DESIGNING AND MODELLING COAST MANAGEMENT GIS FOR BOSPHORUS

M. U. Gumusay [a, *], O. Ozdemir [b], T. Bakirman [a]

[a] YTU, Civil Engineering Faculty, 34220 Esenler Istanbul, Turkey - (gumusay, bakirman)@yildiz.edu.tr
[b] Olcum Muhendislik, 48700, Marmaris, Muğla, Turkey - osmanozdemir105@gmail.com

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ABSTRACT:

Web based geographic information systems (GIS) has great potential based on developments in internet and web technology. Web based GIS is a network based tool that takes advantage of internet with visualizing, analysing and accessing of distributed data and analysis functions. With the length of 30 kilometres, the Bosphorus provides an essential zone that offers great maritime traffic services. This shipping way which connects The Black Sea and The Mediterranean Sea through The Marmara Sea, has no alternative and it is substantial for economies of Black Sea countries. The Bosphorus is one of most important natural straits in the world handling 150 transit ships, 23 freighters with dangerous cargo and 2500 local transport ships with 2 million passengers on daily basis. In this study, it is aimed to create a web based GIS application for an effective coast management which includes berthing factors (anchorage areas, currents, submerged, etc.), maritime traffic factors (traffic separation schemes, traffic flow directions), closed areas and other factors (lighthouses, buoys, beacons, etc.) by digitizing printed navigation charts produced by Turkish Naval Forces, Office of Navigation, Hydrography and Oceanography.

1. INTRODUCTION

Management of the coastal zone is an essential issue due to the growing social, demographic and touristic activities and pressures that threaten its long-term sustainability (Moore et al., 1999). Any developmental activity in the coastal zone requires a clear understanding of the processes controlling coastal stability and persistence (Noujas et al., 2016). In order to practice effective coastal management system, scientists need to understand the way the natural environment and human activities are interconnected to form a system. Key aspects of the system includes four main subjects which are biological (ecosystem, species diversity, etc.), physical (topography, geology, sea levels, etc.), socio-economic (human activities, land use, etc.) and legal (resource use right, law and regulations) (Bartlett and Smith, 2004). The system consists of various topics so it needs a multi-disciplinary approach.

Coastal planning and management relied mainly on field observations and historical data. With the rapid development of computers, information and surveying technologies, geographic information systems (GIS) have revolutionized our ability to understand complex data series, interaction of coastal processes and to manage the resources of the coastal zone more effectively (Mayerle et al., 2016). The need for integration and management of all the factors and aspects related to the coastal zone requires GIS to deal with the current tasks (Rodríguez et al., 2009).

The Bosphorus is one of the busiest and narrowest water channels of the world that provides an essential zone offering great maritime traffic services. It is one of the substantial shipping way that connects the countries in the north of Black Sea and the countries of the Mediterranean for centuries, which situated in the middle of an important commerce, industry, transportation and tourism centre around where 15 million people live (Tasligil, 2004).The Bosphorus is one of most important natural straits in the world handling 150 transit ships, 23 freighters with dangerous cargo and 2500 local transport ships with 2 million passenger on daily basis.

In this study, it aimed to create a Web Based Istanbul Bosphorus GIS with physical and biological components of coast management system to aid military and civil sailors underway, which consists of information about berthing factors (anchorage grounds, depth, sedimentation, currents and submerged etc.), maritime traffic items (traffic separation schemes, traffic flow directions), closed areas, points of interest in sea surface for both sailing and berthing (lighthouse, buoy, beacon) and points of interests in land (radars, elevation points) which were derived by digitizing navigation charts produced by Turkish Naval Forces Office of Navigation, Hydrography and Oceanography.

2. METHODOLOGY

The Bosphorus provides marine traffic service area with the length of 31 kilometres. The width considered as the distance between Anatolia and Rumeli Lighthouse in the north entrance of the strait is 3600 meters. Generally the strait is wider in the northern are and it gets narrower as heading to the south. The narrowest distance in the strait is 698 meters in between Emirgan and Kanlica towns (Tasligil, 2004).

