Chile Litoral

DIÁLOGO CIENTÍFICO SOBRE LOS ECOSISTEMAS COSTEROS

Ronald G. Hellman
Rodrigo Araya
Editores

FLACSO-Chile

ACSS
Americas Center on Science and Society

© FLACSO-Chile
Av. Dag Hammarskjöld 3269.
Vitacura, Santiago de Chile.
Teléfono: 56-2 290 02 00 Fax: 56-2 290 02 63
http://www.flacso.cl
flacso@flacso.cl

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A21st Century Global Ecosystem Observatory
CUNY Graduate Center
Room 7-205
Teléfono: 1-212 817 1800 Fax: 1-212 817 1560
http://web.gc.cuny.edu/sciart/0102/acss.html
acss@gc.cuny.edu

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Í N D I C E

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Integration of Socio-Economic Information with Physical data in the Coastal Zone Using Geographic Information Systems

JEFFREY P. OSLEEB[1]

1. INTRODUCTION

Scientists of different disciplines often have difficulty addressing the same problem because of different orientation to the problem as well as due to the use of differing terminologies, methods and language. Scientists working on problems of the coastal zone face a similar situation. Approaches to studying the coastal zone that permits scientists of different disciplines to share information and to provide a common terminology are extremely important for the successful study of problems of the coastal zone.

Geographic Information Science is a spectrum of technologies that permit scientists of many disciplines to gather, share, analyze and display information about spatial phenomena. Geographic Information Science includes Geographic Information Systems (GIS), Remote Sensing (RS) and Geographic Positioning Systems (GPS). The coastal zone is a perfect candidate for the use of technologies, since it occupies space, requires analysis and can employ maps and other spatial data systems to describe situations and events.

This paper will first review the techniques of Geographic Information Science, then the use of these techniques will be applied to the coastal zone and finally examples will be provided.

[1] Professor of Geography and Executive Officer, Earth and Environmental Sciences Ph.D. Program, City University of New York.

2. BACKGROUND

2.1. Geographic Information Science

In 1988 the US National Science Foundation created the National Center for Geographic Information and Analysis (NCGIA), which was co-located at the University of California-Santa Barbara, State University of New York at Buffalo and the University of Maine. The NCGIA was established to foster research in Geographic Information Science and particularly in its principal component, Geographical Information Systems through the integration of theories and concepts associated with:

Geographic information
Cartography
Surveying
Remote sensing
Geodesy
Photogrammetry
Spatial statistics

In 1996 a parallel consortium of universities, government agencies and private firms was established as the University Consortium for Geographical Information Science (UCGIS). According to the UCGIS, the purpose of Geographical Information Science is to develop theories, methods and software to enhance:

1. Spatial data acquisition and integration.
2. Distributed computing as related to Geographic Information Systems.
3. Geographic representation.
4. Cognition of geographic representation.
5. Interoperability of Geographic Information Systems.
6. Understanding of Scale.
7. Spatial analysis.
8. Spatial information infrastructure.
9. Understanding of Uncertainty in spatial data.
10. The use of Geographic Information Systems and society.

2.2. Geographic Information Systems (GIS)

Osleeb and Kahn (1999) define a geographic information system as a management support system that permits the decision-maker to view and analyze spatial data. Spatial data are geographic data, i.e., data that can be placed on a map. Spatial data are data for which there is a street address a latitude and longitude or and x-y coordinate system or some other system that makes the data mapable.

Examples of geographic data might include:

- Locations of facilities within a region that dump untreated effluence into a stream.
- The route of the stream.
- The distance those facilities are from the coast.
- The socioeconomic condition of the population adjacent to those facilities.
- Proximity of fisheries to the mouth of the stream.

Examples of geographic data might include:

- Locations of hazardous facilities within a region.
- The distance those facilities are from the coast.
- The socioeconomic condition of the population adjacent to those facilities.
- Proximity of fisheries to those hazardous facilities.
- Potential health impacts resulting from proximity to a hazardous facility.

