Civil Engineering and Architecture 10(6): 2554-2571, 2022
DOI: 10.13189/cea.2022.100624 http://www.hrpub.org

A Customized Indicator-Based Tool to Assess Resiliency of Egyptian Coastal Cities: Case Study of Red Sea Cities

Safaa A. Ghoneim*, Walid A. Abdellatif

Faculty of Urban Planning, Cairo University, Giza, Egypt

Received May 20, 2022; Revised June 14, 2022; Accepted August 2, 2022

Cite This Paper in the following Citation Styles

(a): *[1] Safaa A. Ghoneim, Walid A. Abdellatif , "A Customized Indicator-Based Tool to Assess Resiliency of Egyptian Coastal Cities: Case Study of Red Sea Cities," Civil Engineering and Architecture, Vol. 10, No. 6, pp. 2554-2571, 2022. DOI: 10.13189/cea.2022.100624.*

(b): *Safaa A. Ghoneim, Walid A. Abdellatif (2022). A Customized Indicator-Based Tool to Assess Resiliency of Egyptian Coastal Cities: Case Study of Red Sea Cities. Civil Engineering and Architecture, 10(6), 2554-2571. DOI: 10.13189/cea.2022.100624.*

Copyright©2022 by authors, all rights reserved. Authors agree that this article remains permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

Abstract The increasing severity of climate changes and environmental risks led to the paradigm shift in urban planning towards increasing the resilience of cities. However, coastal cities are on the frontline facing these risks and challenges. The local context in developing countries is adding more pressure on city resilience. In Egypt, the Red Sea cities are increasingly exposed to flash floods, and storms under the uncertainties of environmental risks. They have special local environmental, social, cultural, and economic characteristics. This research aims to develop a customized community resiliency assessment tool, which considers the local context of Egyptian coastal cities. The literature shows that more than 30 tools and frameworks to assess resilience have been developed. However, this paper argues that indicator-based tools of assessment should be tailored to reflect the local context. From here, available tools from different perspectives and their associated indicators were reviewed and filtered according to the Egyptian context and national data drivers. Then the special environmental, social, cultural, and economic features of the study area "Red Sea" were highlighted as a reference to the next step of indicator selection. The appropriate criteria were developed and tested using data of Red Sea cities (i.e. Ras-Gharib, Hurghada, Safaga, El-Qusair, Marsa-Alam, Halaib and Shalateen). The case studies application and assessments included analyses of environmental parameters, and statistical analyses of social, and economic parameters. It showed high applicability and produced a resilience index of the coastal cities of the red sea region.

Keywords Community Resilience, Assessment Tools, Coastal Cities, Flash Floods, Egypt

1. Background

1.1. The Importance of Assessing Urban Resilience

Researchers and governments are increasingly interested in urban resilience, especially with the continuation of global urbanization trends [1]. Cities face many natural and man-made risks, and climate changes can cause an increase in the intensity and frequency of these risks, so it is necessary to move towards urban resilience [2]. Due to the imperative of resorting to urban resilience, many cities around the world have taken measures to enhance their resilience. Meanwhile, over the past two decades, there has been a growing interest in developing and implementing sets of indicators, methods and tools for assessing urban resilience [3,4].

Since 1980, the world has seen an increasing trend in the annual number of climatological, hydrological, and meteorological loss events [5]. There is a scientific consensus that climate change has increased the frequency and severity of losses and those losses are expected to increase in the future if the resilience of cities does not increase [6]. The increasing pressure on urban areas can cause serious consequences for the management of cities in the long run [6]. In response to concerns about the

consequences of the increase in the frequency and severity of disaster events, over the past four decades, the concept of community resilience has gained prominence in science and policy circles. The dissemination of the concept of community resilience also refers to the recognition of the fact that not all threats can be avoided and that there must be mechanisms in place to ensure that disruption is minimized. [7]. Additionally, urban resilience means learning lessons from a disruptive event and adopting adaptive approaches that lead to gradual, long-term development of cities. [8,9,10].

1.2. Characteristics & Dimensions of Urban Resilience Assessment

Because of the threatening impacts of climate-related disasters, city planners and policy makers are finding resilience to become an essential feature of urban ecosystems. The Urban Resilience Study provides a comprehensive analysis of climate-induced disaster risks and the resilience of urban ecosystems to such disasters. Five basic characteristics of urban resilience are commonly used to describe the diverse and interrelated capacities of urban ecosystems across resilience phases (before, during and after the event). [11,12,13]. These characteristics are preparedness, absorption, recovery, adaptability, and transformability, These characteristics have an important role with urban resilience [14,15,13,16]. The importance of the values of these characteristics is that they reflect the level of resilience of the system and also guide actions to enhance resilience.

The first characteristic is preparedness, which means the system's ability to plan and prepare for any disaster, whether expected or unexpected [17]. Preparedness facilitates the decision-making process before a disaster occurs. The second characteristic, absorption, as one of the definitions of urban resilience is the ability of a system to absorb any disturbance and to preserve the essential features of the system. [18]. The third is recovery, where disaster recovery planning is a method or plan that is followed during a disaster to gradually restore activity [19]. The fourth is adaptation, which means ensuring the survival and reproduction of organic individuals in living environments that lead to the sustainable survival and evolution of species or ecosystems, while species evolve to become more adapted for survival [20]. The last characteristic, transformability, refers to the ability to create a new system when the existing system is not acceptable due to environmental, economic, or social, political conditions. [21].

The stage of preparedness is before the disaster, while absorption is during the disaster, and recovery, adaptability and convertibility are after the disaster [17].

1.3. Applied Methods of Urban Resilience Assessment

City resilience assessment tools were reviewed from 2000 to 2022, where the oldest resilience measurement tool was (CRM) by Canadian center for Community renewal while the most recent tool for measuring urban resilience was (DEMTAL) in 2022, the number of urban resilience assessment tools has reached 38.

The tools chosen depended on many multi-source data, whether census data, historical records, statistics or reports issued by government institutions.

The tools depended on integrating multiple dimensions and aspects of city resilience assessment processes, after a comprehensive review of the criteria used in these tools and extracted from the literature, five common dimensions were identified: environmental, social, economic, built environment, infrastructure and institutional, Each dimension is divided into several sub-dimensions divided into several criteria.

This paper analyzes the indicators used in these tools to suit the Egyptian cities and add what expresses their specificity in order to reach a composite index to assess the resilience of Egyptian cities.

1.4. Indicators of Resilience

By reviewing a large number of tools for measuring urban resilience (38 tools), each of them has different dimensions of resilience according to the purpose and , the tools that did not include indicators were excluded, and 11 tools for measuring urban resilience were selected as focus:

- **PEOPLES**: The PEOPLES Resilience Framework defines components of functionality using a geospatial-temporal distribution within its geographical influence boundaries. Interdependencies between and among these components are key to determining the resilience of communities. PEOPLES enables the use of various community resilience indices that integrate, over space and time, the system functionality and services of a community in a landscape [22].
  The number of indicators in the PEOPLES tool is 95 indicators in 7 themes, the largest percentage of physical indicators is 35%, followed by economic indicators by 28%, then population indicators by 15%, then social, environmental, governance and lifestyle indicators by 8%, 6%, 4%, 4% arrangement.
- **CRC**: This tool included 61 indicators, which is an Australian index of natural disaster resistance [23].
  The largest percentage of social character indicators is 25%, followed by governance, policy & leadership indicators by 15%, then economic capital indicators by 13%, then infrastructure & planning indicators and community capital indicators by 11% for both of them, then emergency services indicators and information & engagement indicators by 10% for both of them, then community & social engagement by 5%.