The strait has no alternative for sailing from Black Sea to Mediterranean through Marmara Sea and it is also substantial for economies of Black Sea countries. Additionally and most importantly, the residents may face great danger that may be caused by dense maritime traffic in any second. Thus, it is certain that it must be benefited from web based GIS technologies for Bosphorus which has such a significant location and maritime traffic.

* Corresponding Author

The internet changes the way to access, share and distribute information. In this way, it also changes GIS analysis and visualization methods. Web based GIS tools rapidly develop as internet and web technologies improve. Web based GIS, is a GIS tool that uses the internet to access and execute distributed data, analyses and visualizing functions (Sahin and Gumusay, 2007).

Web based GIS uses client server architecture for GIS analysis. Necessary processes are distributed between client and server. The client requests data and analysis functions from the server. The server completes the request and transmits the response or provides data and analysis functions to the client (Peng, 1999). Web based GIS is an interactive system that provides connection with Internet. Web based GIS is a distributed system that it can access data and applications in other computers in a network using internet connection. This system does not require client to have data or application as they are provided by the server once a request is made. Web based GIS is a dynamic system since data and applications are provided by the server, clients are always dynamically kept up to date with the latest information (Fu and Sun, 2010).

In this study, ArcGIS for Server and ArcGIS Online software have been used to create web services and web based GIS applications. ArcGIS for Server software creates web services that can be accessed by various ArcGIS platforms and third-party clients (Figure 1). ArcGIS Online is an online platform that provides mapping service where end user can create web maps and web applications (Figure 2). Thus, mentioned integrated systems approach creates a user-friendly environment (Law, 2013).

Figure 1. Desktop to web workflow

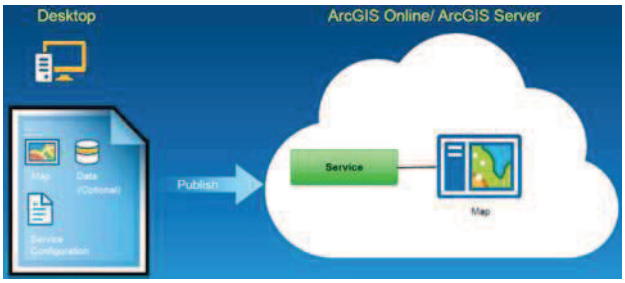


Figure 2. Creating web map

3. SYSTEM DESIGN AND MODELLING

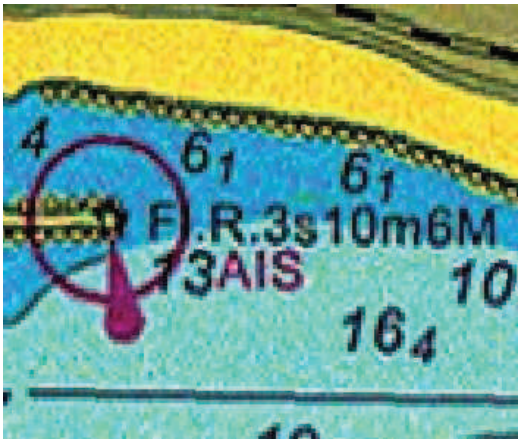
Base data source used in this study are navigation charts in different scales such as 1:60000, 1:50000, 1:30000 and 1:12500 produced by Turkish Naval Forces Office of Navigation, Hydrography and Oceanography. Maritime traffic separation schemes, flow directions and flow regulations, sea floor sedimentation, lighthouses, buoys, beacons, sea floor depths, rocks and other symbols for navigation are to be found in navigation charts.