Fundamentally, a GIS permits us to layer geographic data onto a base map, to interrogate the map about the information it contains and to perform spatial analysis on the information.

A GIS usually includes the following components:

1. Data capture devices that include scanners, digitizers and GPS receivers that permit spatial data to be translated into a digital format.
2. Mapping and graphics software that provides the means for visualizing spatial data.
3. Database management software which is necessary for maintaining large databases as well as providing easy access to data.
4. Spreadsheet functions and statistical routines used to organize the data and provide statistical analysis.

5. Spatial analysis capabilities in which the location of data points relative to other data points can be systematized, explained and visualized in order to test hypotheses.

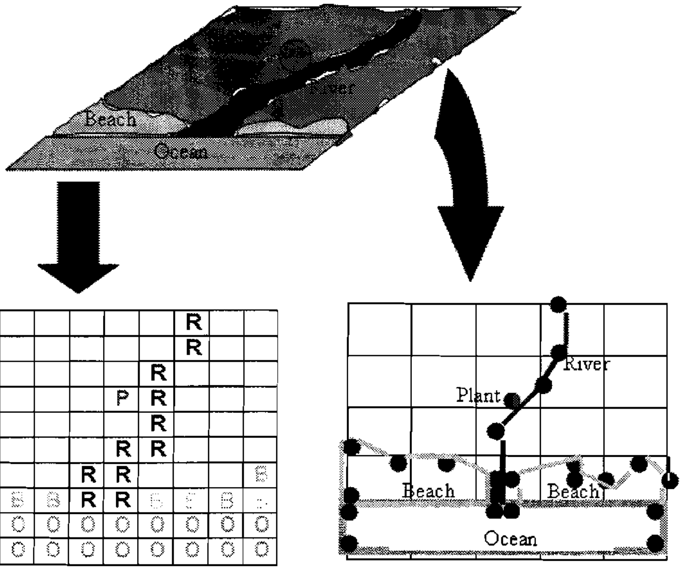
There are two types of GIS, raster and vector. In raster GIS, the earth's surface is depicted by pixels with values which could be color, light intensity, type of feature or some other value. On a map, these pixels can be represented by cells of latitude and longitude or by a Universal Transverse Mercator (UTM) grid.

With vector GIS, the earth's surface is depicted by points, lines and polygons with each having its own attribute. Figure 1 represents the two types of GIS as pertaining to the Coastal Zone.

The figure shows the two ways of depicting spatial information within a GIS data structure, raster and vector. In the case of raster GIS, the landscape is divided into a very fine grid and each of the cells (rasters) are given a value of the predominant feature that dominates the raster (Clarke, 1990). The raster model is a simple data structure that permits a very detailed representation of the landscape. The GIS depicts the earth's surface by pixels with values that could be color, light intensity, or some other value. On a map, these pixels can be represented by cells of latitude and longitude or on a Universal Transverse Mercator (UTM) grid.

Data are often input in the form of satellite imagery or through scanned photographs making data acquisition and entry a fairly low cost task. In the example above, B is Beach, O is Ocean, P is a Plant and R is River. The raster can be given a different color based on the value (B,O,P,R).

Figura 1
A DEPICTION OF VECTOR AND RASTER GIS



Raster GIS Vector GIS

The vector GIS model represents all spatial features on the earth's surface is depicted by points, lines and polygons each having its own attributes. Because all features must be digitized or scanned in individually, the cost of vector GIS is higher to implement than is raster GIS. The primary advantage of the vector structure is the ability to perform spatial analysis due to the incorporation of topological data structure that permits network analysis (Miller and Shaw, 2001).

In Figure 1, the Plant is represented as a point, the River as a line and the Beach and the Ocean as polygons.

2.3. STRENGTHS OF GIS

The greatest strengths of GIS are its abilities to:

- Present spatial information in a visual manner.
- Be able to point to a location on a map and obtain information about that location.

