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ELECTRONIC NAUTICAL CHARTING: ECONOMIC VALUE AND ROLE IN SUSTAINABLE DEVELOPMENT OF MARINE TRANSPORT OPERATIONS

by Joseph R. VADUS [1]

Abstract

Electronic nautical charting plays a major role in providing safe and efficient navigation of vessels primarily involved in commerce, fishery landings, marine recreation, cruises and research activities on the civil side, and naval operations for the military. In order to determine the contributions of electronic charting to marine transport operations, and the priorities for converting to electronic charts, this paper provides a general assessment of the economic value and importance of shipping operations in and out of U.S. ports including: foreign commerce, fishery landings, accidents, oil spills and military needs. This assessment will enable establishing priorities for electronic charts based on importance in serving U.S. Ports and U.S. Coast Guard Districts. Many accidents and spills are due to human error in ship navigation. In many cases these could be averted by using Electronic Nautical Charts (ENC) integrated with other navigation aids to provide features for collision/grounding avoidance. In its supporting role, ENC will help promote sustainable development of marine transport operations. In addition, ENC provides geodetically accurate coastal mapping data to serve as a reference base for Geographic Information Systems (GIS).

INTRODUCTION

The objective of this paper is to show the economic importance of nautical charting, especially ENC, and its integral role in marine transport operations, that contributes well over 500 billion U.S. dollars in handling foreign commerce alone,

[1] National Oceanic and Atmospheric Administration, National Ocean Service/ Coast Survey, 1315 East- West Highway, Silver Spring, Maryland 20910, USA.

and much more, if you consider fishery landings, the supporting maritime industry, port and harbor operations, jobs and related economic beneficiaries.

It is difficult to determine a specific monetary value attributed to electronic charting based on its role in support of marine transport operations, just as it would be to assign a value to e.g. the ship's propulsion system. Yet, it is recognized that electronic charting and navigation systems are critical components in marine transport operations and contribute to the economic gains of such operations.

This paper will compile and illustrate multi-source data on a map of the U.S. in a common form, by overlaying statistical information of several key factors related to economic gains and losses in marine transport operations, and provide a national overview. Presently, the U.S. Coast Guard is preparing an overview of oil spills to be depicted on a national map.

The priorities for providing electronic charts will be based on their importance for safe navigation, especially in ports and waterways subject to: heavy traffic in transporting foreign commerce and fishery landings; frequent accidents and oil spills; and important defense needs.

The age of electronic charting using digital techniques, and its incorporation in integrated navigation systems has begun, and its world-wide implementation is inevitable. This new technology will provide the mariner with more accurate and useful information; increase the efficiency, safety and economic growth of marine transportation; and influence formulation of government policies. C. ANDREASEN's paper, referenced herein, expounds on this subject.

BACKGROUND

Prior to preparation of this paper, the author had contacted several leading sources including, U.S. Coast Guard, U.S. Army Corps of Engineers, NOAA, many of which have computer-compiled statistical data bases that can be analyzed and structured for different needs. Also, libraries of information and research services are available at the National Transportation Research Board and the American Association of Port Authorities. The Marine Board of the National Research Council has conducted comprehensive assessment studies on the subjects of marine navigation, piloting and nautical charting, as reported in their book, "Minding the Helm", published by the National Academy Press in 1994. One recommendation stated that "NOAA should accelerate digitization of hydrographic and topographic data essential for providing nautical charts electronically". The Marine Board has also conducted a study entitled, "Charting a Course into the Digital Era", that provides an assessment of present and future needs of users of nautical charts and related information products. The report stated that the priorities for any new and revised charts should be placed on those areas where hazards to navigation pose the greatest threat to the safety of people and ships. These are areas of known obstructions, and usually the busiest ports and waterways.

There are economic studies, including cost-benefit analyses of nautical charting. Analysis by the Royal Australian Navy's Hydrographic Office indicated that it is difficult to obtain exact cost-benefit ratios, but concludes that "What is beyond reasonable doubt is that the existence of official up-to-date charts has a benefit to the national economy that greatly exceeds the cost of the Hydrographic Programme". The Canadian Hydrographic Service cites benefits to cost ratios ranging between 9.49 and 11.85, in 1989. It is difficult to quantify cost-benefit ratios.