3.1 Lighthouses

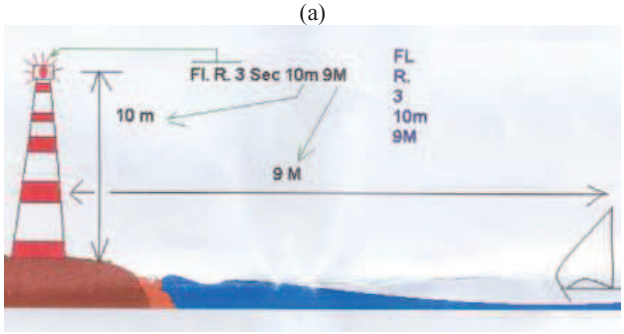
Lighthouses aid sea vehicles to locate position and direction and they can be in different shapes and forms. The abbreviation used for different lighthouses in navigation charts are listed in Table 1 and the symbology of a lighthouse can be viewed in Figure 3.

Abbreviation International	Class of light
F	Fixed
FI	Single-flashing
FFI	Fixed and Flashing
LFI	Long-flashing
W; G; R; Y	W: White; G: Green; R: Red; Y:Yellow
Sec	Second
M.	Mil
m	Meter
Q_k	Continuous quick
IQ	Interrupted quick

Table 1. Lighthouse abbreviations



(a)



(b)

Figure 3. (a) Lighthouse symbology, (b) Abbreviation (FL = Flashing, R = Red (colour), 3 seconds (interval), 10 meters (height), 9 meters (range))

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3.2 Buoys and Beacons

Buoys and beacons equipment are used to mark a zone (submerged area), aid berthing and sailing. Buoys are usually placed at the entrance of ports and since they are connected to sea floor, their position is fixed. Buoys can be found in different shapes such as minor light floats, mooring buoys and special purpose buoys. Symbology of buoys and beacons can be seen in Figure 4.

Figure 4. Symbology of buoys and beacons

3.3 Rocks, Wrecks, Obstructions

Rocks, wrecks and obstructions which are dangerous for sailors are shown in navigation charts. 4 types of presentation is available for this class (Table 2). There are rocks, wrecks and obstructions in 104 points in Bosphorus.

GIS Symbol	Map Symbol	Information
1		Wreck showing any portion of hull or super-structure at level of chart datum
2		Wreck, least depth known by sounding only
3		The wrecks thus represented are than potentially dangerous to vessels with a draught greater than 20 m
4		Wreck, least depth unknown, considered to be potentially dangerous to some surface vessels

Table 2. Rocks, wrecks and obstructions symbols

3.4 Seabed Sedimentation

Seabed sedimentation information which is essential during anchoring is provided in the maps. Anchoring technique and anchor type depend on the sea floor properties as it would not be safe to anchor in rushes or it would damage biodiversity to anchor in coral area. Table 3 shows types of seabed sedimentation and symbology.

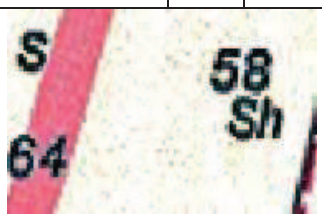
Abb.		Abb.	
S	Sand	P	Pebbles
M	Mud	Cb	Cobbles
Cy	Clay	R	Rock, Rocky
Si	Silt	Bo	Boulders
St	Stones	Co	Coral
G	Gravel	M, Sh	Mud and Shells
Sh	Shells	Wd	Rushes, moss
S/M	Ex: Mud, Sand		
			

Table 3. Seabed sedimentation abbreviations and symbology

3.5 Tides and Currents

Tides and currents are shown in restricted areas. 14 tides and current features are collected from Bosphorus navigation charts (Table 4).

GIS Symbol	Map Symbol	Information
		Current in restricted waters

Table 4. Tides and currents symbology

3.6 Tracks and Routes

Maritime traffic separation scheme, traffic flow directions, port entrances and channels are presented in maps where density of maritime traffic is high, using International Maritime Organization's (IMO) standards (Table 5).