- Undertake spatial analysis about a location to, for example, determine its impact on other locations to permit stakeholders to share information.
- Accumulate spatial information from various sources and multiple disciplines and to be able to represent these data in the same geographic scale.

2.3A PRESENTING INFORMATION IN A VISUAL MANNER

Often information is presented as a list of objects. If the information being presented is geographic data - data for which there is a street address, a latitude and a longitude, or some other means of placing the information on a map, a GIS can be used to display the information that will likely make it more usable. Table 1 is a list of the cities in Chile with populations greater than 115,000 people. These data are geographic since each city has a latitude and longitude associated with its location as well as a number of attributes including populations in 1998, 2000 and 2002 as well as the name of the province in which the city is located. Having the latitude and longitude permits the data to be mappable. Figure 2 is a map of the location of the cities. By mapping the information, one can see the location of the cities relative to one another as well as in relation to the coast.

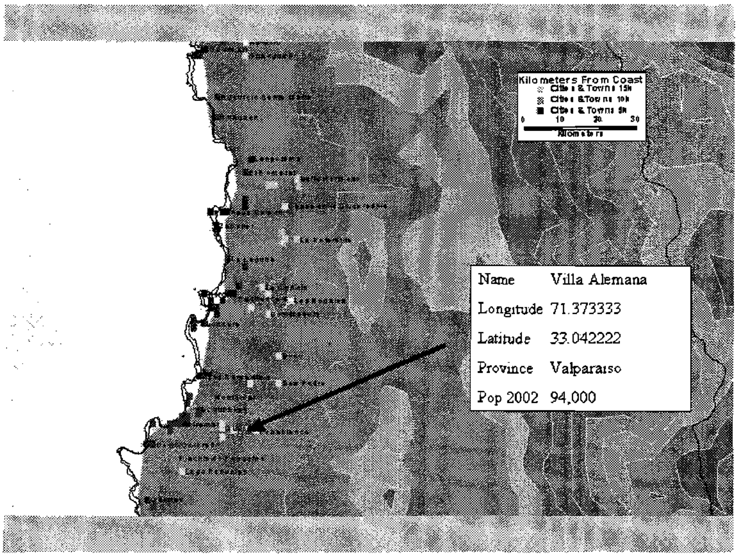
Table 1
CITIES IN CHILE WITH 2002 POPULATIONS GREATER THAN 115,000

• Name	Province	Pop1998	Pop1992	Pop2002
• Punta Arenas	Magallanes y Antartica Chilena	97.137	109.110	116.000
• Puerto Montt	Los Lagos	84.195	110.139	148.000
• Osorno	Los Lagos	95.215	114.239	127.000
• Valdivia	Los Lagos	99.704	112.712	126.000
• Temuco	Araucania	157.297	210.587	261.000
• Concepción	Bío-Bío	266.953	326.784	371.000
• Talcahuano	Bío-Bío	202.264	244.034	245.000
• Chillan	Bío-Bío	118.213	145.759	143.000
• Talca	Maule	128.445	159.711	189.000
• Rancagua	Libertador Bernardo O'Higgins	139.781	179.638	204.000
• San Bernardo	Region Metropolitana	117.132	179.398	230.000
• Puente Alto	Region Metropolitana	110.099	254.127	500.000
• Valparaíso	Valparaíso	271.000	274.228	262.000
• Quilpue	Valparaíso	84.136	102.233	125.000
• Viña del Mar	Valparaíso	263.000	303.589	330.000
• Coquimbo	Coquimbo	86.000	110.139	147.000
• Santiago	Region Metropolitana	3.650.541	4.295.593	4.63.000
• La Serena	Coquimbo	83.009	109.293	144.000
• Copiapo	Atacama	68.953	98.188	124.000
• Antofagasta	Antofagasta	183.333	225.316	294.000
• Calama	Antofagasta	99.000	106.070	120.000

2.3B POINTING AT A LOCATION ON A MAP TO OBTAIN INFORMATION ABOUT THAT LOCATION

Geographic information systems permit the interrogation of the map for the attributes contained within the layer. Figure 3 is a map places in central Chile. The place Villa Alemana has been point to and information on latitude, longitude and population is displayed.

