Estimating Coastal Maritime Risk Using Geographic Information Systems

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ABSTRACT

The US Maritime Administration (MARAD) made a strong commitment to short-sea shipping in 2010 in America's Marine Highways. There is very little data about coastal vessel traffic, however, and even less is known about casualty rates in those waters due to the absence of trip data and the relatively poor quality of casualty data. Geographic information systems (GIS) are unique tools that enable greater visualization and understanding of complex problems. This paper presents a methodology used to adapt a GIS-based highway planning traffic assignment model for use in maritime risk assessment. The planning model routes twelve years of vessel entrance and clearance data through an international waterway network to estimate the number of trips traversing network links by any number of metrics, including year, ship type, flag of registry and draft. The risk methodology deploys a 100 square mile mesh (10 miles by 10 miles) over the entire United States and coastal waters to estimate the highest casualty rate (casualties per million vessel trips) and casualty frequency locations.

KEYWORDS

Marine transportation risk, marine highways, geographic information systems (GIS)

INTRODUCTION

Expanded use of coastal sea lanes has been formally advocated by the U.S. Maritime Administration (MARAD) in the form of America's Marine Highway Program (MARAD website, 2010). Land-based surface transportation capacity has not kept up with demand, and Interstate corridor congestion has grown. "Short-sea shipping" involves the shift of truck freight traffic to coastal shipping lanes as well as inland waterways to alleviate the stress on the infrastructure. This concept is not new, the European Union (EU) has encouraged short-sea-shipping between member states as part of its "Motorways of the Sea" initiative for nearly a decade (Commission of the European Communities, 2001). As the U.S. pursues this strategy, analysis of current operational conditions in these sea lanes should be undertaken. This analysis should include the benchmarking of current levels of maritime traffic and a comprehensive risk assessment along U.S. coasts.

Geographic information systems (GIS) enable complex analysis of objects based on their spatial locations. Similar objects are grouped into layers and information about each object is maintained in a relational database. Objects are typically represented in vector format as points, lines or polygons. Aerial images, such as satellite photos, can also be used in most GIS packages. There are GIS platforms which are meant for specific industries and purposes, including transportation planning, network analysis and logistics. These transportation-specific extensions enable a user to compute shortest paths between origins and destinations that minimize time, length or any other attribute (e.g., accident rate, delays). Links may be selectively enabled and disabled and time penalties may be assessed to represent delays associated with locks or other link types. The model outputs the number of trips traversing each link, as well as travel time between origins and destinations. While these models are meant for highway planning, they may be adapted for use in other transportation modes.

This research makes an important first step in quantifying maritime risk of coastal sealanes using GIS layers and databases maintained by the U.S. Coast Guard (USCG), U.S. Army Corps of Engineers (USACE) and the U.S. Customs and Border Protection Agency (USCBP). The databases mentioned above will serve as building blocks inside a transportation-specific GIS to calculate casualty rates along the US coast. The methodology developed is potentially useful to other research efforts, including understanding the impacts of proposed legislation (e.g., repeal of the Jones Act), simulation of coastal traffic in emissions studies, or planning for a long-term port disabling event (such as a labor dispute or natural disaster). For the purposes of this paper, "casualty" refers to an allision, collision or grounding and "risk" refers to casualties per exposure metric (vessel trips).

LITERATURE REVIEW

The body of literature covering maritime risk in coastal areas and waterborne traffic assignment models is sparse. A fair amount of research that makes use of real-time vessel movement data garnered through automatic identification system (AIS) archives has been undertaken. However, most of this research is aimed at estimating emissions and is confined to a port or relatively small coastal area.

The Canaveral Port Authority recently commissioned a feasibility study on promoting short-sea shipping (Le-Griffin, 2006, Canaveral Port Authority, 2005, Kruse, 2007). However, the study did not address vessel traffic and risk along shipping lanes. Though the Marine Highways program is in its infancy, the demand for short-sea shipping is expected to increase dramatically following the completion of the Panama Canal expansion when feeder services are initiated (Kruse, 2007).

