Using flood map analysis for coastal city resiliency and sea rise level adaptation plan.

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Abstract. The sea-level rise SRL as a problem exacerbated by climate change, is the biggest disaster for coastal cities, especially for the low elevation areas, which will have a calamitous influence on, infrastructure systems destruction and the economy as well. The predicated SRL is changeable every day, therefore exposures studies are essential to prepare the database for achieving the coastal cities’ resiliency, mapping the predicate vulnerability level, indicating all challenges related to the climate changes and sea rise level, and identifying plans for adaptation measures in the context of infrastructure systems. The purpose of the research is to focus on using a “Flood Map “and remote sensing on “Alexandria city – Egypt “which has high economic value. The study is based on making maps overlapping (topographical map, land use, and expected SRL in 2100) to measure and provide precise data for the prone zone and safe zone for city extension, by specifying many scenarios and plans that can achieve future city resilience by creating an end-map user.to address the right direction of city expansion. Finally, the study has shown that a flood map is very helpful and it could be used aligned with a full existence and clarity of all-natural and built environment information.

1. The first section in your paper
A variety of studies have discussed the issue of coastal hazards and resilience. The Royal Institute 2010 British Architects and the College of Civil Engineers have studied existing coastal activities. Flood control in the urban sense and the prospect of coastal lines in cities in the United Kingdom (RIBA and ICE 2010 respectively) [1]. In their research, Rachel et al (2013) analyzed recent concept prototypes. They use an innovative Dutch beach-replenishment adaptive strategy known as ‘mega nutrition ‘and have been examined in some areas exposed to high relative SLR rates. In 2013, Vaz and Bowman conducted an assessment of changes in the Greater Golden Horseshoe coastline’s land use and transitions in Canada. They also suggested the standing to mutual land policies as a mitigation plan for repetitive vulnerable urban environments cases such as erosion situations (Vaz and Bowman 2013) [2]. In addition, Lee (2014) explained the importance of resilient urban development planning strategies and highlighted both the challenges and opportunities for adaptation to the SLR [3]. In addition, Elsharouny (2016) addressed the land use reforming policies and planning approach’s ability to mend waterfronts resiliency in developing countries to respond to the SLR. risks [4], and finally, Abou Samra (2017) assessed the impact of coastal flooding in northern Egyptian coastal cities [5]. The theory of smart growth is concerned with how cities can achieve resilience by predication and preparing adaptation plans
in different conditions to protect coastal cities and recover from the impacts of the dangers of climate change. The urban resiliency strategies could work with mitigation and adaptation plans in a way of protection, accommodation, retreat (the exposed elements transposing as critical infrastructure to a safer boundary), or attack actions (dealing with the problems and exploring advantages in urban planning) and besides of changing urban policies [7]. Gods chalk [8] definite resilient schemes against tragedies on six levels:

• Redundant (numerous similar components’ functions, if one fails the entire system resists)
• Diverse (several diverse components’ functions to handle numerous types of threats);
• Efficient; Autonomous (competent to function without supervision or support);
• Strong; Interdependent (components of a networked system that help one another);
• Adaptable (to achieve suppleness);
• Collaborative (numerous stakeholders’ contributions and incentives).

For saving a life, using programming aids such as Flood map application as a sensitive prediction for natural disasters, there are many different case studies applied around the world as Kerala 2018 Floods by M. Sridevi, Ireland, England, France, Germany, Netherlands, Japan, and Korea flood management by using satellite imagery, because of the Atlantic Storms continuous serial hits the country, and flooding across effectively the full country, a recovery plan on the three levels of nationally, regional and local has been announced by the government. Categorized actions varied between prevention and response and recovery. [8]