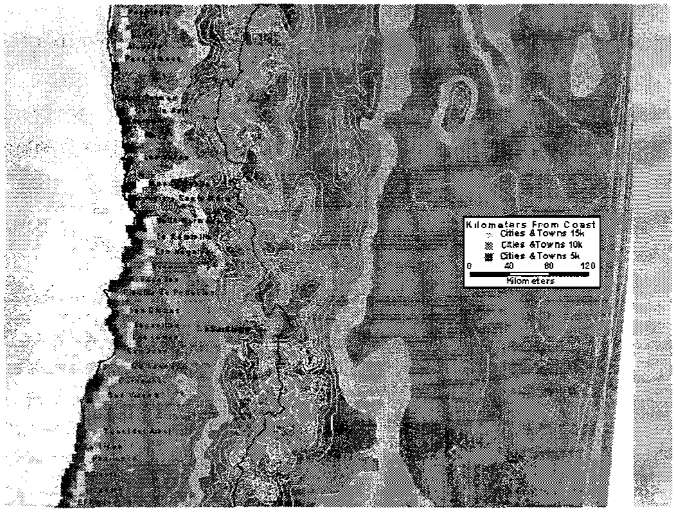
Figure 3
INTERROGATING THE MAP BY POINTING



2.3C UNDERTAKING SPATIAL ANALYSIS WITH GIS

Geographic information systems permit sophisticated and powerful spatial analysis to be undertaken that without such a system would be difficult otherwise impossible to undertake. The establishment of a classification of tree species, the optimal routing for waste transportation, or the location of seafood warehouses that minimize distribution costs between the sources of fish harvest and the demand for the fish are examples of the types of analysis that can be undertaken with GIS. Figure 4 represents a spatial analysis undertaken in which the distance from the coast for different places was determined.

Figure 4
PLACES DIFFERENT DISTANCES FROM THE COAST



In Figure 4 places are given a color based upon their location relative to the coast with yellow places being 5 km from the coast, orange 10km and red 15km. From this we can calculate the population that is within different distances of the coast for emergency preparedness planning.

2.3D *ACCUMULATING SPATIAL INFORMATION FROM VARIOUS SOURCES AND MULTIPLE DISCIPLINES AND REPRESENTING THESE DATA IN THE SAME GEOGRAPHIC SCALE*

Researchers from different disciplines often study the same problem in the geographical area but are unable to coordinate their studies because of problems with definitions or the work was undertaken at a different scale. GIS permits the layering of information gathered by different researchers from different disciplines so as to make the information compatible by providing a unified geographic definition and thereby permitting the researchers to communicate among themselves. At the same time, even if the information had been gathered at different scale or placed on maps of differing scales and /or projections, a GIS is able to make each of the layers comparable thereby permitting the sharing of data, results and conclusions of the research.

Research in the coastal zone may include oceanographers studying the impact of currents on fish productivity while marine biologists are looking at the impacts of pollutants in runoff on the health of the coastal zone. Simultaneously, geographers could be investigating the impact of population centers on the generation of pollution. Three different disciplines are represented here with different terminologies and with data presented at different scales.

The oceanographer may be employing satellite imagery such as is shown in Figure 5 as provided by the United States Geologic Survey.

Figure 5
SATELLITE IMAGE OF CENTRAL CHILE (UNITED STATES GEOLOGICAL SURVEY)

This image can be rectified so that a common coordinate system is being employed enabling other information such as the location of places to be added to the map. Figure 6 represents the same image that has been rectified to place the city of Santiago on the image.