Electronic nautical charting systems and related information and data-bases provide a vital supporting role in ensuring sustainable development of marine transport operations that fulfill national needs that have major economic, social, and environmental implications that equate to hundreds of billions of dollars in the U.S. economy. The primary role of nautical charting is safe and efficient marine navigation of vessels primarily involved with commerce and sustained economic development in harmony with the environment. The navigation function is greatly enhanced by converting these information and databases to digital format to provide accurate electronic charting with data that can be integrated with other navigational aids such as the Global Positioning System(GPS), real time radar displays and real time water levels and currents. Progress toward electronic charting is essential for safety to ensure compatibility and availability for "electronically equipped" foreign vessels entering U.S. waters.

ROLE OF ENC

ENC provide safe and efficient navigation, an accurate baseline for GIS, and a role in maximizing economic growth and gain for marine transport operations. Marine transportation accounts for 99% of the value of U.S. foreign commerce, equating to 562 billion dollars per year in economic terms. Marine transportation of commercial fishery landings at U.S. coastal ports amounts to 1.9 billion dollars per year. ENC can help reduce economic losses due to ship accidents resulting in ship damage, injuries and loss of life, and loss of revenue. Reductions in accidents would also reduce economic losses due to oil spills, resulting in loss of cargo revenue, and damage to the marine environment and marine living resources habitat. Reduction of accidents could contribute to lowering underwriting insurance costs, which is a major operating cost factor. Operational risks may be further reduced by standardizing use of ENC, including use of metric units. ENC incorporated within an integrated navigational system appears to be far more cost effective for oil spill mitigation than double hull conversion and providing spill response capability, though the later is always needed in standby. On a world wide basis, double hull requirements are costing on the order of 20 billion dollars, and standby marine oil spill response capability is costing about 100 million dollars per year in the U.S. alone. For example one single hull ship converted to double hull costs as much as 24 million dollars, about the same cost to convert all one thousand U.S. paper charts to ENC. Also, ENC provides a more accurate, computer-manipulative data base, that is more amenable to ease of update and access, thus further reducing costs.

In addition to navigation, a valuable alternate use of digitally converted electronic charts is to provide a framework for overlaying data bases keyed to

Geographic Information Systems (GIS) of particular importance to decision-makers meeting economic, social, and environmental needs in sustainable coastal ocean space development.

PRIORITY FACTORS

Marine transportation and related systems and facilities provide for the economic growth and jobs needed to support a steadily increasing population growth. This is the positive side of sustainable development. On the negative side, there are economic, social and environmental losses due to accidents, oil and hazardous material spills that result in loss of cargo revenues, injuries, loss of life, as well as pollutants from poor waste management practices.

Economic Gains

Marine transportation accounts for 99% of the value of transport of foreign commerce. The American Association of Port Authorities has reported the value U.S. waterborne foreign commerce at a total of about 562 billion dollars in 1994. The value of commerce handled at the major ports in the U.S. are listed in Table 1. Only the top 20 ports out of a total of over 150 U.S. ports are listed.

The leading ports on the U.S. West Coast are Los Angeles and Long Beach, followed by Oakland and Tacoma. The leading ports on the U.S. East Coast are New York/New Jersey followed by Hampton Roads, VA, Baltimore, Miami and Charleston. The Gulf Coast's leading ports are Houston, New Orleans and South Louisiana. Marine transportation of foreign commerce dwarfs all other uses in economic terms. Since man does not live on bread alone, other uses such as commercial fishery landings, marine recreation and cruises, also provide economic gain.