1.1. Sea rise level (SRL)

The third report projects the average of SRL by 15cm to 95 by 2100 around Africa (IPCC,2001) [10], NASA [11] said that there is an acceleration of the climate change impacts and sea rise level, and the level of sea level raised 3.3 millimeters each year. Flood is causing social aspects loss, economic, and life global loss. The growing coastal settlement; river basins and lakeshores too exaggerate the losses. The Forests elimination and climate change increase the incidence and manifold the influences [12]. Flood damages could be predicted to grow fivefold by 2050 and up to 17-fold by 2080 in Europe [13]. The cost of flooding just one inch of floodwater can cause more than $25,000 in damage. Flood risk is changeable based on weather patterns, land development, and erosion. NASA is observing sea rise level tracking and the main reasons for it from space [11]. As found, the soft technologies include artificial intelligence, clean energy technology, digitalization of climate change, and big data, by using numerous types of tackle, from tidal gauges to satellite remote sensors, whose production may be merged with human involvement collected by inquiry form. In addition, geographic information systems (GIS) associate data from plentiful sources and produce a clarified map. As well, coastal areas are making intersection (SRL) scenarios on ground elevations and the development level in diverse areas to high spot the probably influenced zones – visual demonstrations that are valued for making alertness and for developing reactions as well.

1.2. Flood mapping definition and usage:

Flood mapping is a vital flood risk management instrument to evade or diminish the life property and loss produced by flood, for interactive flood risk, nevertheless, maps are never prevented flood occurrence. Maps like a Flood hazard map identify the scope besides projected water depths/levels of flood for each area in three levels, a low/medium and in case of high possibility scenario or extreme events. While this map expresses population kind, economic zones, and natural environment at submerging probable danger. (Figure 1)

Flood map importance is the soft adaptation instrument to lead to proper and safe development, warning tool, and to moderate future losses. To organize land use, building policies and codes, infrastructure, transportation networks, flood cautioning, and alternative evacuation management planning, to formulate for flood response.
Collecting data (Flood Hazard and Risk Information) for each zone of the city and continuous generation data is helping responsible authorities to identify risky zones, the proper evacuation routes aligned with the response updated plan to submerging by local authorities and alternative respondents. A legal framework must lead the flood map preparation that clearly defines the authority of producing and broadcasting flood maps, outlines roles, responsibilities, and compulsions of all elaborated departments, institutions, and other stakeholders, and puts undoubtedly defined and translucent procedures. SEPA Scottish Environment Protection Agency creates an alive flooding line website, that provides three types of messages for free early announcement of where and when flooding is probable to happen. No country is saved from flooding, like the United States. Especially caused by natural hazards and global warming, flood risk includes flood hazards, flood vulnerability, and flood exposures. [15]

The crisis of sea rise level may demolish the existing settlements and prevent city development, as flood risk may change over intervals due to weather patterns, land development, and erosion.

Alexandria city which has 5,425,625 million citizens considered the most vulnerable city of the SRL, that is why it was selected to be studied to consider the sea rise level consequence that pretentious the city, by using the soft application as ARC- GIS and remote sensing to prepare the flooding map. To measure and provide precise data for prone zones and safe zones for city extension, by specifying many scenarios and plans that can achieve future city resilience.

1.3. About the selected Alexandria city as a case study:
Alexandria Governorate is situated in the northwest of Egypt, it considered the most exposed to SLR in the Middle East and North Africa according to World Bank Report (Eldeberky 2011 & Raey 1999). [17,18]. The development plans for the city of Alexandria were based on the studies prepared for the year 2015 – explain the possibility of extending to the west of the city in anticipation and in accordance
with its striped urbanization, as well as the use of the coastal facades of the city and the exploitation of Lake Marriot in all ways. In the strategic plan for Alexandria city in 2012, attention was not given to the city’s position regarding the occurrence of any environmental problem, and the most important problem that was raised was the rise in sea level - but this proposal was taken with a controversial and uncertain problem.

Alexandria’s Population in 2013 was 4,345,193, growing at a regular yearly rate of 2.3% since 1999. Alexandria's Population in 1999 was 3,132,780, growing at a usual yearly rate of 1.8% since 1987 when its population was 2,558,891. The population forecast will form the basis for the next planning phases of Alex SUP 2032 in helping to address the needs to provide for new housing units, required social services, as well as the creation of new job opportunities for a growing population. This will be critical as the population projection indicates an increase of 2,441,930 inhabitants for Alexandria by the year 2032, also planned and highlighted the northwest and waterfronts as the development area [19].