- **CRDSA**: CRDSA provides an assessment system, with each criterion weighted to evaluate the level of the community resilience to cope with future disasters. This tool creates resilience scores for each of the six dimensions, as well as an overall score. Framework CRDSA is the first milestone towards the process of building community resilience to disaster in Saudi Arabia [24].
  The number of CRDSA indicators is 62, with the highest percentage of health and well-being indicators at 23%, followed by governance and social indicators at 18% for each, then physical and environmental indicators at 16%, information and communication indicators at 15%, and finally economic indicators at 11%.
- **DRI:** DRI was developed as a customizable, self-assessment tool that enables city stakeholders to assess all key dimensions of resilience through a full participatory process [25].
  The number of indicators of the DRI tool is 33 indicators, the highest percentage of critical services & infrastructure resiliency indicators is 39%, followed by legal & institutional indicators and development planning & regulation and risk mitigation indicators with 21% each, and finally awareness and capacity indicators with 18%.
- **CDR:** The resilience indicators for the CDR tool are established in terms of vulnerability or capacity, social, economic, human, physical, natural, environmental, institutional, infrastructure, and societal efficiency. [26].
  The number of CDR tool is 24 indicators, with the highest percentage of human and institutional indicators at 21% for each of them, then physical indicators and environmental indicators at 17% for each of them, followed by social indicators and economic indicators at 13% for each of them.
- **CoBRA:** The focus was on quantitative assessment when developing the CoBRA tool by comparing rates of resilience within societies between normal and crisis periods [27].
  The number of CoBRA indicators is 30 indicators; the largest percentage of financial indicators is 27%, followed by natural indicators and social indicators by 20% for each of them, and finally the physical and human indicators by 17% for each of them.
- **CRF:** The CRF tool aims to achieve 12 goals divided into four sections: the health and well-being of individuals; urban systems and services; economy and society; and finally, leadership and strategy [28].
  Each theme in CRF tool is described by one of the following attributes (integrated - inclusive - reflective - resourceful - robust - redundant – flexible).
- **LDRI:** LDRI designed with the aim of measuring resilience in the Philippines by aggregating the components of resilience at the national level. This tool has been used in multiple studies with the aim of promoting development in various sectors in the Philippines (tourism, environmental and natural resources, forestry, coastal management, disaster and risk management) [29].
- **CRI:** The purpose of the CRI tool is to provide decision makers with an easy and inexpensive way to predict the level of their community after a disaster [30].
- **BRIC:** One of the most important strengths of the BRIC tool is the possibility of its application at any planning level, from the local level to the national level, in addition to the ability to visualize the results, which indicates the places that need urgent interventions according to the indicators [31].
- **CERI:** It consists of 17 indicators divided into four main dimensions: social resilience, economic resilience, institutional resilience, physical resilience [32].

All indicators were monitored in all dimensions stipulated in the literature. Thus, the number of indicators at that stage became 299, and after several steps that will be mentioned in the methodology, the desk analysis extracted a primary set of 86 indicators.

2. Research Methodology and Analysis

This research can be classified as inductive research as it aims at developing a customized assessment tool. However, it goes further than this to test the developed tool using a multi-case study methodology. In order to achieve its aim, the research went through the following stages:

2.1. Selection of Suitable Tools

Table (1) shows the evaluation of tools and the selected tools for the next stage of the research are highlighted.

Table 1. Evaluation and selection of suitable tools

N	Tool	Purpose	Number of indicators	Scale	Dim-ensions	Year	Ref.
1	PEOPLES	Risk management support, supporting regional planning, supporting urban planning,	95	Regional /Local	All	2010	[22]
2	CRC	Risk management support, supporting urban planning	61	Local	All	2015	[23]
3	CRDSA	Risk management support, supporting urban planning	62	Local	All	2015	[24]
4	DRI	Risk management support, supporting regional planning	33	Regional	All	2015	[25]
5	CDR	Risk management support, supporting urban planning	24	Local	All	2015	[26]
6	CoBRA	Risk management support, supporting regional planning, supporting urban planning,	30	Regional /Local	Physical	2014	[27]
7	CRF	Risk management support, supporting urban planning	12	Local	All	2014	[28]
8	LDRI	Risk management support, supporting urban planning	45	Local	All	2013	[29]
9	CRI	Risk management support, supporting regional planning, supporting urban planning,	56	Regional /Local	All	2010	[30]
10	BRIC	Risk management support, supporting urban planning	52	Local	All	2010	[31]
11	CERI	Supporting urban planning	17	Local	Economic	2010	[32]

Source: Author

A sum of 38 available tools and frameworks of resilience assessment reviewed in the previous section were filtered to eleven tools to form a suitable base for the next stage "extracting indicators of assessment". The selected tools met the following criteria:

- their purposes include supporting sustainable development, urban planning, or local communities;
- they are using sets of indicators;
- they developed and applied within the last 20 years;
- they considered climate change or at least one of the natural hazards.

2.2. Extracting Indicators of Assessment

In this stage, the research focus turned to the indicator level. A comparative desk analysis was done using the sets of indicators belong to the above mentioned tools. Several steps of indicator filtering have been carried out to reach the primary suitable set of indicators for the proposed resilience assessment tool. The first step started with a total of 299 indicators representing eight dimensions, as follows:

- Environmental/ Ecosystem,
- Demographic,
- Physical/ Urban,
- Organizational/ governance,
- Lifestyle,
- Capital Culture,
- Economic, and
- Well-being.

2.2.1. Removing duplications

The indicators that include duplication were eliminated to end with 184 indicators.

2.2.2. Checking compatibility

The compatibility of the indicators with the Egyptian local context was checked and 37 indicators were excluded. Examples of these indicators for each dimension could be stated as follows:

- 3 indicators related to the demographic dimension, such as: Percentage of single parent households; and Proficiency in spoken English / language.
- 6 indicators related to the environmental dimension, such as: Households undertaking reforestation activities;
- 6 indicators related to the Health and well-being, such as: Health education programs relevant to crisis; and

Multi-sector engagement for managing food and health crises.

2.2.3. Checking availability of data drivers:

A sum of 70 indicators was excluded in this step due to lack of data availability. Examples of these indicators for each dimension could be stated as follows:

- 23 indicators related to the governance, such as: Mobile resources for reconstruction including trained workers; Emergency agency budgets; and Per capita disaster managers.
- 7 indicators related to the demographic dimension, such as: Percentage of households with one or more residents having a different address one year ago; and Percentage of population with a core activity need for assistance.
- 15 indicators related to the Economic Dimension, such as: Equitable distribution of wealth and livelihood in community; and Small enterprises with protection and business continuity.

At the end of this stage the desk analysis extracted a primary set of 77 applicable indicators and their data could be obtained.

2.3. Designing the tool: Fine Tuning and Weighting Indicators

In this stage the research attempted to solve overlapping among indicators, by merging or replacing several indicators into smaller number but more applicable in the Egyptian cities or available in the existing data drivers. Table (2) shows total numbers of indicators throughout different steps of desk analysis.

Also, the dimensions of Well-being, Lifestyle and Capital Culture were merged into one dimension "Socio-cultural" to give clear vision of dimensions and balanced number of indicators.

The Analytic Hierarchy Process "AHP" was followed to assign the suitable weights for both the indicators and the dimensions [33]. A correlation matrix of the indicators was calculated and scores of importance were rated against each other. The following table summarizes the numbers of indicators resulted from main steps of the desk analyses.

2.4. Application and Testing the Tool Using Case Studies

To test the applicability of the developed tool, a multi-case study methodology was followed using quantitative analytical method to assess and compare the level of resilience of the case studies. Seven coastal cities located in the Red Sea region in Egypt were used in this stage. A comparative analysis was applied on the dimensions' level and the final results of resilience assessment index.