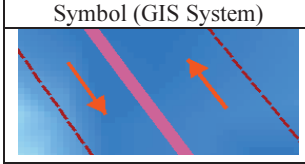
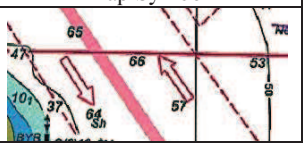
Symbol (GIS System)	Map Symbol
	

Table 5. Tracks and routes symbology. Established (mandatory) direction of traffic flow. Separation line (large-scale, smaller scale).

3.7 Zones

Anchoring and prohibited military zones, anchoring and training areas are presented in navigation charts.

3.8 Energy Transmission Lines

Power transmission lines, radio station lines, submarine lines and line protection areas are marked on navigation charts.

3.9 Sea Depth

Sea depth points presented in navigation charts can be seen in Table 6. These points are shown as values without any points or markings.

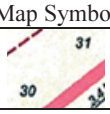
GIS Value	Map Symbol	Information
-31 -30		Sea Depth Point

Table 6. Sea depth points

3.10 Points of Interests in Land

Various of structures in land such as settlements, spot height, chapels, sirens, radar points, radio and TV towers, bridges, transportation lines, hospitals, stadiums etc. are shown in navigation charts.

3.11 Layer and Attribute Design

The design of each layers and attributes that are used in the system is given in Table 7.

Layer of Lights Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
Lights	Lights	Point		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
NameOfLight	Name of Light	String	50	Rumeli Light (Türkeli)
Properties	Properties	String	25	Fl(2)12s58m18M
Label	Label	String	10	Pilon
Information	Information	String	50	Horn 20s (Fog light)

Layer of Buoys and Beacons Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
BuoysAndBeacons	Buoys and Beacons	Point		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
BuoyBeacon	Buoy/Beacon	String	20	Beacons
Information	Information	String	25	Q(6)+LFl15s,YB,AIS

Layer of Rocks, Wrecks Obstruction Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
RocksWrecksObsruction	Rocks Wrecks Obstruction	Point		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
Type	Type	Short Integer		2
Depth	Depth	Float		38
Information	Information	Text	115	

Layer of Nature of the Seabed Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
NatureOfSeabed	Nature of the Seabed	Point		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
Label	Label	String	10	Si.S
NatureSeabed	Nature of the Seabed	String	35	Silt, Sand

Table 7. Design of layers and attributes

Layer of Direction of Current Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
Current	Direction of Current	Line		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
Rates	Rates	String	10	1,5-2 Kn
Information	Information	String	50	Current in restricted waters

Layer of Ferry Quay Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
FerryQuay	Ferry Quay	Point		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
FeryQuayName	Fery Quay Name	String	50	-38
TimeTable	TimeTable	String	200	

Layer of Fog Signal Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
FogSignal	Fog Signal	Point		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
Information	Information	String	15	(2)20s
Label	Label	String	6	Siren

Layer of Radar Points Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
RadarPoints	Radar Points	Point		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
Name	Name	String	15	Radar Tr.
Information	Information	String	20	Radar Points

Layer of Radio Television Tower Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
RadioTelevisionTower	Radio Television Tower	Point		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
Description	Description	String	30	Radio, Television Mast
Label	Label	String	10	Tv.Tr.

Layer of Bridges, Tube and Rail Tube Tunnel Design

Layer Design				
Feature Class Name	*Layer Name*			*Geometry Type*
BridgeTupeMamararay	Bridges, Tube and Rail Tube Tunnel			Line
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
Name	Name	String	50	Boğaziçi Bridge

Layer of Anchoring Area Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
AnchoringArea	Anchoring Area	Polygon		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
Information	Information	String	50	Passenger Ships

Layer of High-Voltage Transmission Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
HighVoltageTransmission Line	High-Voltage Transmission	Line		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
Information	Information	String	50	66 m above sea level
AddInformation	Add Information	String	50	High-Voltage Transmission

Table 7. *Cont.* Design of layers and attributes

Layer of Submarine Cables Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
SubmarineCables	Submarine Cables	Line		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
LineDistance	Cable Distance	String	10	1232 m
Information	Information	String	50	Sabmarine Cable

