accessed January 11th, 2011. http://axiomamuse.wordpress.com/2010/12/30/edmond-info-for-citizens-planning-to-survive-sustainability/

Centre for Geo-Information Technologies (cGIT). 2007. "Building Sustainable Cities Using Enterprise GIS". Article: Coordinates. A monthly magazine on positioning, navigation and beyond. April 2007. Delhi, India. Accessed January 10th, 2009. http://mycoordinates.org/building-sustainable-cities-using-enterprise-gis/

Cho, D., Jeong, H., Kim, C., and Lee, D. 2000. "The Development of Assessment Model on the Sustainable Development and its Applications: The Case of Ulsan Metropolitan City". p. 1-14. Accessed March 3rd, 2009.
http://www.earoph.info/pdf/2000papers/51.pdf

Communities Committee. 2003. "Indicators tool kit. Forest Sustainability Indicator Tools for Communities". Chapter 4, Measuring progress. Accessed February 15th, 2008. http://www.communitiescommittee.org/fsitool

Donlan, J., O'Regan, B., Morrissey, J., Foley, W., Leonard, J., and Moles, R. 2007. "A GIS Tool for Modeling and Visualizing Sustainability Indicators Across Three Regions of Ireland". International conference on whole life Urban Sustainability and its Assessment. Glasgow, Scotland, UK.

Federal Geographic Data Committee. 1996. "Citizens Guide to Spatial Data: What is a GIS?" Western North Carolina, USA. Accessed February 12th, 2008. www.main.nc.us/GIS/what-is-gis.html

Google 2014. Map Data © Google. Google map.

Grey, T. and Siddal, E. 2011. "Sustainability Indicators Framework 2011, Towards a Sustainable Dublin Region". Baile Atha Cliath. Dublin, Ireland.

Harris, J. 2007. "Building sustainable cities using enterprise GIS." Coordinates Magazine 11 (9). Accessed January 12th, 2010. http://mycoordinates.org/building-sustainable-cities-using-enterprise-gis/

Hart, M. 2010. "Sustainable Measures." Article. West Hartford. Accessed April 18th, 2013. www.sustainablemeasures.com/node/89

Hasanein, H. 2005. "Al-Salhia New City." The Arab regional Conference, "Rural and Urban Interdepended" concerning Sustainability of Arab Cities and Security of Housing and Land Tenure and Urban Governance. December 2005.

Helaly, F. 2006. The Formation of Social Networks in New Urban Communities. Urban Engineering Consulting Group, Cairo, Egypt.

Helsinki City Urban Facts Office. 2007. The core Indicators for sustainable development in Helsinki. Economic and Social Affairs. Indicators of Sustainable Development: Guidelines and Methodologies. Third Edition.

Johnson, P. and Lachman, B. 2001. Rapid Scan of Decision Support System Tools for Land-Use Related Decision Making. Association for Biodiversity Information.

Kriken, J., Enquist, P., and Rapaport, R. 2010. City Building: Nine Planning Principles for the Twenty-First Century. New York: Architectural press.

M.H.U.U.D. Ministry of Housing Utilities and Urban Development. 2012. "New Urban Communities Authority." Accessed December 17th, 2014. http://www.nuca.gov.eg/en/Home.aspx

Michigan Government, World Resources Institute 2005. "Environmental indicators." Accessed March 20th, 2009. http://www.wri.org/search/site/environmental%20indicators

Ministry of Construction and New Housing Communities. 2002. The General Authority for Urban Planning . Information Center. Egypt.

Ministry of Housing Utilities and Urban Development, New Urban Communities Authority. New Borg Al-Arab Development Agency. General Organization for Physical planning. 2012. Borg Al-Arab New City Strategic Plan. May 5, 2012.

Ministry of Housing, Utilities and Urban Development. New Urban Communities Authority. New Borg ElArab Development Agency. General Organization for Physical Planning. 2012. New Borg ElArab City Strategic Plan. Phase 1 & 2. Current Conditions. City Vision and Strategic Master Plan. Egypt.

Moreno, S. 2010. "Indicators of Urban Sustainability in Mexico" Number 7(16). Universidad Autónoma del Estado de México, Cerro de Coatepec s/no. Accessed August 22nd, 2010. http://um.ase.ro/no16/4.pdf

New Urban Communities Authority. 2012. "New Cities: New Borg ElArab City." Accessed September 12th, 2013. http://archive.is/Di2w

Pecham, R. 1997. Decision support system in urban planning. Chapter 1, New York: E & FN Spon.