**Table 1:** Alexandria’s demographic and job-based forecasting. [19]

|                      | 2010    | 2020    | 2032    |
|----------------------|---------|---------|---------|
| Demographic Forecast | 4,437,722 | 5,254,700 | 6,339,025 |
| Job-Based Forecast   | 4,488,940 | 5,763,730 | 7,214,117 |
| Balanced Forecast    | 4,463,331 | 5,509,215 | 6,776,57 |

2. **Materials & Research Methodology**

The research objectives include:

- Highlight the importance of soft adaptation technologies all over the world.
- To identify the maximum potential risk of the 3-meter SRL by using the soft technology of adaptation, a “flood map” will help in the identification of the most effective action to bring about flood risk and develop plans to tackle flooding.
- Creating an End-user map as an emergency planning guide and risk management: maps are a significant tool to establish primacies since the maximum risks should be moderated first. Clarify the areas under risk and give clear data for Alexandria city.

The research will be following the below steps to prepare an Alexandria flood map:

**2.1. First, determine flood event scenarios.** by considering the low and extreme predicted sea rise level scenarios (from 1m to 3m until 2100 – based on figure 1) in Alexandria city. [20]

![Figure 3: Digital elevation map for Alexandria](image3.png)

![Figure 4: It is showing the flooding probability in case of sea rise by three-meter height.](image4.png)
2.2. Using a Digital elevation map (DEM) by collecting required data (such as topography, terrain, and hydrological). (Figure 3) [21,22,23]

2.3. Creating flood hazard modeling based on DEM, by using GIS and Flood Map web. Simulating two scenarios 1m and 3-meter SRL. (Figure 4)

2.4. Community modelling: by creating a database for the building’s characteristics (building materials, number of stories, building use, archetypes, foundation type, first-floor elevation, ground elevation, building area, attached garages, maintenance status, and all infrastructure. To identify the urban factors affecting the applicability of resilience methods of application. The application allocates flooding probability, to take proper action alike a retreat or protect or accommodate.

2.4.1. Urban Extent: Alexandria’s Urban Extent towards the east in 2013 was 30,418 hectares, growing at a regular yearly rate of 2.8% since 1999. While 1999, it was 20,356 hectares, growing at a regular yearly percentage of 6.2% since 1987 while the urban expanding almost 9,993 hectares (Figure 5).[24]

2.4.2. Urban Density: In 2013, Alexandria’s built-up area density was 191 persons/hectare, reduced by a regular yearly rate of -0.4% starting from 1999. The density of the urbanized areas in 1999 was 202 persons/hectare, decreasing at a regular yearly rate of -4.2% since 1987 when the density of urbanized areas was 327.29 persons/hectare. [24] Since 1999 the city extension has -0.5% decline attracting – 143 persons/hectare in 2013, while in 1999 the density was 154 persons/hectare, declining at an average rate of -4.4% since 1987 when it was 256 persons/hectare. (Figure 6)

Figure 5: Map courtesy - Dr. Hany Ayad, Alexandria University

The dense incessant residential urban fabric
The streets are drawing the building limits, forming informal urban areas which are not considered slums, with 200 and 450 inhabitants/hectare average density

The averagely dense continuous residential urban fabric: It is similar to the previous urban feature, while it has a few greenery parcels with a percentage of 10-25% of the urban built area

Not much dense
The green areas are covered by 25-40% of the urban built area, with areas that are occupied by 450 and 1000 inhabitants/hectare

The discontinuous residential urban fabric
Over half of the urban fabric is segregated from the other areas

Isolated communities
As private buildings with green spaces surrounding, occupied with a population density between 100 - 200 inhabitants/hectare.
Regrouped informal housing (Slums)
The governorate's slum areas are characterized by a high density of population, poor facilities such as roads, transportation, or infrastructure, and a high rate of unemployment. They are facing environmental problems and poverty and density with an average of 1000 to 4700 inhabitants/hectare.

Disseminated informal housing might be well designed, while neither well planned nor organized. The distributed populations density in areas with less than 100 inhabitants/hectare.