Figure 6
RECTIFIED SATELLITE IMAGE WITH THE PLACEMENT OF SANTIAGO

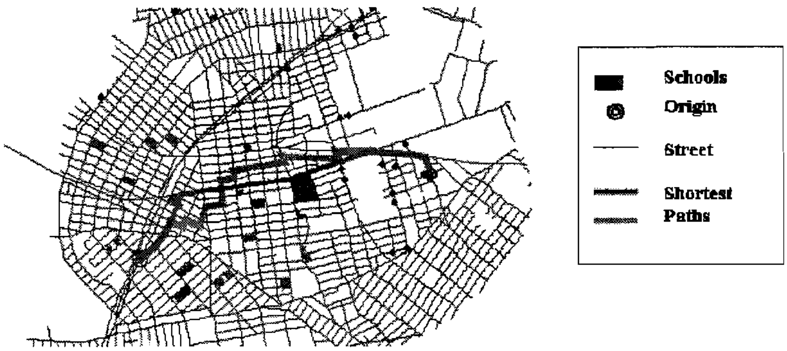
Finally, in order to precisely locate activities on the map that might not have a geographic coordinate but a street address, the street system and a map of the built environment could be layered onto the map. An example of this is shown in Figure 7 that shows the street system of Valparaíso. In this case the street was system was digitized as a layer without the system topology being specified. In this case the layer may be used as a picture layer that in combination with other layers that can be rectified to it can be used to locate objects. However, a layer that does not have an included topology as does the TIGER file of the US Census Bureau is incapable of permitting spatial analysis. TIGER stands for topologically integrated geographic encoding and referencing. In this file objects are denoted as points (e.g. places), lines (e.g. streets) and polygons (e.g. census tracts). These files were structured topologically, data structures that store additional characteristics of connectivity and adjacency. The basic objects are node, the link and the chain to which is added direction and hierarchy that supports linkages to adjacent objects.

In this way objects are related to one another that integrates the network into a system permitting network analytical techniques. An example of such a network with the resulting ability to undertake network analysis is shown in figure 8 below.

Figure 8 is from a study assessing the environment of a part of New York City (Ahearn and Osleeb, 1994). The figure shows an analysis of a comparison of truck routes through the community. The initial route was first determined to be the shortest path (shown by the red line) between the truck's origin and its local destination, the closest entrance to a limited access highway passing through the community. The second route (shown in green) was the shortest route when trucks were not permitted to pass too closely to schools.

Figure 7
STREET LAYER, VALPARAÍSO, CHILE

Figure 8
PERFORMING SPATIAL ANALYSIS ON THE TIGER FILE



3. COASTAL AND MARINE USES OF GIS AND RELATED SPATIAL ANALYSIS

The US Army Corps of Engineers (USACE) has commissioned a number of GIS tools for the specific use for maritime analysis. Two tools will be discussed in this paper: Beach Tools and the Commodity Logistics System.

3.1. BEACHTOOLS

BeachTools was developed for the USACE in order to "identify and quantitatively establish the position of the coastline and other coastal features from aerial imagery" (Hoeke, Zerillo and Snyder, 2001). These tools were designed to be used in conjunction with ArcView 3.x GIS. ArcView is a vector based GIS produced by Environmental Science Research Institute which has the ability to layer raster images. BeachTools was designed to help study coastal inlet geomorphology, the calculation of sediment budgets and to analyze inlet ebb-shoal evolution. The tools include:

- Clipping and Mosaicing Imagery.
- Image Histogram Sketching.
- Automatic Delineation of Coastal Features.
- Calculation of Aerial Extent of Coastal Features.
- Tools for Baseline and Transect Generation.

These tools remove the tedium and subjectivity of extracting data by hand, and allow for much greater precision of beach measurements. An example of BeachTools is shown in Figure 9 (see figure below) where two lines are automatically delineated depicting the Wet/Dry Line and the Vegetation Line on the beach.

3.2. COMMODITY LOGISTICS SYSTEM

The Commodity Logistics System (COLS) is a multi-commodity multi-modal transportation logistics system developed to optimizing the maritime transportation system of a country (Osleeb et al, 1990). The system utilizes a Spatial Decision Support System framework to determine the best locations for ports to interface with land transportation systems for the optimization of commodity flow for system-wide port planning providing information and analysis for port sizing, facility location, dredging investments and other maritime decisions.