Vessel traffic patterns in the Houston/Galveston nonattainment area were modeled using an archive of Automatic Identification System (AIS) data (Perez, 2009). Researchers intended to use the AIS data to show the start and stop time of the vessel to estimate commercial marine vessel emissions in Texas waters. Ultimately, the researchers used trips data from the US Army Corps of Engineers on a subset of the National Waterway Network (NWN). The decision to use trips data was influenced by gaps and errors in the AIS data archive. Wang, Corbett and Firestone used vessel trip data and historical ship coordinate data to create an empirical international waterway network (Wang, 2007). This network is known as the Ship Traffic, Energy and Environment Model (STEEM). The vessel traffic density of each network segment was computed and used to estimate vessel emissions.

Merrick investigated the risks of expanded ferry service inside the San Francisco Bay by creating a vessel traffic simulation model (Merrick, 2003). The pre-expansion traffic patterns were modeled as a base case scenario using data from the San Francisco Bay Vessel Traffic System (VTS), ferry route GIS layers and historical weather data in conjunction with a visibility model. Researchers identified current high risk areas and simulated the effects of the proposed service expansions. The expected rates of vessel interactions for the grid area were charted and compared to the base case grid.

Other attempts at characterizing vessel traffic and quantifying risk have focused on the risk associated with maritime oil transport. A systems engineering simulation model has been created to predict and analyze the risk of oil transport through the waters of Prince William Sound (Merrick, 2000). The model was built using archived data from vessel traffic services (VTS) and information from vessel transit logs and transit route maps, and published ferry schedules. The simulations were used to examine the effectiveness of potential risk mitigation strategies. Woolgar used international shipping data to create an oil tanker route network in Southeast Asia using GIS (Woolgar, 2008). Tanker movements were aggregated to determine vessel traffic and tonnage for each route. The International Tanker Owners Pollution Federation Limited (IOTPF) maintains a database on historical tanker accidents and a web-based GIS where worldwide tanker movements and tonnages are displayed (IOTPF, 2010). The tanker movements and overall volumes are not related to the accident data, and absolute numbers are not available (only ranges of movements and tons and year to year changes).

Dobbins and Abkowitz used geographic information systems (GIS) to analyze inland marine casualty data in the U.S. (Dobbins and Abkowitz, 2010). By examining more than 25 years of inland marine casualty data in a GIS environment, the top 25 most frequent incident locations were identified and studied using aerial photography from Microsoft Virtual Earth and Google Earth. The quality of historical U.S. Coast Guard (USCG) casualty data was noted as poor, but improving as of late. The absence of high-resolution, publicly-available inland marine trip data was also documented. While tonnage data is published on a link-by-link basis (USACE website, 2010), trip data is aggregated to the waterway level in order to protect business book information of inland marine carriers. This analysis of accident frequency was simplified by the use of the inland waterways' milepost system.

In summary, research efforts have been undertaken where vessel movements are quantified and in some cases related to marine casualty data, but the sources of data have typically been vessel traffic services (VTS) and archives of AIS data. It follows that these efforts have been limited in geographic coverage and scope, with most studies limited to a port or region and a specific vessel type.

DATA SOURCES

The Waterborne Commerce Statistics Center (WCSC) of the U.S. Army Corps of Engineers (USACE) "collects, processes, distributes and archives vessel trip and cargo data" (USACE website, 2010). These data sources cover foreign and domestic waterborne commerce and the data are updated as often as monthly, as in the case of lock performance. Several of the datasets released to the public via the website are aggregated so as not to reveal any confidential business data. The data sources used in this research included the National Waterway Network (NWN) and Manuscript Cargo Files.

The NWN is a GIS layer of navigable waterways in and around the United States. This network was designed in 1991 and continues to be updated by the USACE. The network's attributes include control depth, functional classification, milepost numbers (if applicable), geographic class, link type, nautical chart reference number and waterway code. The nodes are an important part of the network, as they represent US ports and the codes are used in the agency's waterborne commerce. The links vary in length, ranging from 0.02 miles (locks) to 7,000 miles (offshore links) with an average length of 27.7 miles. Manuscript Cargo Files are published annually and are the source of data for the annual Waterborne Commerce of the United States (WCUS) publications (USACE, 2010). Waterborne movements are reported to the Corps and the resulting dataset of trips and drafts includes the following key pieces of information:

- *WATERWAY* – four-digit WCSC waterway code
- *ALLO_1* and *ALLO_2* – codes that represent the type of movement (upbound/downbound, inbound/outbound, local, through movement, etc.)
- *VES_TYPE* – general vessel type (self-propelled dry cargo, self-propelled tanker, towboat, non-self-propelled dry cargo, non-self-propelled tanker, other)
- *DRAFT* – the draft of the vessel in feet
- *TRIPS* – number of vessel movements occurring on the waterway, a trip is logged between ports of departure and arrival for self-propelled vessels and point of loading to unloading for non-self-propelled vessels
- *YEAR* – year in which the movements took place

Vessel trip data recorded using 4-digit WCSC waterway codes does not support high-resolution analysis. WCSC waterway codes have a one-to-many relationship with NWN links. For example, waterway code 6034 on the Lower Mississippi River stretches from Baton Rouge, LA to Cairo, IL (over 712 miles). However, foreign and intraport trips are included in the data. The trips and drafts data is supplemented by data obtained from the Port Import Export Reporting Service (PIERS), a firm that specializes in collecting and disseminating US import/export data. The trips and drafts data is the best available source of trips data on the intracoastal waterways. Therefore, trips and drafts data from 2006 through 2008 were aggregated to determine the average number of trips occurring on these links.

The US Customs and Border Protection (USCBP) agency collects information from all ships entering and departing US ports via Form 1300. WCSC distributes this data on the website in the structure described in Table 1 (USACE, 2010). The research used an archive of vessel entrances and clearances dating from January 1997 through December 2008. Of note is the number of ship categories in the datasets. The Manuscript Cargo files report trips in 7 general categories (self-propelled dry, tanker, towboat, dry cargo barge, liquid barge, other and rafted logs), but there are over 69 distinct International Classification of Ships by Type (ICST) types reported in the entrances and clearances data.

TABLE 1 Vessel Entrance/Clearance Data Structure

FIELDNAME	DESCRIPTION
TYPEDOC	Whether the record represents entrance or clearance
ECDATE	Entrance/clearance date
PORT	WCSC port code
PWW_IND	Port or waterway indicator
PWW_NAME	WCSC port or waterway description
VESSNAME	Vessel name
RIG	Type of vessel
ICST	International Classification of Ships by Type
FLAG	Vessel's flag of registry
WHERE_PORT	Previous or next domestic port of call
WHERE_SCHK	Previous or next foreign port of call (Schedule K code)
WHERE_IND	Domestic or foreign indicator (for next or previous port of call)
WHERE_NAME	Domestic port or foreign country (of next or previous port of call)
NRT	Net registered tonnage
GRT	Gross registered tonnage
DRAFT	Vessel draft in feet
CONTAINER	Container indicator
IMO	Unique vessel identifier (International Maritime Organization number)

The United States Coast Guard (USCG) is tasked with investigating marine casualties occurring on US navigable waterways. With regard to vessels, the term "marine casualty" includes (but is not limited to) grounding, stranding, foundering, flooding, collision, allision, explosion, fire and reduction or loss of a vessel's electrical power, propulsion, or steering capabilities (46 CFR Sec. 4.03-1(a)). This research effort's case study casualty database only contains allisions, collisions and groundings. These casualty types were analyzed since other types (including fire, explosions, crew injuries) happen independently of location, channel configuration, and vessel traffic. The casualty data available to this project consisted of 38,491 casualties occurring from January 1, 1980, through December 31, 2007. There are several issues that affect the quality of the casualty data including the three reporting systems used by the USCG during this timeframe (CASMAIN, MINMod, and MISLE), variances in district reporting, and quality of the geographic coordinate reporting. Dobbins and Abkowitz detail these issues (Dobbins and Abkowitz, 2010). It should be noted here that the USCG is not the only source of marine casualty data; Lloyd's of London has an extensive database of such incidents. However, repeated attempts to procure casualty data from the agency were unsuccessful.

The former Minerals Management Service (MMS), now known as Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), maintains several GIS layers related to oil and gas exploration in the Gulf of Mexico, including oil platforms and shipping fairways (BOEMRE, 2010). Though these GIS layers were not directly used in the risk assessment methodology, they are useful in validating the USCG casualty data (namely allisions) occurring in the Gulf of Mexico. The shipping lanes layer was used to modify the NWN so that the links represent the actual areas vessels transit when entering and departing ports. Figure 1 shows the 3,724 active oil platforms in the Gulf of Mexico along with the allisions occurring between 1980 and 2007.