2.4.3. Additional Area Configuration: Between 1999 and 2013, the Alexandria urban area grew by 7,317 hectares, it was divided into infill, extension, leapfrog, and inclusion accounting in order as 24%, 49%, 4%, 23% of the additional built-up area, while during thirty years before 1999, these percentages were 17%, 58%, 0%, 25% of the growth of 7,749 hectares. (Figure 6).

2.4.4. Roads: The main network road direction still until now as a grid of two axes, AlGayish road as the main road is parallel to the seashore long and perpendicular lanes driving through the entire built city - as Suez Canal. The width average of the road in the Alexandria 1990-2014 extension area was 9.08 meters, likened to its pre-1990 area to become 16.53 m. In 2014, the occupancy of the urbanized area in Alexandria full by roads has increased by 1.44% compared to the pre-1990 area (Figure 7) to be 23% of the 1990-2014 expansion area.
2.4.5. Blocks and Plots: In comparison between Alexandria’s 1990-2014 expansions area and its area before 1990, the average block size has increased by a percentage of 2.95% to be 5.2 hectares.

| Land-use type                        | Al-Montaza District | Sharq District | Wasat, Gharb and Al-Gomrok Districts | Al-Amreya District | Borg Al-Arab | TOTAL       |
|--------------------------------------|--------------------|----------------|-------------------------------------|--------------------|--------------|-------------|
| Residential artificialized territories | 1873.33            | 1369.01        | 1212.71                             | 9214.04            | 4307.49      | 18041.69    |
| Industrial and commercial areas      | 227.88             | 404.05         | 693.77                              | 2447.19            | 1049.70      | 4876        |
| Storage place and Warehouse          | 15.27              | 4.22           | 48.33                               | 489.69             | 0            | 558.33      |
| Harbour Areas                        | 72.63              | 0              | 134.47                              | 254.25             | 0            | 544.43      |
| Airport                              | 0                  | 4.02           | 297.80                              | 2911.78            | 933.36       | 4147        |
| Facilities                           | 655.34             | 237.69         | 334.24                              | 791.40             |              |             |
| Cemetery                             | 8.44               | 2.50           | 59.16                               | 4.64               |              |             |
| Mines, landfills and worksites       |                    |                |                                     |                    |              | 4435        |
| Urban green areas                    | 4.74               | 59.35          | 12.45                               | 37.81              |              | 124.42      |
| Sports and leisure facilities        | 161.01             | 110.48         | 40.89                               | 66.58              |              | 405.72      |
| Agricultural territories             | 3733.23            | 963.69         | 49.88                               | 69485.75           |              | 94886.01    |
| Orchards and small fruit             | 0.51               | 0.99           | 82.14                               | 238.91             | 1784.59      | 2024.99     |
2.4.6. Urban Patterns: A Variety of Residential Land-Use Patterns from the Alexandrian Cityscape are analysing the urban fabric of Alexandria one can identify five distinct spatial patterns, each of which features a class of sub-patterns. Certain topographic, historic, functional, and spatial features define each of the main pattern groups. The map on the next page shows the extent and location of the five main patterns (Figure 8).

2.4.7. Buildings conditions: The most observed building construction in the most was used of reinforced concrete, and different types were found at the back of the city. As (Figure 8)

2.4.8. Building Height: A high percentage of the newest constructions were 5 to 13 floors – all older buildings were between 3-5 floors. (Figure 9)

2.4.9. Building Structure System: Over 60% of the buildings were in a good condition while there is a large number of buildings that need maintenance and reinforcement, A few percentage needs for rebuilt in all of their bad condition (Figure 10).

2.4.10. City land use: The most of residential uses took place on waterfronts- parallel to the sea edge or Marriott Lake Edge. The agriculture zone is extending back to the city by twice times of residential areas.

2.5. Assessment methodologies

(Identify the exposure areas and their risk level between high, medium, and low). Flood exposure can be identified by matching and overlapping the flood map with the community model to find the building which will be affected by flooding. [25]

2.6. Map products

Flood vulnerability means estimating the damages by vulnerability analysis methods- if the big data of building elements in the community are available, it will facilitate damage categorization, then planning for the adaptation starts based on the level of damage. That leads for establish a comprehensive plan on different aspects, by creating a database of the current circumstances concerning all urban fabric and buildings’ characteristics, conditions, values, and kinds of householding, and investigate the level of resilience in each expected scenario and each area vulnerability to submersion events. This study will be followed by generating the zone map to show zone categorization according to risk levels and interferences are compulsory for more resilience levels. Identify mitigation and adaptation plans, and an end-user map (The end-user map expresses diverse planning issues and are developed according to the necessity).