A Spatial Decision Support System (SDSS) is a management tool that merges the technologies of geographic information systems with powerful mathematical models. SDSS allows the decision-maker to consider a series of "what if" questions (Ralston, 1991, Arentze, Borgers and Timmermans, 1996, Peterson, 1993, Carver, 1991). The decision-maker is able to address "semi-structured" problems that typically require the selection of a set of solutions from a set of alternatives (Densham and Goodchild, 1989). In addition SDSS permits the decision-maker to track such measures as the cost of various solutions while determining the efficiency of each solution. This analysis is imperative in determining not only which solution is preferred, but also whether a problem should be solved at all, or left unresolved. In this way an evaluation of the cost of solving the problem as opposed to leaving the problem unresolved can be made.

Once developed, the model can easily be utilized to address many similar situations while using different data and assessing various scenarios. Smotritsky, Osleeb and Mellot (1993) found that SDSS could increase citizen participation because citizens could propose alternative scenarios that would then be evaluated in a real time environment against the current situation as well as against other proposed solutions.

The objectives of COLS are to:

- Simultaneously trace the transportation chain of each commodity.
- Determine the port infrastructure requirements for each port during the planning horizon.
- Analyze dredging options.

Figure 9
EXAMPLE OF VEGETATION LINE AND WET/DRY LINE DELINEATED BY A VECTOR POLYGON AS DEVELOPED BY BEACHTOOLS (SOURCE HOEKE, ZERILLO AND SNYDER, 2001)

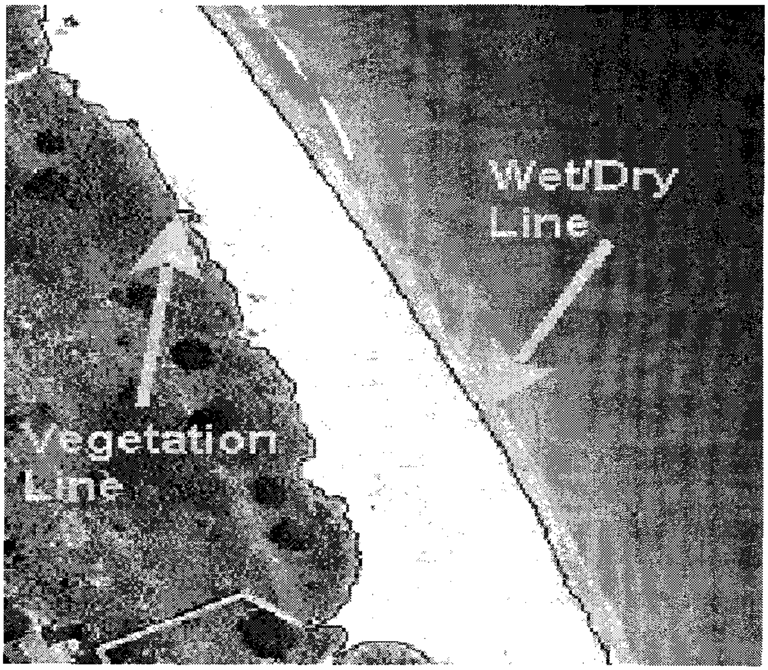


Figure 10
THE COMMODITY LOGISTICS SYSTEM WITH THE IMBEDED PORT EXPANSION SYSTEM (SOURCE OSLEEB ET AL)