Layer of Sea Depth Point Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
SeaDephtPoint	Sea Depht Point	Point		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
SeaDephtPoint	Sea Depht Point	Float		-38

Layer of Depth of Correlate Point Design

Layer Design				
Feature Class Name	*Layer Name*	*Geometry Type*		
CorrelatePoint	Correlate Point	Point		
Attribute Design				
Name	*Alias*	*Type*	*Length*	*Sample Data*
PointNumber	Point Number	String	20	Coralete Point 1

Table 7. *Cont.* Design of layers and attributes

4. WEB BASED GIS APPLICATION

All navigation charts have been imported into GIS environment and georeferencing has been performed for each map. Total of 3032 features have been digitized in accordance with layer designs (Table 8).

Layer Name	Number of Digitizing Item	Layer Name	Number of Digitizing Item
Lights	43	Depth of Sea	2349
Buoys and Beacons	45	Rocks Wrecks Obstruction	104
Nature of the Seabed	46	Direction of Current	23
Traffic Direction of Flow	46	Traffic Separator	2
Traffic Boundary	7	Military Training Area	1
Anchoring Area	2	Forbidden Line	9
Forbidden Zone	4	High-Voltage Transmission	2
Submarine Cables	7	Submarine Cable Area	2
Chimney	3	Fog Signals	1
Radio Television Tower	7	Prayer Place	80
Land Elevation Point	44	Radar Points	7
Ferry Quay	48	Settlement Centres	102
Building	30	Bridges, Tube and Rail Tube Tunnel	17
GS Island	1		

Table 8. Digitized layer feature counts

In order to acquire topography of the seafloor, a digital terrain model has been produced using sea depth points by performing ANUDEM (Hutchinson, 2011). Seafloor topography of Bosphorus can be seen in Figure 5.

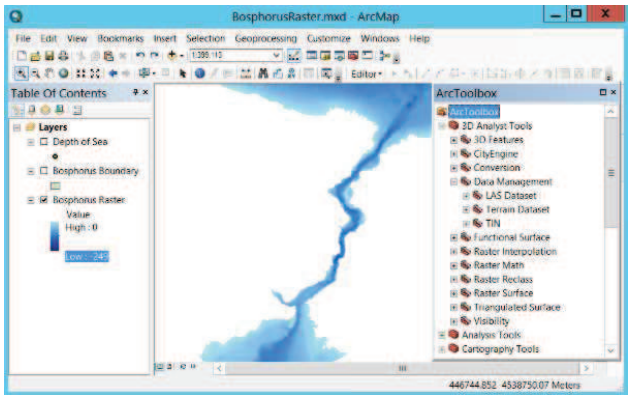


Figure 5. Seafloor topography

Web based GIS application have been developed using Web AppBuilder interface. In order to create an application in Web AppBuilder, created geographic database must be shared as service using ArcGIS Server or cloud. Therefore, once integration and analysis are performed, all data have been published as web services.

Search and query widgets have been created using Web AppBuilder to provide end-users ability to find detailed information (Figure 6).

Figure 6. Widget design

PC and mobile compatible versions of web application have been created separately since orientation and resolution need to be suitable for both devices. Web based GIS application can be accessed using this link: www.gis.yildiz.edu.tr/webservices.html Final look of the web application can be seen in Figure 7.