Table 2. Numbers of indicators in the main steps; Source: Author

Dimensions \ Indicators		Total Number	Not Applicable	No Data drivers	Merged	Final
Demographic		23	3	8	8	4
Environmental		18	6	2	4	6
Governance		39	8	23	2	6
Physical		23	2	4	3	14
Economic		36	12	15	3	6
Economic Socio-Cultural	Life Style	17	1	7	6	6
	Cultural Capital	15	4	4		
	Well-being	13	6	4		
total		184	37	70	26	42

Table 3. Summary of results of indicator desk analyses (final stage)

Dime-msion	Final set of indicators	Desk analysis			The related tools	References
		Selected	Merged	Adapted		
DEMOGRAPHICS	Ratio of males to females in population	y			PEOPLES, CRC, CRDSA, CDR	[22], [23], [24], [26]
	Percent of one person households			y	CRC, CDR	[23], [26]
	% labour force employed	y			CRC, BRIC, CERI	[23], [31], [32]
	% Labor force employed by government		y		BRIC	[31]
	% of the population under 15 and over 65 years		y		CRC, CDR, BRIC, CERI	[23], [26], [31], [32]
ENVIRONMENTAL	Hazard exposure and mapping	y			CRF, CRI	[28], [30]
	Effectively managed protective ecosystems	y			CRF, CRI	[28], [30]
	Average number of rainy days	y			CDR	[26]
	Average days of over 80 mm/day precipitation	y			CDR	[26]
	Average elevation	y			CDR	[26]
	The percentage of green areas			y	PEOPLES, CoBRA	[22], [27]
	% of Cultivated area			y	PEOPLES, CoBRA	[22], [27]
GOVERNANCE	Accessible critical emergency facilities	y			LDRI	[29]
	Proximity of county seat to state capital	y			BRIC	[31]
	Major road egress points per 10,000 persons			y	BRIC	[31]
	Legal/Security services			y	PEOPLES	[22]
	Shelters availability during emergencies	y			CRDSA, BRIC	[24], [31]
	novelty of development plan			y	CRF, CRI	[28], [30]
PHYSICAL	% of weak dwelling types (wooden,..)	y			PEOPLES, CRC, CRF, CERI	[22], [23], [28], [32]
	Percent of impervious surface and urban areas	y			CDR	[26]
	Number of dams	y			CDR	[26]
	Hotels/motels per 10,000 persons	y			CDR, BRIC	[26], [31]
	Distribution of commercial Facilities	y			PEOPLES	[22]
	Distribution of Cultural Facilities	y			PEOPLES	[22]
	% households with electricity supply	y			PEOPLES, DRI, CoBRA, CRF, LI	[22], [25], [27], [28], [29], [30]
	Access to adequate sanitation	y			DRI, CRF, CRI	[25], [28], [30]
	Aviation /airports	y			PEOPLES, DRI, CRF, LDRI	[22], [25], [28], [29]
	Number of Bridges	y			PEOPLES, DRI, CRF, LDRI	[22], [25], [28], [29]
	Number of Highways	y			PEOPLES, DRI, CRF, LDRI	[22], [25], [28], [29]
	Number of Railways	y			PEOPLES, DRI, CRF, LDRI	[22], [25], [28], [29]
	Number of Waterways	y			PEOPLES, DRI, CRF, LDRI	[22], [25], [28], [29]
	Coverage with a good water network	y			PEOPLES, CRDSA, DRI, CoBRA	[22], [24], [25], [27], [28], [29], [30]
ECONOMIC	Distribution of employment over economic sectors	y			PEOPLES	[22]
	Home ownership	y			PEOPLES, CRC, CRDSA, DRI, B	[22], [23], [24], [25], [31]
	Access to saving and credit facilities			y	CoBRA	[27]
	Number of Banks and Credit Unions			y	PEOPLES	[22]
	Level and diversity of economic resources		y		CRDSA	[24]
	Labor force ratio		y		CRC, BRIC, CERI	[23], [31], [32]
	Housing levels			y	CoBRA, CERI	[27], [32]
SOCIO-CULTURAL	Access to social services	y			CRC	[23]
	Sport and recreation	y			CRC	[23]
	Child and Elderly Services	y			PEOPLES	[22]
	% Population without physical, or mental disability	y			BRIC, CERI	[31], [32]
	Education Services		y		PEOPLES, CRI	[22], [30]
	% population living in peace and security	y			CoBRA	[27]
	availability of health services		y		PEOPLES, CRDSA, CRF, CRI	[22], [24], [28], [30]
	Hospital beds per 10,000 persons	y			CRDSA, BRIC	[24], [31]
	crowding rate			y	CRC	[23]

Source: Author

3. Case Study

3.1. The Local Context of Coastal Cities in Egypt

The length of the Egyptian coast is approximately three thousand kilometers: 1150 km on the Mediterranean Sea, extending from Al-Salloum in the west to Rafah in the east; and 1,850 km covering the Egyptian Red Sea coasts (about 1200 km on the main basin of the Red Sea, and about 650 km on the Gulf of Suez and obstacle) [34].

The coastal cities in Egypt are an important source of living and non-living wealth and a focal point for many projects in various economic and social fields, such as recreational and tourism projects, fisheries projects, manufacturing, export and free zones.

The coastal cities in Egypt are located into 4 zones as shown in Figure 1, each of zone has a specificity reflected in the sustainability of the cities therein. These areas are:

- Zone (1): Cities on the Red Sea Coast
- Zone (2): Cities on the North Central Coast (Northern Delta)
- Zone (3): Cities on the Northwest Coast
- Zone (4): Cities located on the coast of Sinai

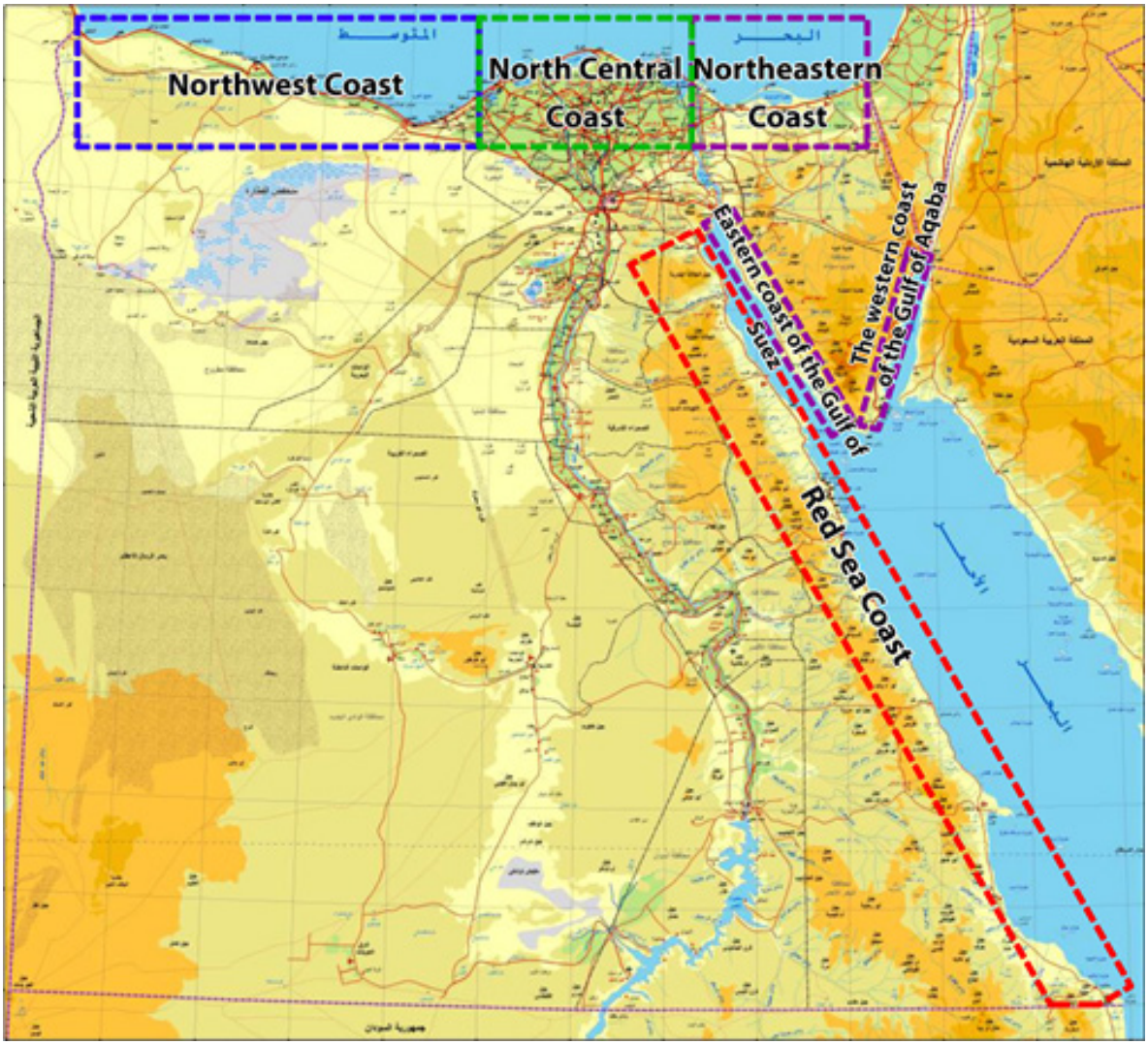


Figure 1. The Egyptian Coastal zones - Adapted from [35]

The reason for choosing the Red Sea coast as a case study is the exposure of the Red Sea cities to many natural hazards (flash floods, earthquakes, and faults) that greatly threaten the lives of residents, in addition to the increased losses resulting from flash floods in the Red Sea cities in the past years.