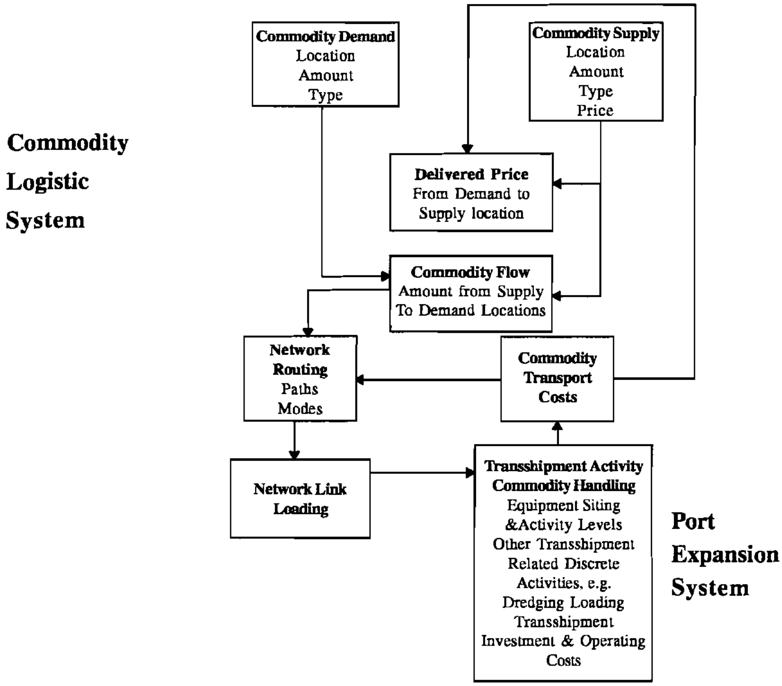
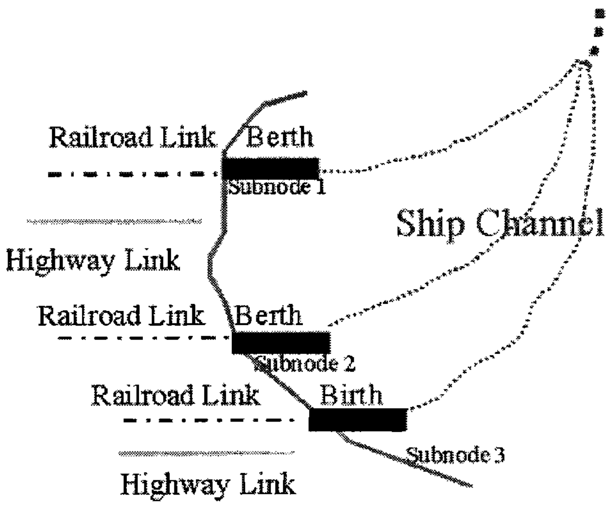


Figure 10 is the flowchart of the logic of the COLS model. Imbeded within the COLS model is a separate Port Expansion System that provides a very precise mathematical representation of the operations of each of the ports in the system. Figure 11 is a diagram of the approach by which the Port Expansion System depicts the port, potential facility locations and intermodal capabilities. Mathematical equations depict the modes entering and leaving a port, the location of loading and unloading sites and the depth of channel and the restrictions those channel depths place on ship size.

Figure 11
A TYPICAL PORT AS REPRESENTED BY THE PORT EXPANSION SYSTEM OF COLS (SOURCE OSLEEB ET AL).



The results of the COLS spatial decision support system are as follows:

- Route, transport mode, and amount of commodity to be transported between its point of origin and the "best" transshipment location.
- Cost of commodity transportation.
- Number of tons of commodity transported through each port.
- Types and locations of facilities necessary to transfer the commodity at transshipment points.
- Cost of handling the commodity at transshipment points.
- Degree to which existing capacity is utilized at transshipment points.
- Amount and type of new transshipment capacity or infrastructure improvements (including dredging) necessary to make the transshipment of the commodities more efficient.
- Investment costs associated with these new facilities and improvements.
- Implications of environmental restrictions.

4. SUMMARY AND CONCLUSIONS

This paper has reviewed the manner in which Geographic Information Science and specifically Geographic Information Systems (GIS) can be used as an analytical methodology to address problems of the coastal zone. While no specific problems of the coast or of coastal zone management were specifically addressed, in most cases coastal examples of the ways in which GIS may be used have been offered. GIS technology has been discussed with respect to definitions, required inputs and the outputs that can be achieved.