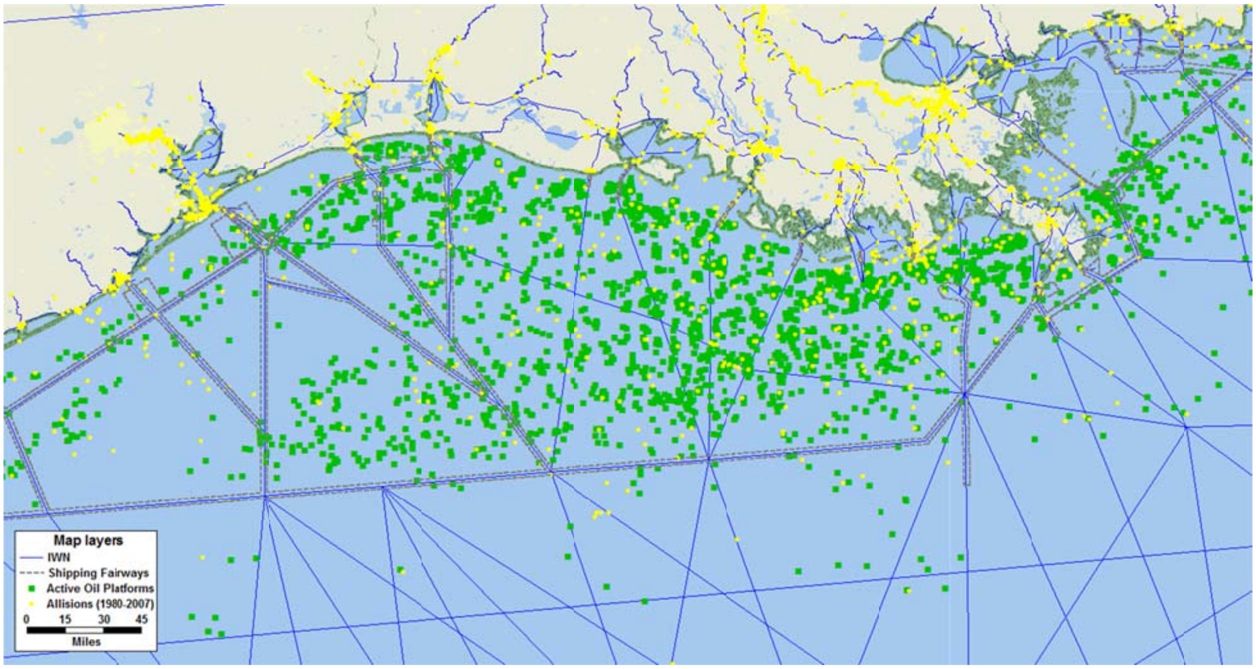

FIGURE 1 Oil platforms and allisions in the Gulf of Mexico

METHODOLOGY

The first step in estimating risk is to establish the number of trips to serve as the denominator in the casualty rate calculation. Aggregation of the trip data from the manuscript cargo files yielded the average number of trips by WCSC waterway codes for 2006-2008. This average number of trips was joined to the NWN as a new attribute. The subset of NWN links for which trips were calculated is shown in Figure 2.