3.2. Characteristics of the Cities of the Red Sea Coast

The Red Sea coast includes both the governorates of (Suez and the Red Sea) with a total area of about 128.10 thousand km^2, 12.7% of the total area of Egypt. It extends with a length of about 1445 km on the coast of the Red Sea and the western coast of the Gulf of Suez, characterized by the diversity of its environments between coastal and desert.

The administrative structure of the coastal zone in the Red Sea consists of a total of 8 cities. Suez Governorate contains 5 districts in Suez City, and the Red Sea Governorate contains 7 cities [36].

A large part of the coastal area is located within the boundaries of nature reserves, and therefore the development process may be affected by this huge area due to the need for these reserves for special development requirements, in addition to torrential rains, erosion of beaches and sand dunes, faults, cracks and earthquakes [36].

The study cases are the cities of the Red Sea Governorate (7 cities), which are from north to south (Ras Ghareb, Hurghada, Safaga, Quseir, Marsa Alam, Shalateen, Halayeb) (figure 3). These cities are exposed to many risks affecting their sustainability, the most important of which is the risk of torrential rains, which have caused many human and material losses in recent years.

The existing urban structure is characterized by high urbanization, where about 96.5% of the total population of the governorate resides in those cities. The urban pattern prevailing in the governorate is the scattered pattern of distributed communities on the Red Sea coast.

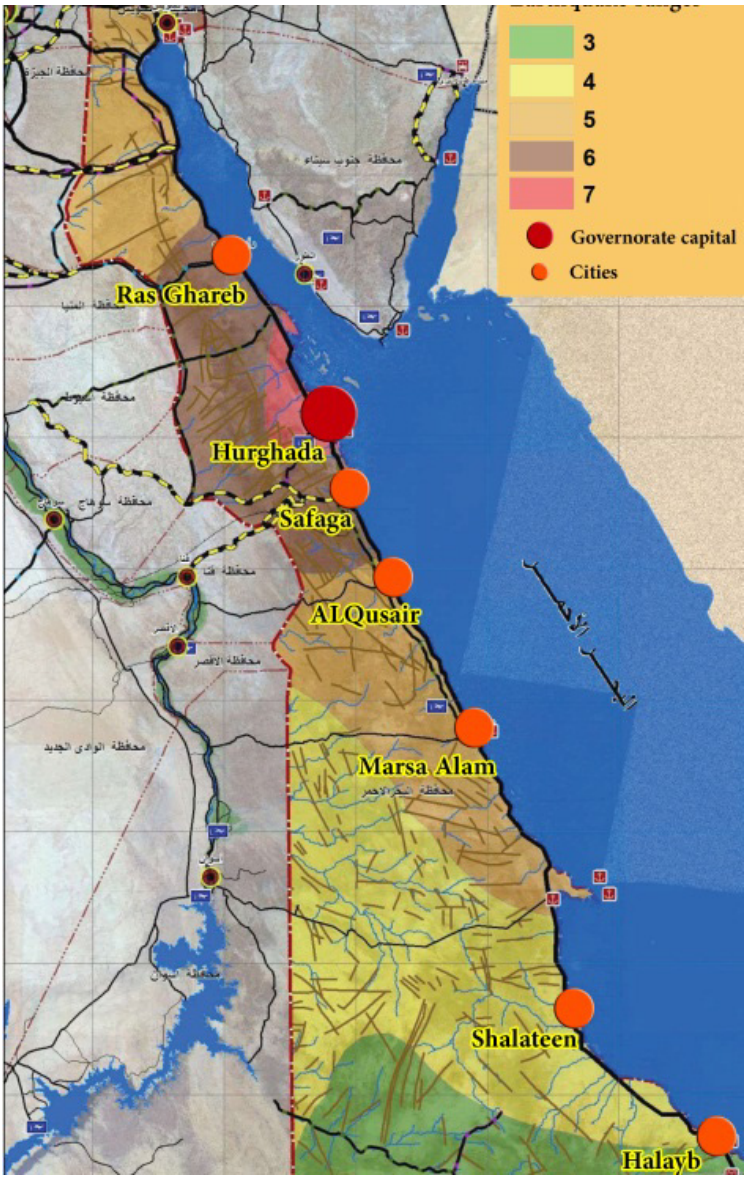


Figure 2. Locations of case studies; Adapted from [36]

Table 4. Basic information for case-studies; collected from [37].

N	City	Area (acre)	Population	Density (person/acre)
1	Ras Ghareb	909160	41272	0.05
2	Hurghada	141134	190632	1.35
3	Safaga	231812	49358	0.21
4	ALQusair	233716	46747	0.20
5	Marsa Alam	62594	4883	0.08
6	Shalateen	73780	11430	0.15
7	Halayb	9996	3050	0.31
Average		237456	49625	0.34

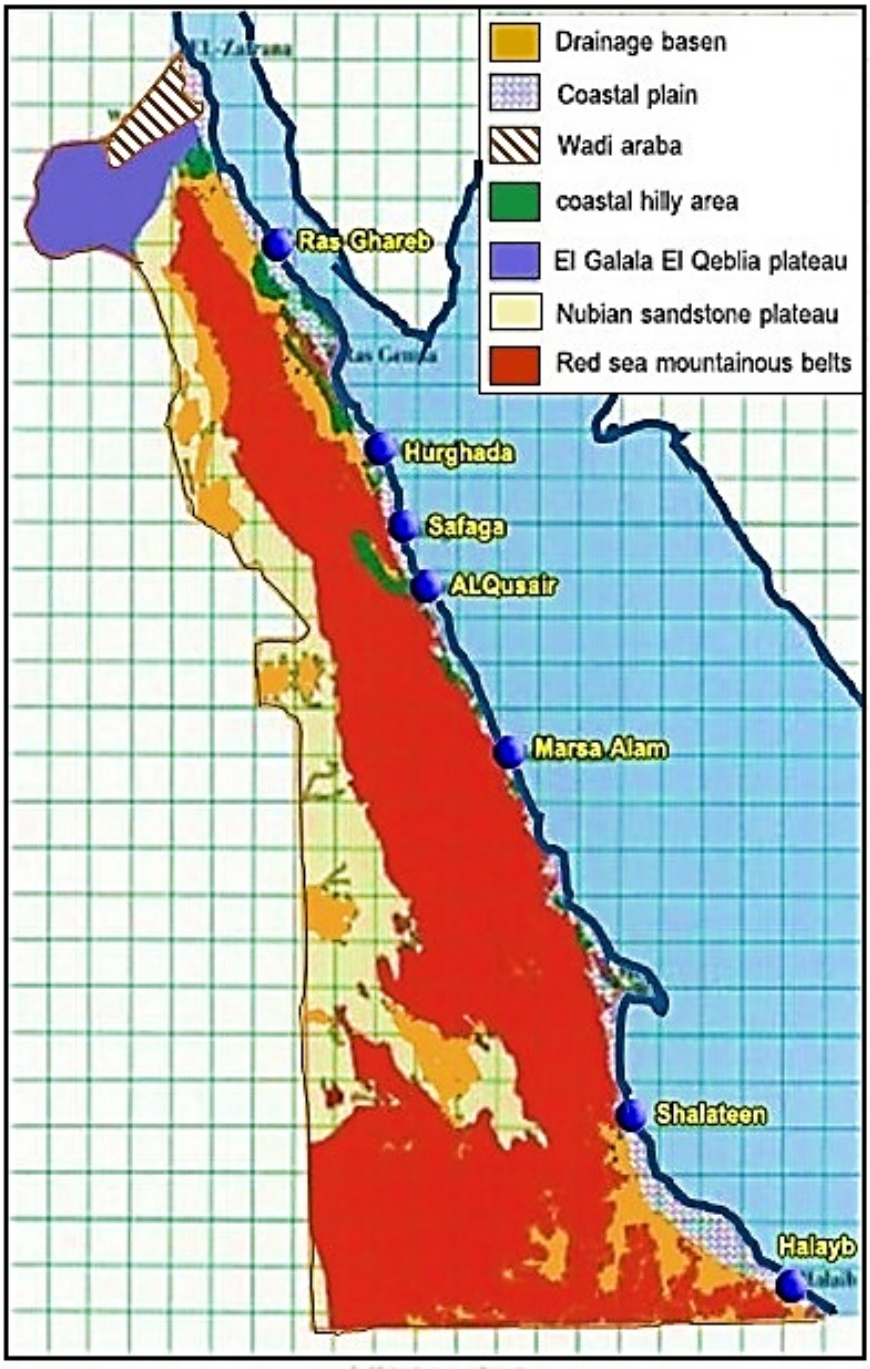


Figure 3. Geomorphological map of the red sea coast; Adapted from [38].