According to the National Marine Fisheries Service, commercial fishery landings in the U.S. amounted to a total of about 3.5 billion dollars in 1993. However, U.S. coastal ports accounted for about 1.9 billion dollars. Coastal port ranking, based on value in millions of dollars, is given in Table 2 and illustrated in Figure 2. Only the top 26 coastal ports in commercial fishery landings are listed. Alaska is the leading state with the ports of Dutch Harbor, Kodiak, Petersburg, Ketchikan, Kenai, and Westport providing 19% of the U.S. coastal landings. The North East Atlantic Region ports of New Bedford, MA, Portland, ME, Cape May, NJ, Point Judith, RI and Gloucester, MA provide about 14%. The ten Gulf of Mexico ports listed provide about 16%.

Economic and Environmental Losses

The U.S. Coast Guard has provided data on commercial vessel accidents as reported in their eight districts, during the period 1992-1994. Table 3 and Figure 3 are based on summarizing that data. The accidents include collisions, groundings

Table 1 Port Ranking in Foreign Commerce
(1994 Value in Billions USD)

Los Angeles, CA	$74	Charleston, SC	$18
Long Beach, CA	71	New Orleans, LA	14
New York/New Jersey	63	Savannah, GA	12
Seattle, WA	41	South Louisiana, LA	10
Houston, TX	29	Portland, OR	10
Oakland, CA	29	Jacksonvile, FL	10
Hampton Roads, VA	23	Port Everglades, FL	7
Tacoma, WA	21	Philadelphia, PA	6
Baltimore, MD	19	Baton Rouge LA	5
Miami, FL	19	Wilmington, NC	4

1994 Total for All Ports = $562 Billion

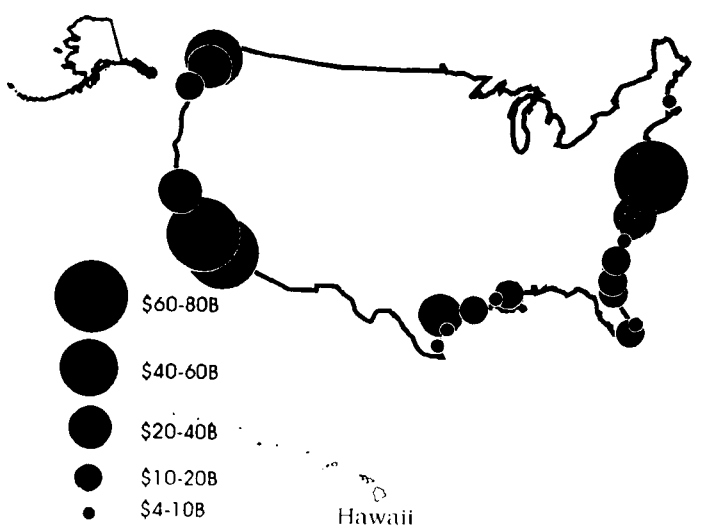


FIG. 1.- 1994 U.S. Waterborne Foreign Commerce (value at major ports).

and allisions, a Coast Guard term for colliding with fixed structures such as bridges or offshore stations. The numbering of the districts reflects earlier consolidations. In regard to district size and activity, District 08 headquartered in New Orleans includes e.g. the major ports of New Orleans, Houston, Galveston, Corpus Christi, Mobile, Pascagoula and the port of South Louisiana. Therefore, the numbers for District 08 are so much larger than all the other districts. The number of accidents in District 08 is almost 57% of the total, and almost an order of magnitude greater than any other district. The other districts are comparable with one another. The damage figures for all districts are those reported at the scene and may not track final figures. During this three year period, the damage reported at each district ranged between 1 to 5 millions dollars, except for District 08 at about $23 million. These

Table 2 Port Ranking in Commercial Fishery Landings (1993 Value in Millions USD)

Dutch Harbor-Unalaska, AK	$161	Cameron, LA	$27
New Bedford, MA	108	Ketchikan, AK	27
Kodiak, AK	82	Kenai, AK	27
Empire-Venice, LA	52	Golden Meadow-Leeville, LA	26
Brownsville-Port Isabel, TX	50	Bayou LaBatre, AL	24
Portland, ME	49	Aransas Pass-Rockport, TX	24
Honolulu, HI	49	Bellingham, WA	20
Dulac-Chauvin, LA	48	Tampa-St. Petersburg, FL	20
Cape May-Wildwood, NJ	36	Astoria, OR	19
Point Judith, RI	35	Olympia, WA	19
Key West, FL	35	Galveston, TX	18
Petersburg, AK	33	Port Arthur, TX	18
Gloucester, MA	31	Westport, AK	18