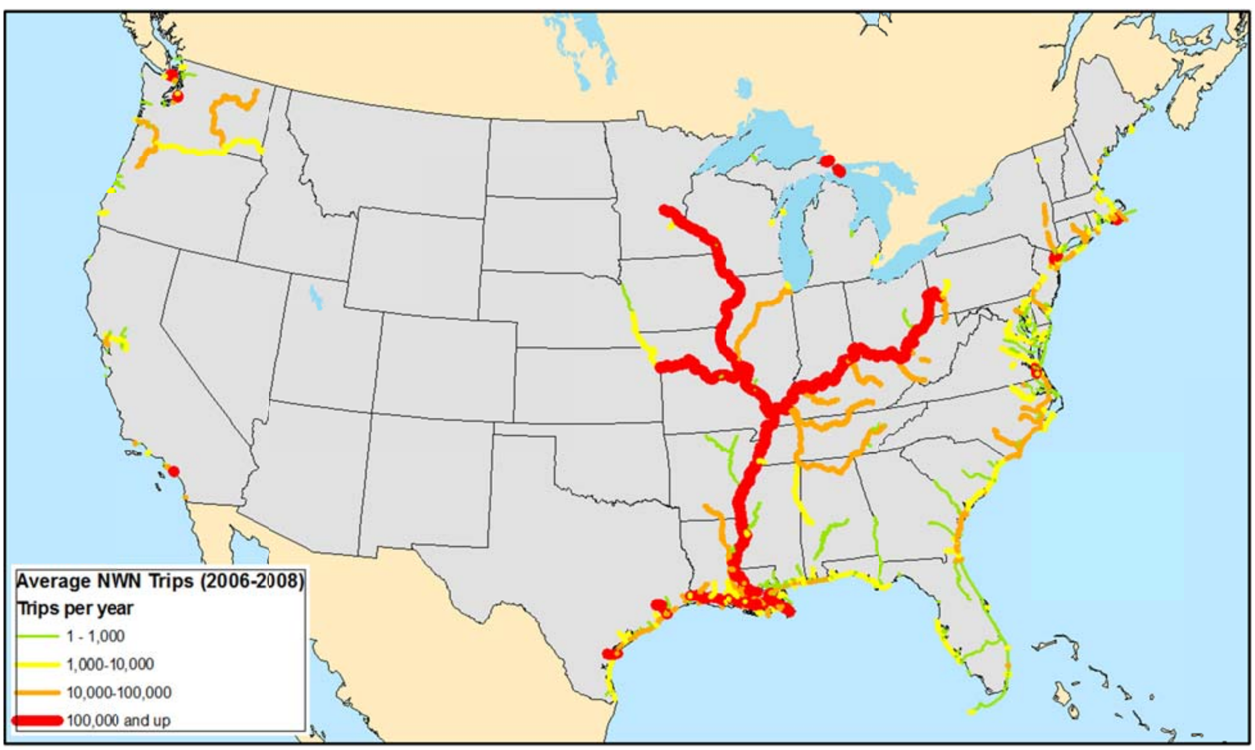

FIGURE 2 National Waterway Network trips (WCUS data)

The entrance and clearance data contains port destinations and origins outside the NWN (e.g., Schedule K codes). The entrance and clearance database contains over 2 million O-D pairs, and there were 1,842 unique foreign ports connected to the network. The International Waterway Network (IWN), used to calculate port to port distances (Daniel, Dobbins and Abkowitz, 2010), served as the base network through which these trips would be routed. For several entrances and clearances in the database, the port of origin (entrance) or destination (clearance) are unknown or listed as “High Seas.” In these situations, a node near the sea buoy outside the port was designated for trips with unknown origins (entrances) and destinations (clearances). Most offshore supply vessel trips have “unknown” destinations. As both domestic entrances and clearances are in the database, domestic clearances were removed from the database to eliminate the double-counting of this movement (the next port’s entrance would reflect the movement).

A very useful feature of the IWN is the inclusion of the NWN attributes. This enables line features to be selectively disabled. The following situations are representative of links that were disabled to ensure realistic routing results:

- Intracoastal waterways and inland locks – used mainly for inland navigation, vessel movements in the entrance and clearance database (such as container ships and tankers) do not travel these segments.
- Waterways not used for navigation – links whose functional classification stated the segment was non-navigable, traveled by special vessels only or shallow draft (field “FUNC” values of ‘N’, ‘S’, and ‘U’) were disabled.
- Visually selected links – some links (such as the Cross-Florida barge canal, Okeechobee Waterway and miscellaneous waterways in and around the Florida Keys) would serve as “shortcuts” between the Gulf of Mexico and the Atlantic Ocean.

A database query aggregated the entrance and clearance data into 4 separate matrix input files (year, flag, ship type, draft) containing the number of trips occurring between network nodes. These matrices are all that is needed to perform the vessel traffic assignment using the IWN. The traffic assignment model chosen for this research was a multi-modal, all or nothing traffic assignment. “Multi-modal” in traditional traffic assignment models tracks trips by vehicle type (e.g., passenger vehicles, single-unit trucks and multi-unit trucks). In this adaptation for vessel traffic assignment, unique values of the metric being routed (year, ship type, drafts, flag) serve as the “mode.” Thus, the model’s results are the number of trips on each network link: by year, flag of registry, ship type and draft. “All or nothing” means all traffic will travel the shortest cost path (length, though any attribute may be minimized) between origin and destination (Hensher and Button, 2000). The shortest-path routing results appear reasonable. However, there are no public-domain data sources against which to validate.