3.2.1. Topography and Geomorphology of the Cities of the Red Sea Coast

The surface of the land in the Red Sea Governorate is very tortuous, with mountainous masses emerging, and the coastal plain is somewhat flat. The general slop is towards the east and west, and the slop is rapid and sharp towards the sea in the east, while it is relatively gradual towards the Nile Valley in the west [38].

3.2.2. Drainage Basins of the Cities of the Red Sea Coast

The drainage network of the Red Sea region consists of four huge basins, which are from south to north [38]:

- The basins of Wadi Daib (whose sources are located in Sudanese territory)
- The western group originates from the Western Sahara.
- Wadi Hawdeen (where it is the longest valley on the coast, the largest in area, and the most numerous and longest tributaries)
- Wadi Araba, and Wadi Gharibah.

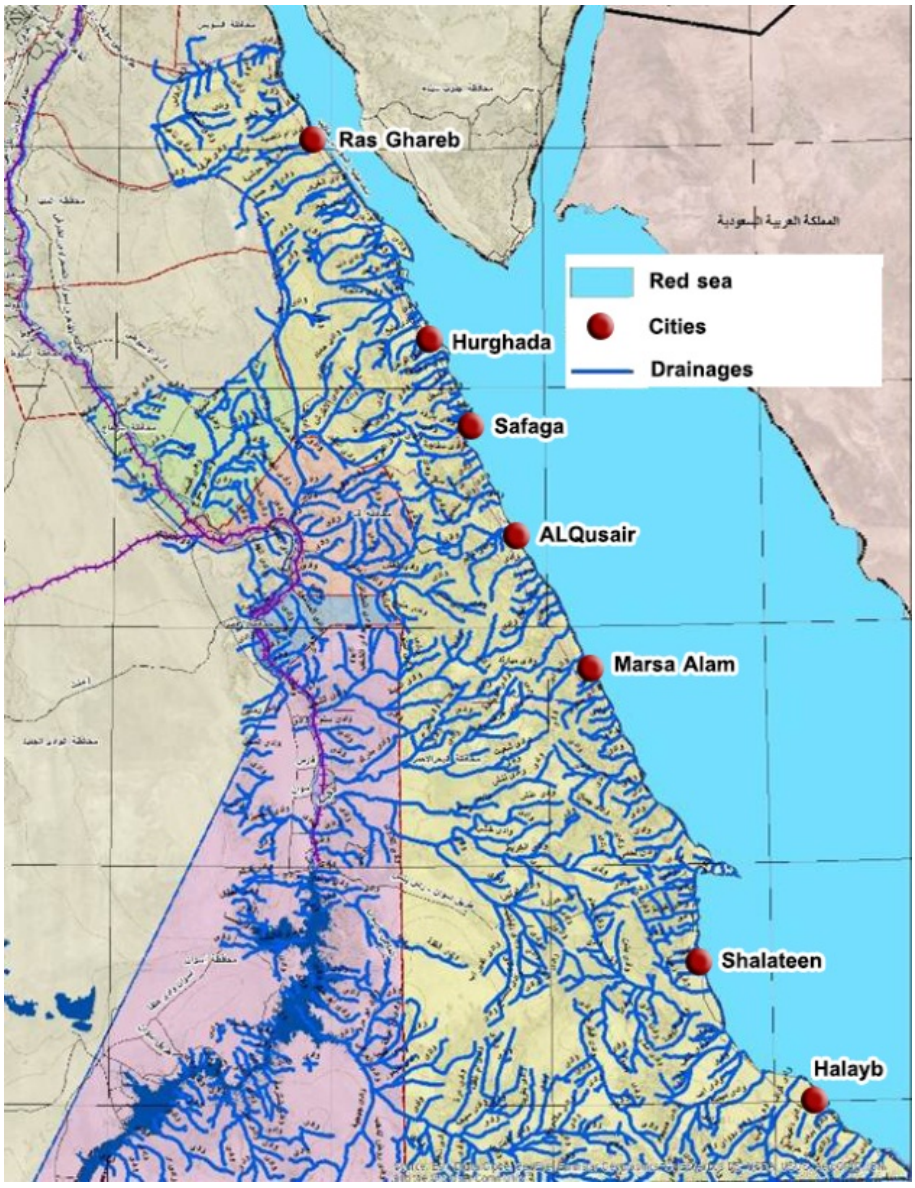


Figure 4. Drainages map of the red sea coast; Adapted from [38]

There are various forms of drainage basins in the Red Sea in general, between dendritic, parallel, and cubic. The shape of the drainage basins depends on the topographic and geological factors. The drainage basins also widen and narrow in light of these factors.

4. Materials and Data Drivers

4.1. Materials

The first stage of the research relied on secondary data/literature review to form the theoretical basis for resilience assessments and collect related indicators.

Case studies data: the application stage of the research relayed is focused on the indicators, which included both qualitative and quantitative data types. However, most of the indicators are qualitative especially related to the economic and demographic dimensions, they directly transformed into percentages then to decimal scale. While some qualitative indicators included in the environmental, physical and governance, their data was evaluated in ordered categories, then transformed into the same decimal scale (from 0 to 10).

4.2. Data Drivers

Data availability is avital for the applicability of any indicator-based tools, especially with a large number of indicators and especially when applied in developing countries. So, the available data drivers were considered from the designing stage of this developed tool. Two main data drivers were used to cover a good proportion of the indicators of the case studies: the census of population and the census of buildings; and both of them are nationally produced every 10 years. However, reports of

strategic planning of the case studied were used to cover most of indicators related to urban areas, services, infrastructure, natural environment, etc. The reports of the strategic planning of cities were used, particularly in the application to ensure the targeted integration between the developed tool and strategic planning. Satellite data sources were also, used to cover the indicators of flood exposure.

5. Research Results

5.1. Tailored Indicator-Based Tool to Assess Resiliency of the Egypt Coastal Cities

The main result of this research is a resiliency assessment tool which considers the local context of the Egyptian coastal cities. This included: dimensions of assessment, tailored set of indicators for each dimension, weights of indicators within their dimension, and weights of dimensions to help producing final value of resilience. Table (4) shows details of the developed tool. It includes 42 indicator covering six dimensions (i.e. Environmental, Physical, Demographic, Economic, Governance, And Socio-Cultural). The weighing system gives the environmental characteristics the top priority, followed by the physical, however, the economic and the governance took the next level, and the people related dimensions took minor levels of weight. Some highlights could be stated for each dimension could be stated, as follows:

- The environmental dimension: three indicators dominate this dimension: exposure to hazards, topography, and precipitation rates. They are representing vulnerability. However, the other indicators representing controls and mitigation factors took relatively less importance.
- The Physical dimension: the most dimension represented in a big number of indicators (i.e. 14 indicators) the regional controls of hazards, such as the number of dams took the top priority, followed by the construction and networks related indicators. The other indicators representing helping factors in the emergency time, such as main roads, green areas, shelters/ temporal accommodation came by the end of the importance levels.
- Economic dimension: level of income and diversity of economic base took the top importance as they reflect the satiability of the community.
- Governance dimension: raises the importance of dynamic adaptive planning and availability of shelters for emergencies, or in other words: the preparedness of the community to mitigate any natural hazard and avoid damages.
- The demographic dimension: highly considered the vulnerable/ weak categories of society, especially in case of emergency (e.g. children, old people, disabled people, etc.). On the other hand, the increase in the labor force is seen as a supportive factor.
- The socio-cultural dimension is reflected in some physical components, such as social and educational services as priority supportive factors while crowding rates reflects the vulnerability to hazards.