1993 Total of All Coastal Ports = $1.9B

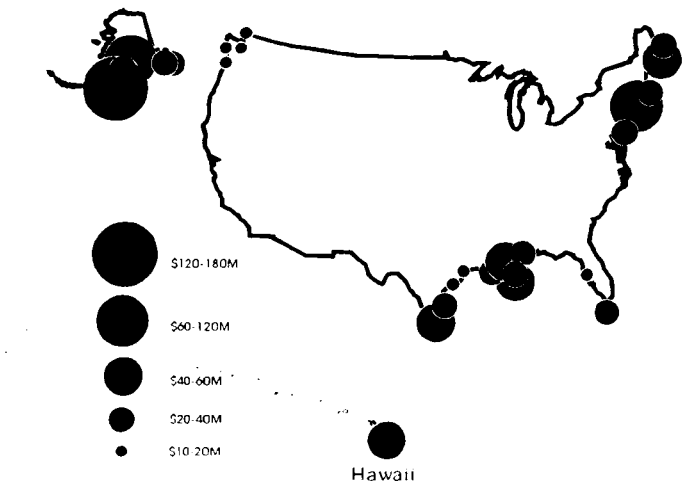


FIG. 2.- 1993 Commercial Fishery Landings (value at major ports).

accidents cause damage to the ships, injuries to people, loss of lives, loss of cargo revenue and damage to the environment. In 1992, the QUEEN ELIZABETH II, one of the world's premier cruise ships, ran aground and was damaged in Vineyard Sound on an unchartered rock. The task of surveying and charting is an important ongoing requirement. Also, ENC integrated with navigational aids such as radar, differential GPS and vessel traffic systems can provide a major improvement in ship navigation and accident avoidance.

Accidents causing hazardous material and oil spills not only represent lost revenue but can be damaging to the environment, especially to living and non living marine resources i.e. fisheries, marine habitat, wetlands, beaches and coastal

Table 3 Commercial Vessel Accidents (1992-94)
(by U.S. Coast Guard District)

District	Port	Accidents	Deaths	Damage ($M)
08	New Orleans	302	20	$23.0
14	Hawaii	41	0	5.4
07	Miami	41	0	1.6
05	Portsmouth, VA	39	0	1.0
11	Long Beach	34	0	1.0
17	Juneau	34	0	2.3
01	Boston	31	1	1.0
13	Seattle	13	0	1.5
TOTAL		535	21	$36.8