A screenshot of the International Waterway Network displaying containership flows is presented in Figure 3. Any host of other maps could be generated using the entrance and clearance database with the IWN. Examples include trips made by vessels with drafts greater than 45 feet, the proportion of coastal trips made by Liberian-flagged vessels, and the percentage of trips made by passenger vessels, to name a few.

FIGURE 3 International Waterway Network (IWN) with containership trips (1997-2008)

Now that the number of trips has been estimated, the remaining piece of the risk calculation was the number of casualties occurring on each link. All 38,491 casualties were mapped as point features and a spatial join made between each casualty and the nearest link. This spatial join added two fields to the casualty database, nearest link identification number and the distance to the link. Casualties whose coordinates placed the event more than 100 miles from the US coast or more than 20 miles from the nearest link were removed from the analysis (roughly 10%). A raw map of the casualties is presented in Figure 4.

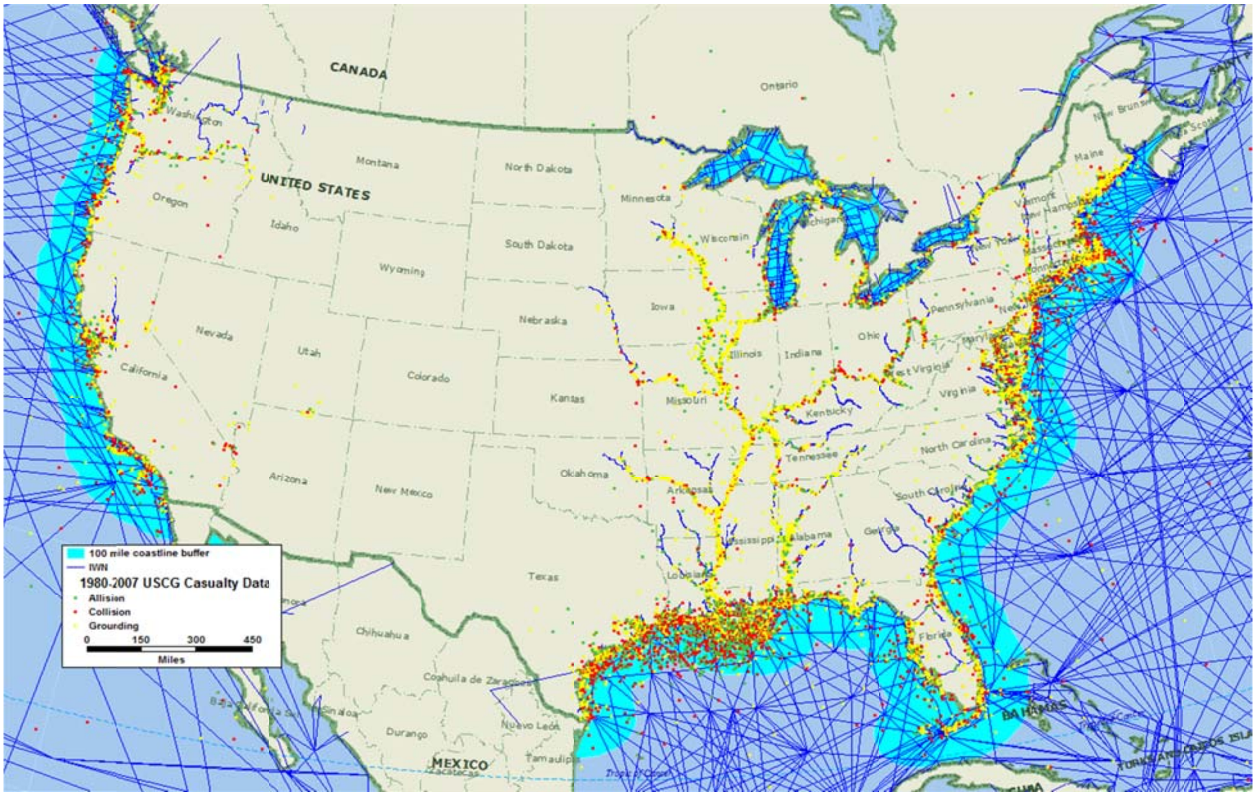

FIGURE 4 USCG Casualty Data (1980-2007)