Table 5. Weighing system of the developed tool

Dimension	Indicators	Indicators weight	Dimension weight
DEMO-GRAPHICS	Ratio of males to females in population	0.30	0.07
	% Labor force employed	0.44	
	% Labor force employed by government	0.07	
	% of the population under 15 and over 65 years	0.20	
ENVIRONMENT-AL	Hazard exposure and mapping	0.40	0.35
	Effectively managed protective ecosystems	0.09	
	Average days of over 80 mm/day precipitation	0.23	
	Average elevation	0.18	
	The percentage of green areas	0.04	
	% of Cultivated area	0.07	
GOVERNANCE	Accessible critical emergency facilities	0.11	0.11
	Proximity of county seat to state capital	0.07	
	Major road egress points per 10,000 persons	0.16	
	Legal/Security services	0.12	
	Shelters availability during emergencies	0.31	
	Novelty of development plan	0.23	
PHYSICAL	% of weak dwelling types (wooden,..)	0.12	0.23
	Percent of impervious surface and urban areas	0.11	
	Number of dams	0.15	
	Hotels/motels per 10,000 persons	0.06	
	Distribution of commercial Facilities	0.05	
	Distribution of Cultural Facilities	0.02	
	% households with electricity supply	0.10	
	Access to adequate sanitation	0.09	
	Aviation /airports	0.03	
	Number of Bridges	0.05	
	Number of Highways	0.08	
	Number of Railways	0.04	
	Number of Waterways	0.05	
	Coverage with a good water network	0.03	
ECONOMIC	Distribution of employment over economic sectors	0.17	0.18
	Home ownership	0.09	
	Access to saving and credit facilities	0.08	
	Level and diversity of economic resources	0.19	
	Labor force ratio	0.17	
	Housing levels	0.30	
SOCIO-CULTURAL	Access to social services	0.13	0.05
	Sport and recreation	0.03	
	Child and Elderly Services	0.08	
	Education Services	0.15	
	Health services	0.22	
	Hospital beds per 10,000 persons	0.22	
	crowding rate	0.18	

Source: Author

5.1. Results of testing and applying the developed tool using multi-case studies

Testing the developed tool through a multi-case study application showed a high level of applicability and the results reflected the differences between them. All the indicators of the developed tool were assessed for each of the eight case-studies; and a resilience index for the cities of the Red Sea was produced. The bar chart in figure (5) shows the overall index of the case studies. The main results of resilience assessment can be highlighted as follows:

- The Resilience index: Hurghada came at the top of the index with a notable difference from the next city of Ras-ghareb. Also, the index clearly showed different levels of resilience among the next three cities. However, EL-Qusair came by the end of the in with a minor difference with its earlier city Marsa-Alam.
    - Dimensions of Resilience: In general, the environmental dimension witnessed a significant decline in resilience for all the case studies. This could be explained due to the

geomorphological attributes and the difficult terrain of the Red Sea regions. The environmental resiliency of Marsa-Alam, El-Qusair, and Safaga dramatically reached the lowest degrees. As for the urban dimension, which is the focus of this research, Hurghada also topped the results, and the cities of Halayeb and Shalateen, with their small size and limited scattered urban mass, fell sharply. On the contrary, Shalateen scored the highest results in the governance dimension. This can be explained, as well, because the city has received a concentration of emergency and security services to support its regional role in the far south of Egypt.

- Hurghada: The results indicate a notable equilibrium of the different dimensions in the city with some superiority in the economic dimension and a relative decrease in the environmental dimension.
- The detailed results of resilience assessment for each city - in both levels of indicators and dimensions- could advise urban planning to achieve sustainability, especially the indicators related to physical, governance, and environmental dimensions. However, indicators of other indicators (socio-cultural, economic, and demographic) also, reflect the community's needs for specific services. See figures (7) and (8).

6. Synthesis

The research has developed an indicator-based resilient assessment tool, which considers the local context of Egyptian coastal cities. The case studies application showed a high applicability of the tool; and produced a resilience index of the coastal cities of the red sea region. The results on both the dimensions' level and the indicators level could be considered a very powerful decision support tool, as they clearly highlight gaps and priority dimensions for the urban/city planner and managers to work on. Also, the overall Resilience Index could inform and support regional development plans.

List of Acronyms

CRM: Community Resilience Manual

DEMTAL: The Decision-Making Trial and evaluation Laboratory

PEOPLES: Population and Demographics, Environmental/Ecosystem, Organized Governmental Services, Physical Infrastructure, Lifestyle and Community Competence, Economic Development, and Social-Cultural Capital.

CRC: Cooperative Research Centers

CRDSA: Community Resilience factors to Disaster in Saudi Arabia

DRI: Disaster Resilience Index

CDR: Community Disaster Resilience

CoBRA: Community Based Resilience Analysis

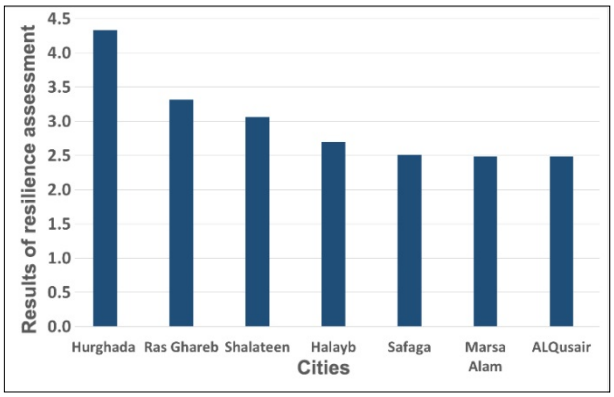
CRF: City Resilience Framework

LDRI: Localized Disaster Resilience Index

CRI: Coastal Resilience Index

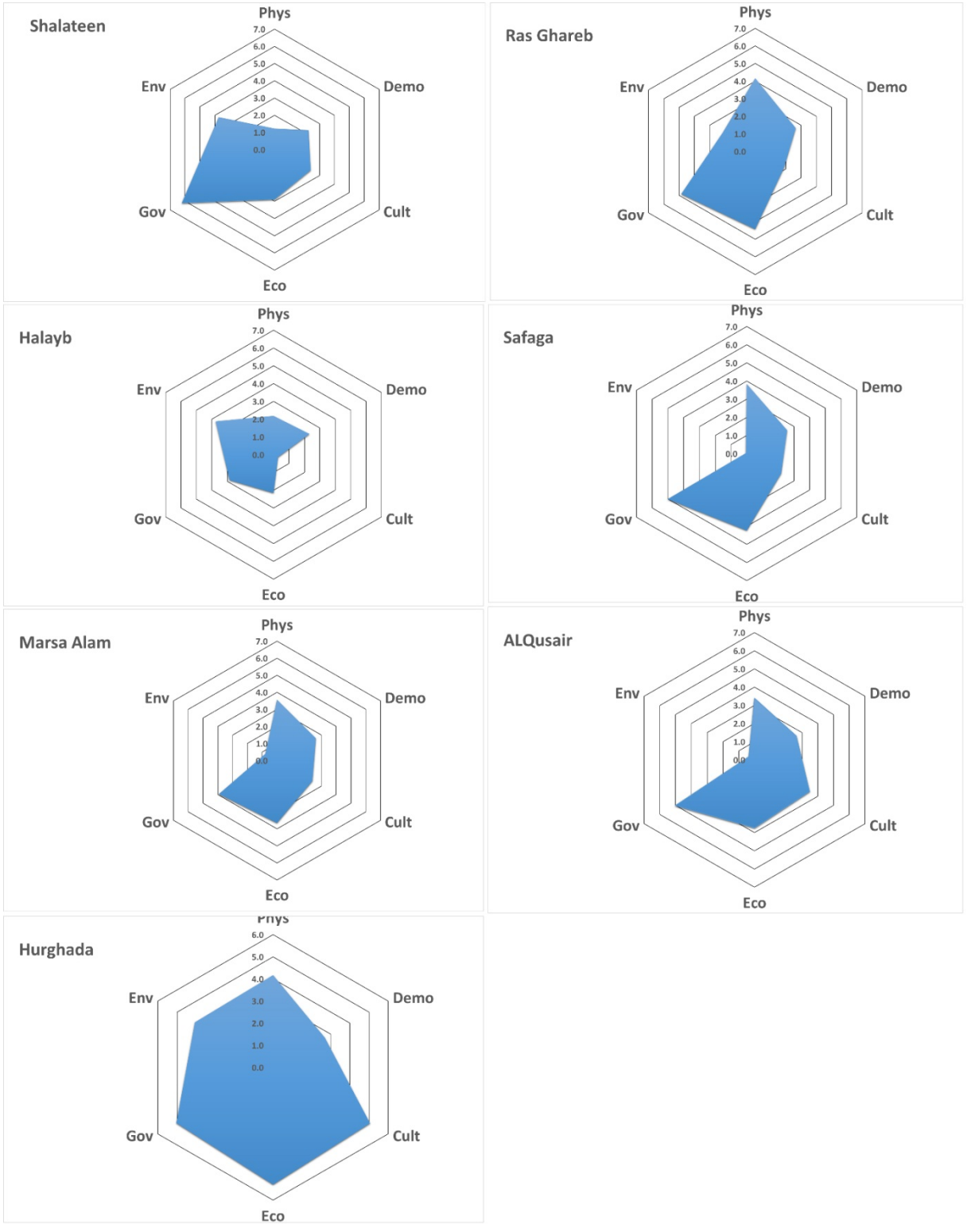
BRIC: Baseline Resilience Indicators for Communities