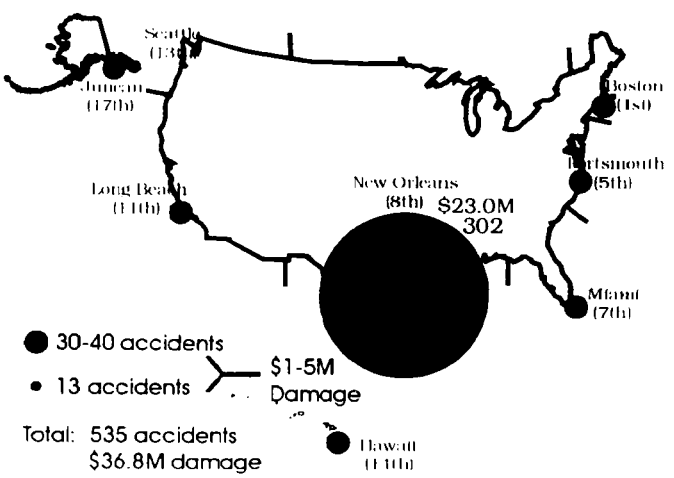
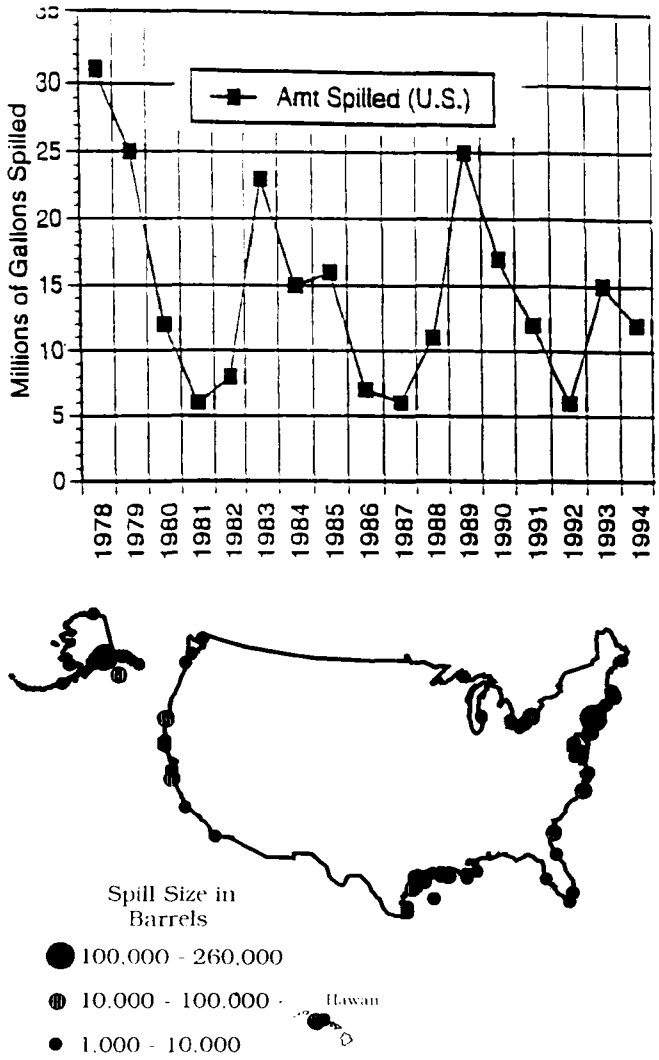


FIG. 3.- Commercial Vessel Accidents (1992-1994) and Damage Values by Coast Guard District.

properties. Figure 4 illustrates the amount of oil spilled (in millions of gallons) in the U.S. over the past 15 years, and Figure 5 illustrates the locations of the major spills in barrels (31.5 gallons per barrel). The most notable spill in recent years was the Exxon Valdez spill in Prince William Sound, Alaska in 1989, which will eventually cost on the order of four billion dollars for restoration and settlements.

The Woods Hole Oceanographic Institution conducted a dynamic economic analysis using optimal control theory and computer simulation to examine the relative cost-effectiveness of providing double hulls for tankers, and use of electronic charts. The report states that, "results indicate that electronic charts may be a far more cost effective approach to marine pollution control".



FIGS. 4 and 5.- Oil Spills.

Defense Needs

Economic security is interwoven with national security. The Department of Defense(DOD) relies on accurate and up - to - date charts. ENC integrated with the multi navigational aids of a naval vessel are essential in providing quick response and maximum and safe maneuverability. Table 4 is a listing of DOD nautical chart priorities for the top 30 ports or bays, selected for a variety of reasons, and are presented in three goupings of ten each for convenience of presentation. These ports are illustrated in Figure 6. In general, they favour the Atlantic Coast plus Los Angeles, Long Beach and Pearl Harbor, followed by the Gulf of Mexico and the West

Coast. Selected DOD charting needs are fulfilled by NOAA, through direct funding by DOD.