3. Results and discussions

In case of no action is taken on the global or national level for mitigation, a 1.0-meter SRL level will submerge about 30% of the city. While the case of increasing the level to 3-meter height, the loss will
be over 50% including residential areas, agriculture zones, industrial, leisure spaces, and ports in the North West. 

The overlay flood map showed:

The most threatened area as shown in (Figure.12) was the back of the city which is the lowland that connected with the delta, which extended to submerge the area around the lake of Marriott – some points there may have a 10-meter water elevation because it is 7 meters below the sea-level. The study showed the sinking of the international coastal road as well as Al-Azab such as Al-Qurashi, Al-Tawfiqia, Al-Prince Al-Bahariyah, Khorshid Al-Qibliya, Al-Maraghi, Al-Boss, Al-Dhaif, Green Palace and Shooting Club, Izbat Wadi Al Qamar, Al Dekheila, and Hanovil, and Izbat Omar Abu Hafizah, in addition to, the Waterfronts will be affected and submerged as eastern and western ports and their infrastructure. 100% loss of agricultural zones has been found, the fatal effect of damage in the heritage area as Qaitbay citadel, and Maria area in Wadi Marriott required a specific action. Northern west beach and resorts are at risk of damage in its construction. All areas that have been backfilled of the original lake Marriott body will return to be covered by water again which conveys the risk in construction investment around the rest of Lake Marriott. Some areas in the built areas will be treated and may it couldn’t have stayed in the long duration of the flood.

The west south of the city as Borg Al Arab and Wadi Al Natron are the safe places for constructing new settlements, in contrast to, the comprehensive plan of Alexandria 2032 which planned and highlighted the northwest as the development area.

Figure 12: Simulation for SRL 3 m height in Alexandria city.

The classified as
- The safe places
- The prone areas for SRL as full submerged areas
**Table 2: Example of urban planning recommended actions**

| Urban planning recommendation                                                                 | Intervention level | Within 5 years | Before 2050 |
|-----------------------------------------------------------------------------------------------|--------------------|----------------|-------------|
| Multiple Risks Management                                                                    |                    |                |             |
| Implement building and urban procedures                                                       | National action    | Required       |             |
| Adaption and mitigation plan for the climatically changes                                     | Regional action    | Required       |             |
| Positive measures for protective city population vulnerable as Abo Qir area                   | Local action       | Required       |             |
| Measures for preventing disasters in areas prone to SRLs: as El-Max Bay                       | Local action       | Required       |             |
| Climate risk sensitivity city map testing for the expected new expansions                      | Regional action    | Required       |             |
| Management of ground instability/seismicity                                                   | Regional action    | Required       |             |
| Flood control                                                                                 |                    |                |             |
| Runoff management plan in future urban development                                            | Regional action    | Required       |             |

3.1. **End-user map**

After analyzing and preparing the project identification, action plans should be addressed based on the flooding map and current situation that help in institutions and urban planning. The end-user map will draw the objectives for the strategic plan for the city resiliency until 2047 and 2100. By addressing the defense actions, retreat actions, urban expansion policies, and raising public awareness.

For urban expansion and Population displacement to avoid SRL flooding risk, it is mandatory to select all safe areas southwest of the city (Figure 13), this new settlement will be including a new industrial zone, housing project by enhancing infill land with a mixed-use vertical housing project, providing affordable housing in the new settlement in a safe place of hazards, upgrading slums by creating affordable housing in the old building areas.

The required defenses actions: (at A regional level) are including buffer areas designed by natural elements along the coastline and delta, substituted as shield precincts, making fitting defences systems to avoid SRL by using breakwaters, coastal armouring, and seawalls even movable or fixed barriers (Figure 14).