CERI: Community Economic Resiliency Initiative



Source: Author

Figure 5. Resilience Index of the Egyptian Red Sea Cities using the developed tool



Source: Author

Figure 6. Results of applying the developed assessment tool on the case-studies – Main Dimensions of Resilience

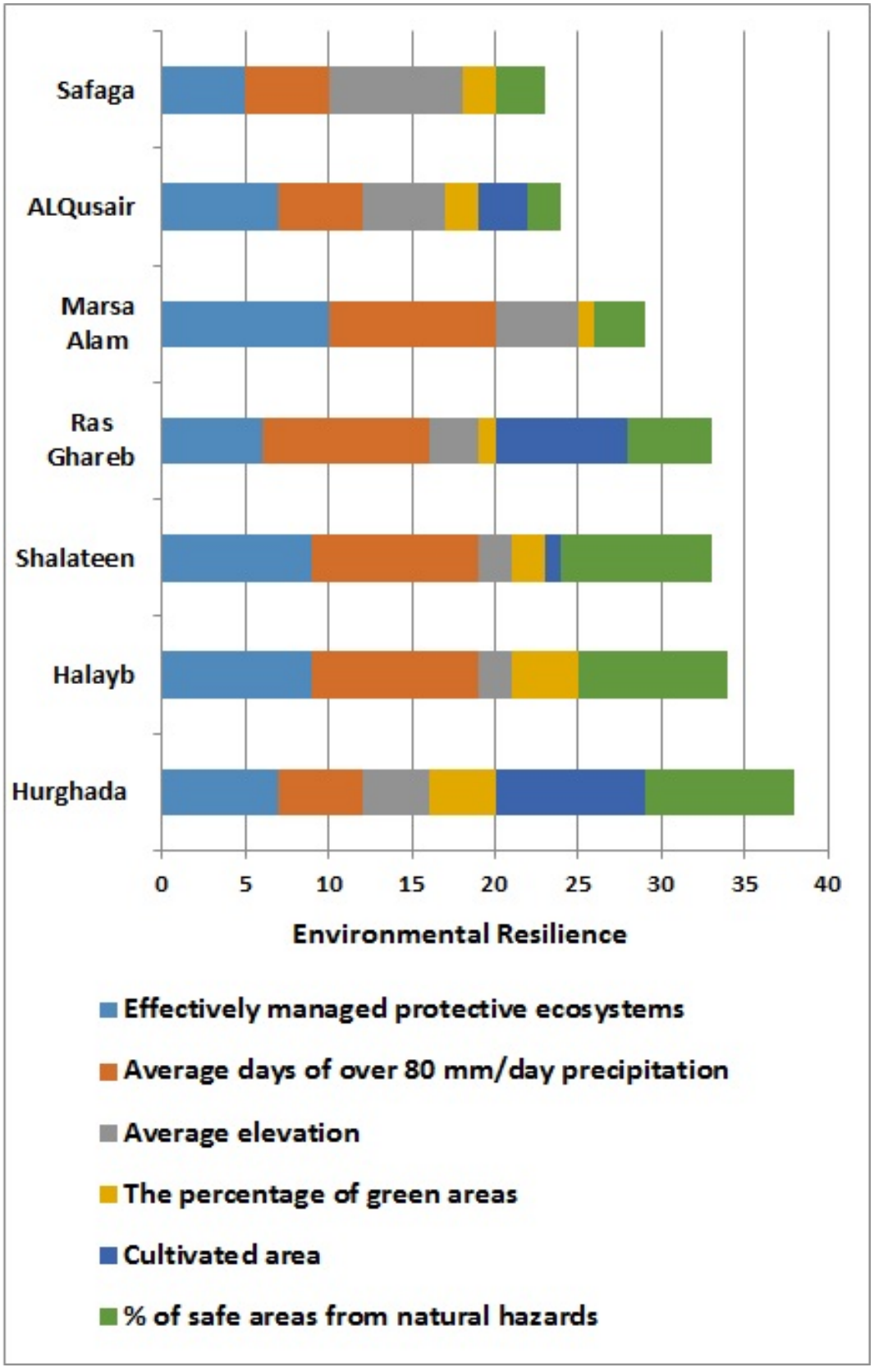


Figure 7. Environmental Resilience of the case-studies – indicators level

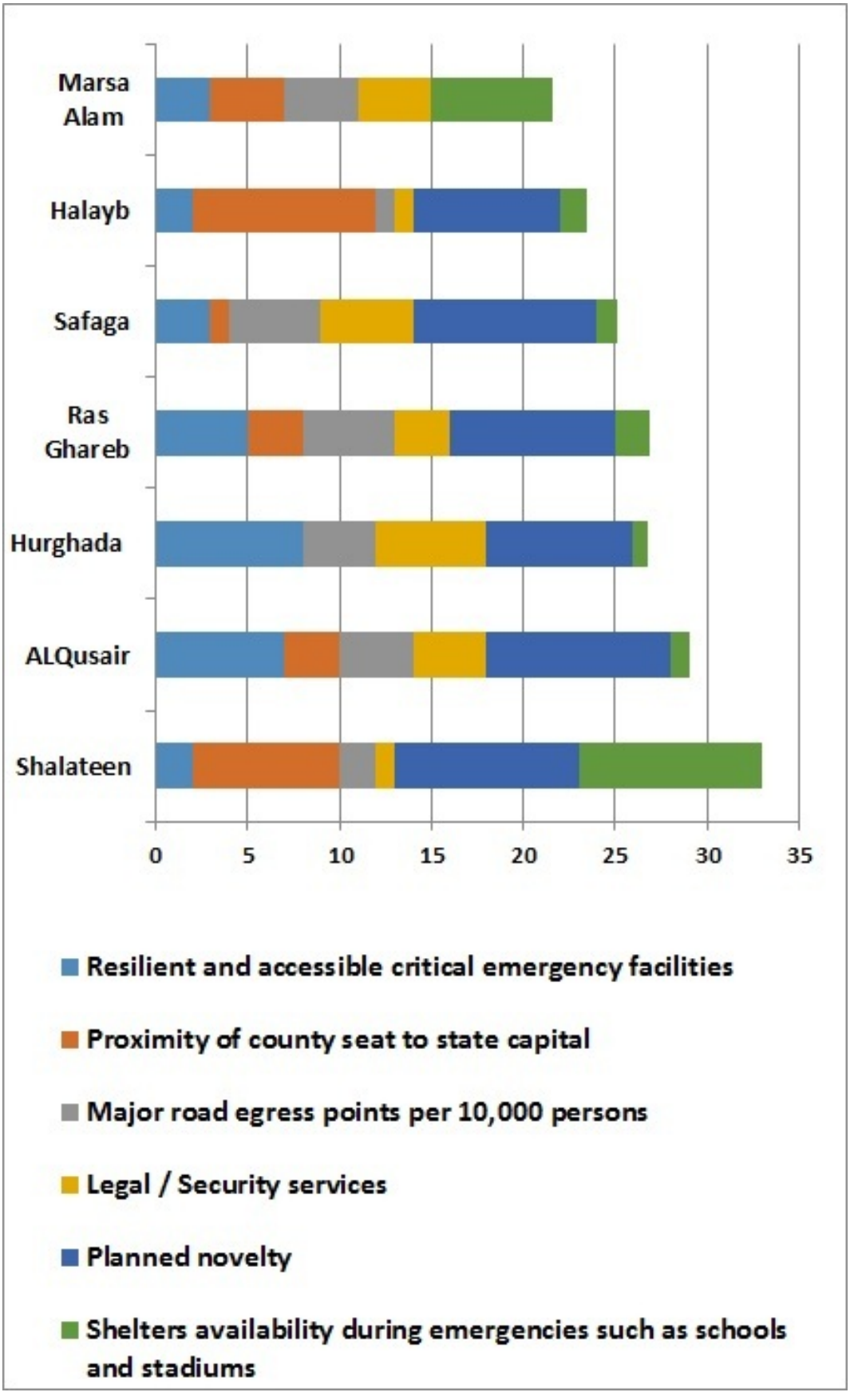


Figure 8. Governance Resilience of the case-studies – indicators level

Acknowledgments

We are very grateful to the international conference of "Contingency Planning and Adaptive Urbanism" for supporting publication of this piece of research.

REFERENCES

[1] Sharifi, A.; Yamagata, Y. Resilience-Oriented Urban Planning. In Resilience-Oriented Urban Planning: Theoretical and Empirical Insights; Yamagata, Y., Sharifi, A., Eds.; Springer International Publishing: Cham, Switzerland, 2018; pp. 3–27.

[2] Leichenko, R. (2011). Climate change and urban resilience, Current opinion in environmental sustainability. Amsterdam: Elsevier, 164–168.

[3] Sharifi, A. A Critical Review of Selected Tools for Assessing Community Resilience. Ecol. Indicat. 2016, 69, 629–647.

[4] Sharifi, A.; Yamagata, Y. towards an Integrated Approach to Urban Resilience Assessment. APN Sci. Bull. 2017, 7.

[5] MunichRe, 2015. Loss Events Worldwide 1980–2014. Munich Re.

[6] Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E.,Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R., White, L.L., 2014. IPCC, 2014: climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral aspects. In: Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press Cambridge, United Kingdom and New York, NY, USA.

[7] Renschler, C., Frazier, A., Arendt, L., Cimellaro, G.P., Reinhorn, A., Bruneau, M.,2010a. Developing the 'PEOPLES 'resilience framework for defining and measuring disaster resilience at the community scale. In: Proceedings of the9th US National and 10th Canadian Conference on Earthquake Engineering(9USN/10CCEE), Toronto, pp. 25–29.

[8] Elmqvist, Thomas. (2014). Urban resilience thinking. Solutions. The Solutions Journal, 5. 26-30.

[9] Matyas, D., Pelling, M., 2015. Positioning resilience for 2015: the role of resistance, incremental adjustment and transformation in disaster risk management policy. Disasters 39 (Suppl. 1), S1–S18.

[10] Sharifi, A., Yamagata, Y., 2016. Principles and criteria for assessing urban energy resilience: a literature review. Renewable and Sustainable Energy Reviews. 60, 1654–1677

[11] Sharifi, L. Chelleri, C. Fox-Lent, S. Grafakos, M. Pathak, M. Olazabal, et al., Conceptualizing dimensions and characteristics of urban resilience: insights from a Co-design process, Sustainability 9 (2017) 1032, https://doi.org/10.3390/ su9061032.

[12] D. Serre, C. Heinzlef, Assessing and mapping urban resilience to floods with respect to cascading effects through critical infrastructure networks, Int. J. Disaster Risk Reduct. 30 (2018) 235–243.

[13] C. Folke, S.R. Carpenter, B. Walker, M. Scheffer, T. Chapin, J. Rockstrom, Resilience thinking: integrating resilience, adaptability and transformability, Ecol. Soc. 15 (2010).

[14] C.S. Holling, Resilience and stability of ecological systems, Annual Review of Ecology and Systematics. 4 (1973) 1–23.

[15] Steve Carpenter, B. Walker, J.M. Anderies, N. Abel, from metaphor to measurement: resilience of what to what? Ecosystems, Springer-Verlag, 4 (2001) 765–781.