The datasets had varying timelines; the entrance and clearance data ranged from 1997-2008, the USCG casualty data ranged from 1980-2007 and the trips and drafts data ranged from 2006-2008. Since casualty occurrences are low (the highest number of casualties on a given link during the 28-year period was 27, or just under one per year), the trips data was averaged annually, then multiplied by 28 (years) to get an estimate of how many trips were made during the period. It should be clarified here that this is only for the purposes of risk calculation, so the time periods of the trip and casualty data correspond. This is a rough method of estimating vessel trips and does not take into account changes in vessel capacity, fleet size, or fluctuations in economic activity. However, annual vessel trips (by IWN link) for 1997-2008 are accurate attributes of the IWN (thanks to the route assignment model). The denominator of the risk calculation was trip-miles, which removes bias toward longer links. The number of casualties on each link was divided by the trip-miles and then multiplied by 1,000,000 to get a number of casualties per million trip-miles.

Upon examination of the IWN casualty rates, large variations in length (up to 564 miles) of the IWN links precluded the identification of particularly hazardous segments. Several links span open sea and harbor approaches; these disparate channel types are likely to have varying casualty rates. In order to normalize the results, a ten mile by ten mile square mesh was overlaid with the IWN trips data as well as the casualties. For each 100 square mile cell, the number of trip-miles and casualties was calculated using GIS routines before dividing to find an areal casualty rate. Figure 5 displays 287 grid cells (minimum 1,000 trips) color-coded by casualty rate.

FIGURE 5 Casualty rates (casualties per million trip-miles, minimum 1,000 trips)

RESULTS

The planned casualty rate methodology transformed from a link-based risk analysis to a cell-based grid analysis. Grids where trips were computed using WCUS data were excluded from the results analysis to better test the entrance and clearance data methodology of estimating trips and casualty counts. The observations in this section are all based on the entrance and clearance trip data. Upon closer examination, some trends appear:

- The numerous oil platforms oil platforms in the Gulf of Mexico do not create significantly higher casualty rates in the Gulf of Mexico shipping channels. While high-casualty rate grids do exist along the Louisiana and Texas oilfields, the highest casualty rates are concentrated near the intersections of shipping lanes. Prior to performing the research, it was expected that a high number of vessel-platform allisions might be occurring in areas other than the designated shipping lanes (i.e., vessels might be tempted to leave the shipping lanes to save time).
- Most of the high casualty-rate grid cells are located at entrances to major ports. The top ten grids as far as casualty rates are the entrance to the port of San Francisco (outside the Golden Gate Bridge), the Southwest Pass and approaches to the Port of New Orleans in Louisiana, San Diego, Everett (WA), and the approaches to Bellingham, WA. Recreational vessels in these areas play a major role in the high number of casualties. Recreational vessels made up less than 2.5% (overall) of allisions, collisions and groundings from 2002-2009 (MISLE-reported events). However, more than 22% of reported casualties in Everett and Bellingham involved recreational vessels (MISLE data). Similarly, commercial fishing accounted for 10% of casualties in the entire database, but almost 19% outside of Everett and Bellingham.
- The entrance to the Galveston Bay (where the intracoastal waterway meets the Houston Ship Channel) had the cell with the greatest number of casualties (681) during the 28 year period. Silting conditions that require unique vessel maneuvers (e.g., “Texas Chicken”) and crossing situations with intracoastal waterway traffic likely contribute to this large number.
- There are no cells in open water with high casualty frequencies. The highest number of casualties in a cell 75-100 miles from the coast is 4 (in the Gulf of Mexico oil fields). Coming closer to shore, no cell 50-75 miles from the coast has more than 6 casualties (also in the Gulf of Mexico oil fields).
- Unfortunately, it is not possible to directly compare casualty rates among ship types. This is due to the misalignment of vessel categories in the casualty and entrance/clearance data as well as the lack of detailed trip data on the inland waterways.

- Inland towboats and barges comprise an overwhelming majority of the casualty records (60% since 2002) in the case study database. However, this is to be expected, as towboats and barges maneuver through obstacles (locks and dams, bridges, other vessels) at close quarters throughout the duration of the trip. Deepwater ports also make use of sea pilots and docking masters to maneuver ships from the sea buoy to the terminal, the most congested part of the trip.