Peck, S., Peck and Associates, and Dauncey, G. 2002. "12 Features of sustainable community development: social, economic and environmental Benefits and two case studies. New Urban Agenda. Sustainable communities' consultancy." Accessed October 10th, 2010. www.cardinalgroup.ca/nua/ip/ip01.htm

Perloff, H.S. 1980. Planning the Post-Industrial City. Washington: Planners Press. p. 3-18.

Plöger, J. 2007. "Bilbao City Report." Case report 43, Centre for Analysis of Social Exclusion. An ESRC Research Centre. p. 1-40. Accessed November 12th, 2009. http://eprints.lse.ac.uk/3624/1/Bilbao_city_report_(final).pdf

The gate to Egyptian cities. 2002. "Borg ElArab City." Accessed August 12th, 2009. http://www.borgelarab.info/maps.php

UN-HABITAT Indicators. 2009. "Urban Indicators Guidelines." Accessed July 29th, 2009. http://unstats.un.org/unsd/iiss/Urban-Indicators-Programme-Guidelines-UIP.ashx

Urban Guard. 2005. Capacity Building for Enabling the Incorporation of Sustainability Parameters in Urban Spatial Development and Planning Policies and Practices through the Use of Indicators in Cyprus. Project summary, Republic of Cyprus, Ministry of the Interior, Department of Town Planning and Housing.

USGS. 2012. "Citizens Guide to Spatial Data: What is a GIS?" The Oak Ridge National Laboratory. Accessed June 11th, 2012. www.main.nc.us/GIS/what-is-gis.html

Williams, R.A. 2000. "Environmental planning for Sustainable Urban Environment, Caribbean Water and Wastewater Association". 9th Annual Conference and Exhibition at Chaguaramas, Trinidad. 2:6 October 2000. p. 1-35.

APPENDICES

Appendix 1. Questionnaire (English version).

"New Borg ElArab" Questionnaire: English Version

Rank the following answers according to their importance respectively:

1.What is the main reason for the "daily work trip" problems from Alexandria to New Borg ElArab City"?

-Cost of living in the city is relatively high.
-High cost of purchasing residential units.
-Insufficiency and lack of services.
-The closeness of Alexandria to the original home of residence.
-Social and family relationship reasons in the original home of residence.
-Majority of jobs opportunities contracts are temporary.
-The spread of speculation phenomenon in the field of purchasing, selling and rental of residential units.

2.What is the main reason for jobs opportunities problems in New Borg ElArab City?

-Lack of compensation for labours.
-Wages and salaries are incompatible with the living cost of the city.
-Insufficient employment job opportunities.
-The formal labour regulations are not organized to suit investment projects.
-Job opportunities specialized for investment projects are incompatible with the necessary qualifications.
-Temporary job opportunities contracts.
-Lack of transportation means.
-Inadequate provision of social and medical services for labours in all sectors.

3.What are the main reasons for the city residence?

-Lack of services (education - security - transportation ...etc.).
-High cost of living.
-Inadequate residential units.
-Inadequate standard of living.
-Failure to achieve full benefits from job opportunities.

Appendix 2. Selected Indicators used in the auditing study.