[16] D. Matyas, M. Pelling, Positioning resilience for 2015: the role of resistance, incremental adjustment and transformation in disaster risk management policy, Disasters (2015).

[17] Wardekker, B. Wilk, V. Brown, Assessing Urban Resilience in Rotterdam Using Resilience Principles: Workshop Report, Copernicus Institute of Sustainable Development, Utrecht University, 2017.

[18] Bui, H. T., & Saito, H. (2022). Resource convergence for post disaster recovery. Annals of Tourism Research.

[19] Anitha, S. (2020). The Importance of Disaster Recovery Planning. IJARIIE.

[20] Huicong Jia, F. C. (2021). Adaptation to Disaster Risk - An Overview. International journal of environmental research and public health.

[21] Brian Walker, C. S. (2004). Resilience, Adaptability and Transformability in Social–ecological Systems. Ecology and Society.

[22] Renschler, C. S., Fraizer, A. E., Arendt, L. A., Cimellaro, G. P., Reinhorn, A. M., & Bruneau, M. (2010). A Framework for Defining and Measuring Resilience at the Community Scale: The PEOPLES Resilience Framework. National Institute of Standards and Tchonology.

[23] Parsons, M., Morley, P., Marshall, M., Hastings, P., Glavac, S., Stayner, R., et al. (2016). THE AUSTRALIAN NATURAL DISASTER RESILIENCE INDEX - Conceptual framework and indicator approach. Australia: Bushfire and Natural Hazards CRC.

[24] Alshehri, S. A., Rezgui, Y., & Li, H. (2015). Disaster community resilience assessment method: a consensus-based Delphi and AHP approach. Springer Science+Business Media Dordrecht.

[25] Khazai, B., Bendimerad, F., Cardona, O.-D., Carreño, M.-L., Barbat, A. H., & Burton, C. G. (2015). A GUIDE TO MEASURING URBAN RISK RESILIENCE - Principles, Tools and Practice of Urban Indicators. Quezon: Earthquakes and Megacities Initiative.

[26] Yoon, D. K., Kang, J. E., & Brody, S. D. (2015). A measurement of community disaster resilience in Korea. Journal of Environmental Planning and Management.

[27] UNDP. (2019). Community Based Resilience Analysis (CoBRA) Conceptual Framework and Methodology. UNDP Drylands Development Centre.

[28] Arup. (2015). City Resilience Framework. The Rockefeller Foundation - Arup.

[29] Orencio, P. M., & Fujii, M. (2013). A localized disaster-resilience index to assess coastal communities based on an analytic hierarchy process.

[30] Sempier, T. T., & Swann, D. L. (2010). A Community Self-Assessment Understanding how prepared your community is for a disaster. The University of Southern Mississippi.

[31] Cutter, S. L., Burton, C. G., & Emrich, C. T. (2010). Disaster Resilience Indicators for Benchmarking Baseline Conditions. Journal of Homeland Security and Emergency Management.

[32] Syed Ainuddin, J. K. (2012). Earthquake hazards and community resilience in Baluchistan. Natural Hazards Journal, Springer.

[33] Forman, Ernest H.; Saul I. Gass (July 2001). "The analytical hierarchy process—an exposition". Operations Research. 49 (4): 469–487. doi:10.1287/opre.49.4.469.11231.

[34] Egyptian Environmental Affairs Agency. (2008). Report on the state of the environment in Egypt. Cairo: The Ministry of Environment.

[35] Egyptian Survey Authority. (2014). Topographic Map Index. Cairo: Ministry of Water Resources and Irrigation.

[36] General Organization for Physical Planning (GOPP). (2017). Urban development strategy for coastal facades - the scope of the Red Sea coast. Cairo: (GOPP).

[37] Center Agency for Public Mobilization and Statistics. (2017). general population census. Cairo: Capmas.

[38] General Organization for Physical Planning. (2019). The strategic plan for the Red Sea Governorate. Cairo: GOPP.