Table 4

U.S. Department of Defense
Nautical Chart Priorities
(Top 30 Ports/Bays-1994)

Norfolk, VA	Brunswick, GA	Los Angeles/Long Beach
Baltimore/Annapolis, MD	Corpus Christi, TX	Oakland, CA
Long Island Sound	Pensacola, FL	Port Hueneme, CA
Providence, RI	Key West, FL	San Clemente, CA
Port of New York/New Jersey	Florida Keys, FL	Monterey Bay, CA
Moorhead City, NC	Tampa, FL	Newport, OR
Delaware Bay, DE	Charleston, SC	Coos Bay, OR
Wilmington, NC	Savannah, GA	Humboldt Bay, CA
San Diego, CA	Panama City, FL	San Francisco, CA
Oahu/Pearl Harbor, HI	Cape Canaveral, FL	Jacksonville, FL

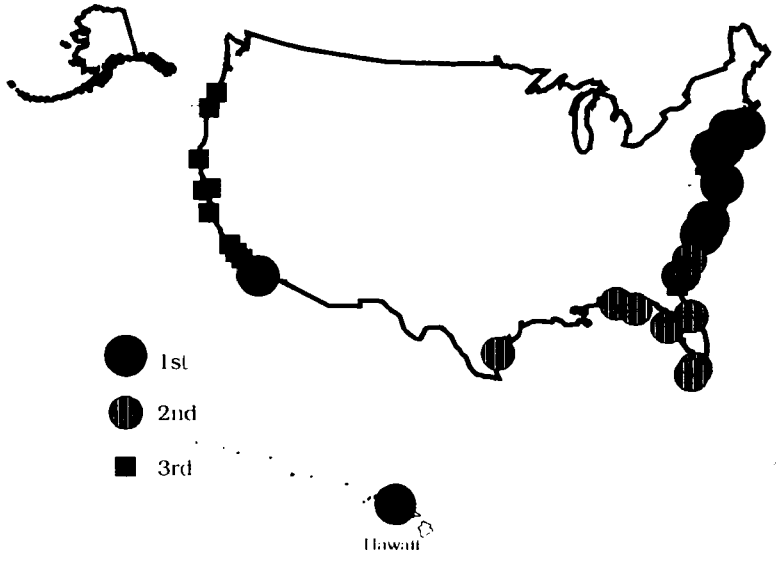


FIG. 6.- US Department of Defense Charting Priorities for Ports/Bays (Top 30 1994).

A typical process for chart selection is illustrated in Figure 7. Step 1 is dominated by the priority factors previously described. Step 2 provides criteria to aid in priority selection of specific charts, based on the factors noted. Emergency and critical needs should receive quick response. Typically charts having scale factors of 1:< 100,000 are more important because they usually include the waterways and approaches to the ports. The location and depth of clearance of the obstructions and age of the last surveys are important considerations.

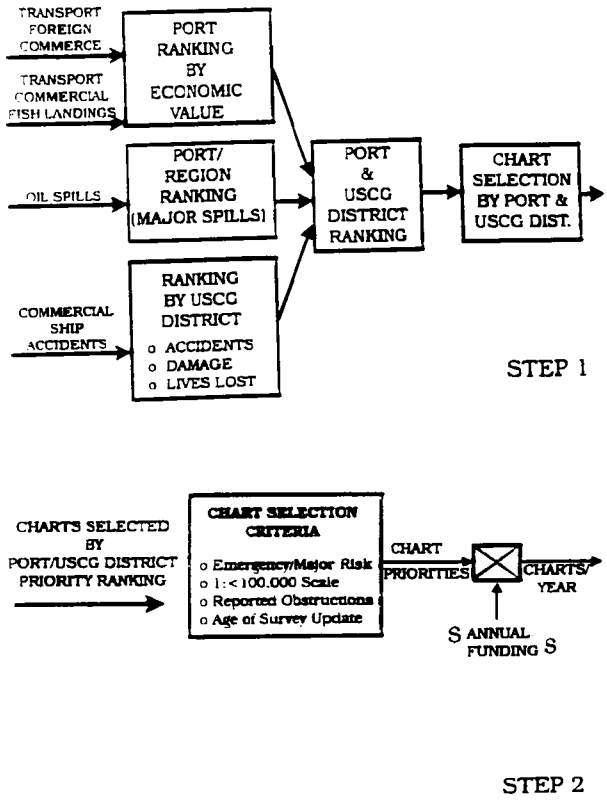


FIG. 7.- Priority Selection Process.