Protect El Max marine and AlDikhila, AboQir as well as raising the level of the beaches North of Abu Qir, Alexandria, East to West, Ajami shores resort, the beaches of the North Coast tourist villages to rise 3 meters above sea level. And all the industrial drying beaches along the northern coast of Western Sahara through raising the water level to the same extent over the sea level, taking the necessary action to protect all residential and tourist threatened amenities, with raising the level of the industrial city of El Arish Beach new (Western) of the same height. And sing all of these coastal defences on plans to dump water and drained away from the sea, SRL may rise the winter wave’s height and its ability to overcome some of the barriers to natural or industrial along the shoreline, plan to create a network of pipes or channels to dump water will penetrate coastal defences along the coast and cash in low desert areas away from the beach, the sea serves as a bank for seawater, so it is inevitable for the search for non-conventional policies to protect the Egyptian territory from SRL risks, transforming the threat into an opportunity to maximize the water in power plant.

Elevated development might be involved in the new construction and upgrade defense action plan of the regional mobility network, which should include replacing the train line with a metro high-speed line, (Figure 15) which should be an elevated monorail to connect the city district with the line of the safe place (evacuation speedy lanes for Creating evacuation plans) towards the safe areas (Figure 16). In addition to, upgrading the cars, bicycles, pedestrian network and replacing the traditional bus with a floated bus (such as the Dutchman bus in the Netherlands) to be used as a seaway using clear energy. A
floatable road system would be ideal along the south waterfront, upgrading the existing road net to integrate supplementary exits and entries to the areas.

One of the most vital components for decreasing damage in future catastrophes is achieving an adaptable urban environment to a natural dynamic force, by properly zoning sensitive areas and taking the susceptibility of hazard-prone locations into consideration, and changing the urban policy consider a must, by controlling building heights and open space allocation and population density reduction of the vulnerable urban fabrics. Executing a comprehensive resilience plan for the steady urban policies. In addition, protecting strategies for monumental places and cultural landmarks is one of the important objectives, otherwise, the retreat action should be taken.

Infill threatened lands by elevated building and floated construction as the area of Al Matter Lake and all waterfront at the north and around of Lake Marriot. (Figure 17).

The retreating actions, first of all, actions are to manage the retreat and evacuation plan for the settlement and the exit from Abo Qir. Infrastructure restoration or relocating or establishment. On the other side, the historical building located in the submerged areas should be moved away from the heritage building to safe areas, otherwise, protection is a priority.

Establish a monitoring unit, by using a prompt warning national system, backup reaction and withdrawal plan, public data and alertness approach, and office management to raise public awareness, this kind of system should be connected by a software application to reach rapidly the city inhabitants.

![Figure 13: Safe areas of flood, considering its height characteristic](image13.png)

![Figure 14: Waterfronts’ ideas for protection, including living shore line, coastal armouring, etc. [20]](image14.png)
Figure 15: Emergency transportation Plan - rail speed from the new terminal to the old city Center. Monorail along Al Mahmoudia Canal and Under the Track along the Suez Canal axes overlapping with the other line from abo Qir to al Shohada train station linked by the waterfront of the sea and construction road to Borg Al Arab. Elevated the construction road level. Monorail above the Suez Canal.

Figure 16: Regional Transportation project

Figure 17: Infill threatened lands by elevated building and floated construction
4. Conclusions
Soft technologies such as the flood map analysis are vital in risk management in the case of data affordability, so the city should work on:
- Collecting precise data to find a suitable way of adaptation and mitigation. And for reducing future flooding damage and activate the insurance for buildings.
- These data should include the community’s flood risk zone, and its changes will affect personal property.
- Building the framework for flood mapping and development of national and regional policy.
- Activate the communication with the community to high rise public awareness of flood risk to update the public on current risks, in addition, to asking community volunteers to support in collecting of information.
- Incorporate sea level rise adaptation into redevelopment urban policies.
- Keep monitoring and updating the emergency plan, and provide transportation means to ensure safety for the community and link the safe zone with the prone ones.
- The national authorities should accelerate the application of adaptation planning to avoid high damage and loss of resources and human lives.
- In the case of Alexandria city exposures, regional planning is needed to maintain the right way of ensuring resilience for the whole country of Egypt and Alexandria as well.

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