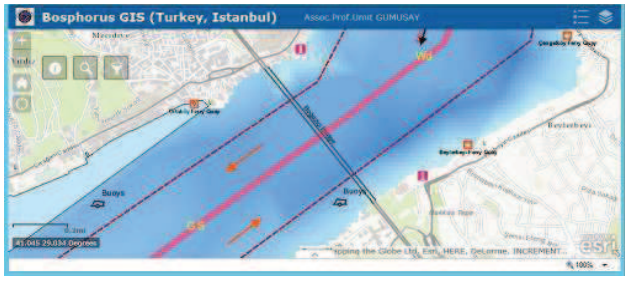
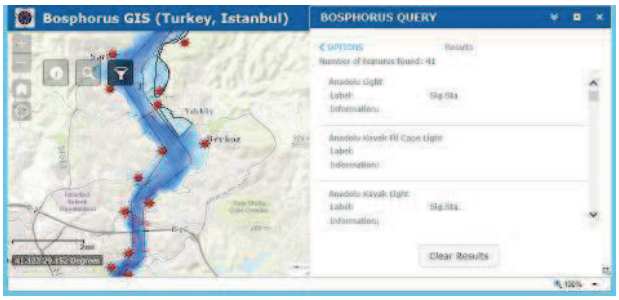
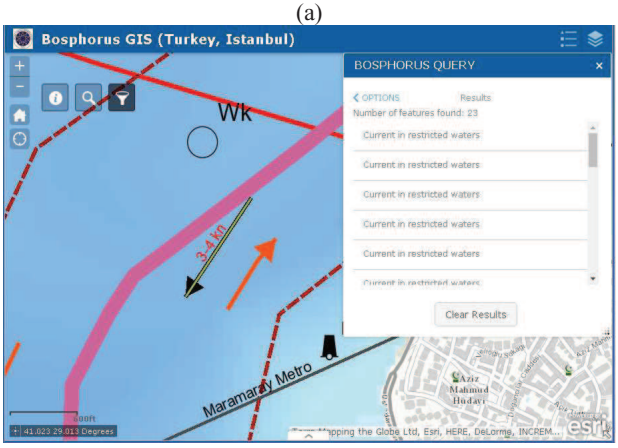


Figure 7. Web based GIS application

Users can search and query all the features in the system such as piers, lighthouses, currents etc. Lighthouses play a key role for sailing during night. So, created system allows users to query location and information about lighthouses or any other features in the web application. Sample queries can be seen in Figure 8.



(a)



(b)

Figure 8. (a) Lighthouse query, (b) Current query

Mobile compatibility of the created application has been tested using Apple iPhone 5. The system has the ability to locate the user's location using mobile device's GPS (Figure 9).

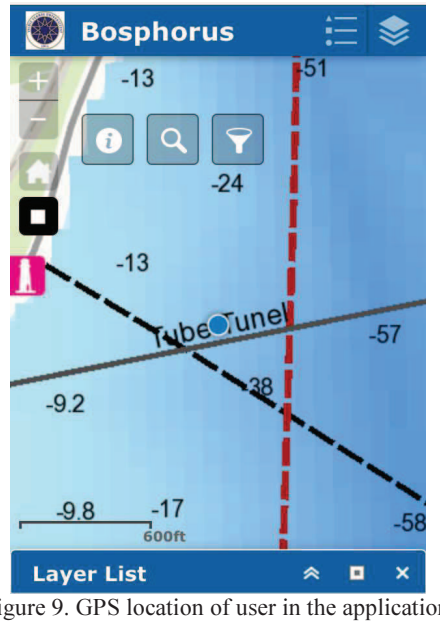


Figure 9. GPS location of user in the application

5. RESULTS

In this study, a web based coastal management GIS application of Bosphorus with physical and biological components of coast management system have designed and developed using ArcGIS Online. Designed system allows users to obtain detailed information about anchorage grounds, depth, sedimentation, currents, wrecks, traffic separation schemes, traffic flow directions, closed areas, lighthouses, buoys, beacons and points of interests in land along Bosphorus coast and sea. ArcGIS Online and Web AppBuilder interfaces which were used to create this web application allows users to rapidly create web services and web mapping applications.

Web based geographic information system are being widely used through the developments of mobile, internet and web technologies. Widespread use of web GIS makes daily life easier and practical. Consequently, developing integrated coastal zone management processes for cities along shoreline with the help GIS and web technologies will yield the problems relate to management of resources, sustainability of sea and marine protected areas.

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