SUSTAINABLE DEVELOPMENT

Sustainable development of marine shipping operations is an important national objective, especially in view of increasing population growth and expected continued growth in foreign commerce. This can be accomplished by striving to ensure that future generations will have safe, productive ship operations to provide for economic growth and jobs and, at the same time, minimize losses due to accidents, hazardous spills, and damage to the marine environment and its resources. This can be accomplished by increasing the economic growth per capita and at the same time decreasing the losses per capita. In a general sense, this criteria is reasonable for pursuing sustainable development of marine transport operations. If one assumes a modest goal of wanting to at least maintain or sustain our present posture, then Figure 8 can represent a snapshot in time where the gains and losses are in balance today. This implies that while seeking economic growth and expansion to accommodate the needs of increasing population, we should not create economic, social and environmental losses. A modest objective is to maintain development in balance with the environment.

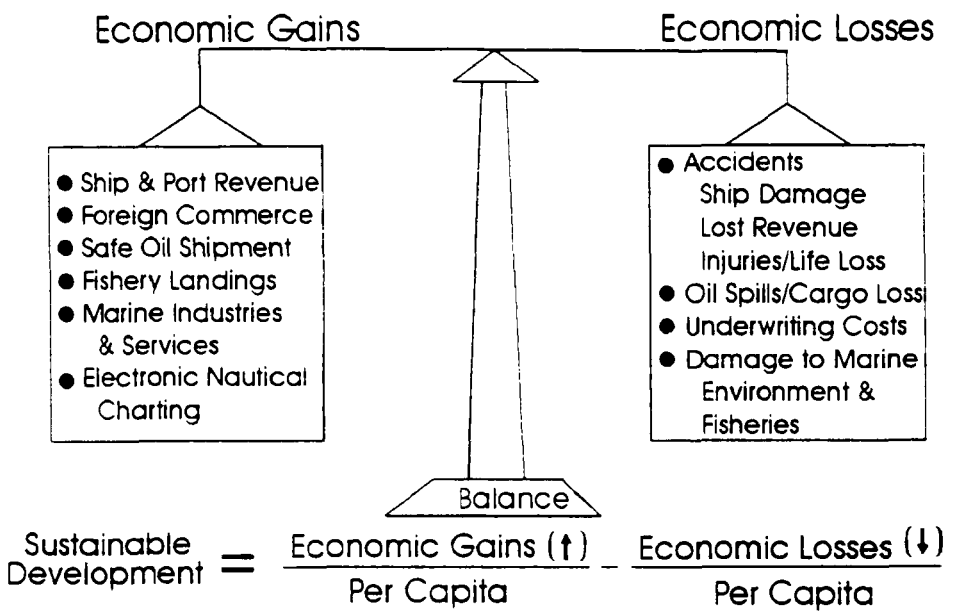


FIG. 8.- Sustainable Development of Marine Transport Operations.

CONCLUSIONS

This assessment provides some economic, social and environmental factors to facilitate the process of selecting ENC relative to their value in supporting safe and efficient marine transport operations. It provides a port or coastal area ranking order based on these factors. In economic terms, marine transport of foreign commerce valued at 562 billion U.S. dollars is dominant. However, commercial fishery landings, and minimizing the frequency of ship accidents and hazardous spills, are equally important in their own right. Since economic security and national security are interwoven, DOD charting needs must remain a high priority.

ENC plays an integral and vital role in providing navigation for safe and efficient ship operations, and thus helps to ensure economic growth and sustainable development of marine transport operations.

It is hoped that other nations, especially members of the International Hydrographic Bureau (IHB) in Monaco, can make use of some of the points made herein to help justify the importance of electronic charting and safe navigation. Also, perhaps the IHB could compile similar information from other nations to enable developing a world-wide perspective. Further, it is possible to refine this information by applying risk management modeling techniques to determine more specific monetary values attributable to electronic charting and integrated navigation systems.

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