A central theme of this paper is the idea that many different types of data from extremely diverse sources can be handled by the current technology and indeed these diverse data are required and desired to solve many of the coastal zone questions posed today. At the same time, GIS technology has the ability to integrate this disparate data by permitting it to be placed on the same map, in one scale, making meaningful analysis and comparison possible.

While the technology is only thirty years old, significant improvements and advancements have been made that permits GIS to be used effectively in most environments. With the advent of the powerful and inexpensive PC and commercialization of software packages, GIS is available on most desktops today at reasonable cost. In addition data acquisition technology such as satellite imaging, global positioning systems (GPS) technology and government involvement in developing data structures (such as TIGRE by the US Bureau of Census) and in the mass production and dissemination of spatial information has made GIS technology more accessible. Recognizing the advantages of GIS technology for analyzing the coastal zone, in recent years there have been major add on's to existing technology that addresses specific problems of the coastal zone. BeachTools is one such package. In addition as computing power available to GIS has been increased, more complete spatial models could be incorporated with the GIS model to form Spatial Decision Support Systems that at their simplest can produce the shortest route between points and at their most sophisticated can be used as a planning tool for an entire regional intermodal transportation network.

Finally, this paper was meant to provide an overview of GIS and to demonstrate what may be possible in the use of GIS for solving coastal zone issue. With the power of the map and other models now available to the researcher, planner or analyst, it is now a matter of imagination as to how these tools and technologies can be employed and further eveloped for the betterment of the coastal zone.

BIBLIOGRAPHY

AHEARN, S. and J. OSLEEB (1993) "Greenpoint/Williamsburg Environmental Benefits Program: Development of a Pilot Geographic Information System", *GIS/LIS Proceedings*, Vol. 1, November 1993, pp.10-18.

ARENTZE, A.T., A.W.J. BORGERS and H.J.P. TIMMERMANS (1996) Design of a View-Based DSS for Location Planning. *International Journal of Geographical Systems*, 10(2): 219-236.

CARVER, S. J., I HEYWOOD, S. CORNELIUS and D. SEAR (1995) "Evaluating Field-Based GIS for Environmental Characterization, Modeling and Decision Support", *International Journal of Geographical Systems*, 9(4): 475-486.

CLARK, K. (1990) Analytical and Computer Cartography, Prentice Hall, New Jersey.

DENSHAM, P.J. and M.F. GOODCHILD (1989) "Spatial Decision Support Systems: A Research Agenda"' *Proceedings of GIS/LIS*, Orlando, FL. (2) 707-716.

HOEKE, R., G. ZARILLO and M. SNYDER (2001) *A GIS Tool for Extracting Shoreline Positions from Aerial Imagery*, US Army Engineer and Development Center, Vicksburg.

MILLER, H. and S. SHAW (2001) Geographical Information Systems for Transportation: Principles and Applications, Oxford University Press, New York.

OSLEEB, J. and S. KAHN (1999) "Integration of Geographic Information" in *Tools to Aid Environmental Decision-makers*, edited by M. English and V. Dale, National Center for Environmental Decision-making Research, Springer Verlog, pp. 161-189.

OSLEEB, J., M. KUBY and S. RATICK (1990) "The Coal Logistics System (COLS)", *Transportation Research Record, Transportation Research Board*, No. 1222, Washington, D.C., pp. 6-13.

PETERSON, K. (1993) "Spatial Decision Support Systems for Real Estate Investment Analysis", *International Journal of Geographical Systems*, 7(4): 379-392.

RALSTON, B.A. (1992) "Implementing a Spatial Decision Support System or Take My Computer, Please", *Published Abstract*, Association of American Geographers Annual Meeting, San Diego.

SMOTRITSKY, Y., J. OSLEEB and J. MELLOT (1993). *Route Location Algorithm for Transportation and Utility Corridors*. National Science Foundation. Washington, D.C.