Indicator Category	Indicator Sets/Overall Objective	Individual Core Indicators	Indicator Parameters	Formulas Used for Auditing
Economic Dimension	**1-Economic Prosperity** *Overall Objective: To promote better employment opportunities and livelihood of residents, and vitality and pre-conditions of a healthy urban economy, which among other things enables maintain the service level.*	1 -Rate of unemployment	% of population	(Total Number of citizens without a job/total number of residents) x100
		2- Jobs/housing balance	Ratio	Total number of jobs/ Total number of dwelling Units
		3- Resource efficiency of local business	% of Industrial organisations	% of organizations that have adopted environmental management procedures
		4- Employment	Number/acre	Number of employees per net acre of land, designated for employment uses
	2-Innovation and Education *Overall Objective: It's a prerequisite for promoting the behavioural changes and providing all citizens with the key competency needed to achieve sustainable development.*	5- Literacy Rate	% of population	(Number of literate citizens/Total number of citizens) x100
		6- Student/teacher ratio	Ratio	Number of Students/Number of teachers
		7- Access to basic Education	%	300m buffer area with access to basic educations/Total area of selected study area
	3-Health and Well Being *Overall Objective: To promote good public health on equal conditions and improve protection against health threats*	8- Maternal Mortality Rate (per 100000 live birth	Ratio	Maternal-Related deaths in one year/Total births in the same year.
		9- Human life expectancy at birth	Number of years	Life expectancy at birth in years
		10- Access to health service	% of population	(400-metres buffer area with access to health services /Total area of selected study area) x100
	4-Housing and Cultural Development *Overall Objective: To improve better living conditions.*	11- Housing Affordability	%	Monthly domestic payment/Average of low family income x100
		12- Preservation of historic and archaeological sites and buildings	%	(Area of historic sites designated for preservation/Total built area) x100
		13- Density	Number/Hectare	Persons/ residential built-up area in Hectare
Environmental Dimension	**5-Efficient resource management** *Overall objectives: To improve management and avoid over exploitation of natural resources, recognising the values of ecosystem services*	14- Domestic waste production per inhabitant	Kg/citizen/day	Weight of domestic waste in kg/capita/day
		15- Waste generation and management	Tons (annual)	Amount of Waste recycled and reused in Tons
		16- Water Consumption	litres/capita/day	Total water use in litres/capita/day
		17- Domestic Water Consumption	Litres/capita/day	Total domestic water use in litres/capita/day
	6-Climate change and Energy *Overall Objective: To limit change and its costs and negative effect to society and environment*	18- Ambient Air Quality	Microgram/m3	Concentration of air pollutant gases and particulates in microgram/m^3
		19- Noise pollution	%	Area inhabited exposed to traffic noise pollution greater than 65 dB (buffer distance of 35m)
		20- Renewable Total Energy Consumption	MW/day	Total power of renewable energy in MW/day
	7-Biodiversity and Environmental protection *Overall Objective: To limit environmental deteriorations and emphasize the concept of SD.*	21- Public access to open space	%	300m buffer area with access to open spaces/Total area of selected study area
		22- Agricultural land conversion	Acres/year	Acres of agricultural land/year
		23- Open space protection	%	Land dedicated to open space/Total land x100
Social Dimension	**8-Governance, citizenship and community engagement** *Overall Objective: To encourage citizenship and community to take part in the decision making process.*	24- Voter participation	%	(Number of eligible people participating in elections/Total eligible people) x100
		25- Citizens satisfaction with the local community	Satisfied, not satisfied	Logic
	9-Integrated Land Use, spatial and Infrastructure planning Overall Objective: The development in land use and community structure affects people's lives and nature's well-being in many ways.	26- Mix Use	ratio	Ratio of non-residential to residential Land use
		27- Green Space availability	m^2/person	Green space area in m^2/total number of population
	10-Movement and Transport Overall Objective: To ensure that the Transport system meet society's economic, social and environmental needs, whilst minimizing its undesirable impacts.	28- Transit Proximity	%	Number of inhabitants within 500m buffer from transit node/Total built up area x100
		29- Length of mass transport network	Km/Km^2	Total Length of mass transport/Total land area
		30- Superior public transport network	Km/Km^2	Total Length of superior public transport network/Total land area

Appendix 3. Coupling "ArcGIS" platform with indicators. (Selected Examples)

	Example 1	Example 2	Example 3
Indicator category	Economic Dimension	Economic Dimension	Social Dimension

Indicator Sets/ Overall Objective	03- Health and Well Being.	04- Housing and Cultural Development Overall Objective: To improve better living conditions.	10-Movement and Transport Overall Objective: To ensure that the Transport system meet society's economic, social and environmental needs, whilst minimizing its undesirable impacts.
Individual Core Indicators	**10- Access to health service**	**12- Preservation of historic and archaeological sites and buildings**	**28- Transit Proximity**
Indicator Parameters	% of population	%	%
Formulas Used for Auditing	300-metres buffer area with access to health services /Total area of selected study area) x100	(Area of historic sites designated for preservation/Total built area) x100	Number of inhabitants within 500m buffer from transit node/Total built up area x100
Data source and GIS analysis	- Borg ElArab new strategic plan - Ministry of housing, NUCA, GOPP GIS was used to determine the distribution of the land use data. Once the borders of the health services have been allocated on the GIS, the areas within a radius of 300m from the borders arc identified (Buffer creation). Thus the municipal land will appear to be divided into two areas. The GIS is consulted to obtain the percentage of areas of the 300m belts. (NB: Area and analysis (Buffer Analysis) retrieved from GIS)	- Borg ElArab new strategic plan - Ministry of housing, NUCA, GOPP A GIS analysis was used to figure out the area of the cultural spaces in the city and then it was compared to the total built-up area	- Borg ElArab new Strategic Plan - Ministry of Housing, NUCA, GOPP - Sustainable cities.net A GIS analysis was used to figure out the area of transit proximity buffer zone (500 meters) done by authors
GIS final coverage