To summarize the results of the cell-based analysis, Table 2 presents the top 10 port entrances in terms of casualty rate and casualty frequency (minimum 1,000 trips in each cell with at least 50 casualties from 1980-2007). Only the cell containing the Southwest Pass to the Lower Mississippi River appears in both columns. Marrero, LA is listed twice in the casualty frequency column since the area is located on the border of two high casualty-rate cells.

TABLE 2 Top Ten Casualty Rate and Frequency Locations

Rank	Casualty Frequency (casualties/100 mi^2)	Casualty Rate (casualties per million trip-miles)
1	Galveston, TX (681)	Gloucester, MA (470)
2	Bayonne, NJ (321) – *New York entrance*	Coos Bay, OR (241)
3	Marrero, LA (311) – *New Orleans*	Mobile, AL (223)
4	Hoboken, NJ (289)	St. Petersburg, FL (199)
5	Houma, LA (260)	Cape Canaveral, FL (198)
6	Baytown, TX (248) - *Houston Ship Channel*	Richmond, CA (135)
7	Marrero, LA (227) – *New Orleans*	Chalmette, LA (108) – *Southwest Pass*
8	La Porte, TX (216) – *Houston Ship Channel*	Boston, MA (91)
9	Victoria, TX (213)	Kenner, LA (66.9) – *New Orleans*
10	Chalmette, LA (185) – *Southwest Pass*	Biloxi, MS (62)

Finally, casualties and vessel traffic were analyzed within the 100-mile buffer from the US coastline. Table 3 contains the number of casualties and trip-miles based on the distance from shore. It is intuitive that casualties will occur more often closer to shore. However, the cumulative effect of coastal trips is very strong, with 5 times as much traffic (in terms of trip-miles) between 25 and 50 miles from shore compared to within 25 miles (including port arrivals). It should be noted that these trip-miles are a rough approximation of shipping lanes and are not the actual paths taken by vessels. Future research should examine AIS data archives to find the preferred routes and exact coastal traffic levels.

TABLE 3 Breakdown of Location of Casualties and Trip-miles within 100-mile Buffer

	Casualties	Trip-miles
0-25 miles	12,263 (92.2%)	4,274,306 (10.8%)
25-50 miles	552 (4.2%)	19,517,008 (49.3%)
50-75 miles	350 (2.6%)	8,958,341 (22.6%)
75-100 miles	133 (1.0%)	6,810,775 (17.2%)
Totals	**13,298**	**39,560,430**

CONCLUSIONS

This paper presented a methodology for adapting a highway traffic assignment model for use in maritime transportation risk assessment. Specifically, existing vessel traffic volumes along US coasts were quantified using historical USCBP entrance and clearance data. The traffic assignment model used in the research is capable of showing vessel traffic by any attribute contained in the entrances and clearances database (year, flag of registry, ICST ship type and draft). Such specific routing capabilities can serve as a valuable information resource for evaluating effects of expanded infrastructure (i.e., Panama Canal expansion), dredging ship channels to greater depths and proposed legislation. The research is also transferable in the area of coastal and marine spatial planning. This refers to a planning process "for analyzing current and anticipated uses of ocean, coastal and Great Lakes areas" (NOAA website, 2010). The process makes extensive use of GIS for identifying suitable areas for activities that minimize conflicts and adverse environmental impacts and balance competing demands for marine resources. The methodology and results (GIS layers) from this research could serve as an important facet to understanding the waterborne commerce patterns, interactions and risks along U.S. coasts.

Casualty rate was computed for all coastal and deepwater port approach links. Due to the geographic spread and long return period of casualties, a 100 square mile mesh-based approach to quantifying casualty rates was adopted in favor of a link-based approach. The calculation of casualties per million vessel trips is not a complete risk assessment picture. Additional datasets including weather data (severe weather, wind speed and visibility) and consequences data (probability of a spill resulting from a vessel-platform allision), would make the risk assessment calculations more complete.

Additional datasets could be integrated with the routing results from the study. The Automated Mutual-Assistance Vessel Rescue System (AMVER) is a ship position reporting system used to coordinate search and rescue operations when a vessel broadcasts a mayday call. As the ships report in at least upon departure, arrival and once every 48 hours while at sea, the system's historical data would serve as a great source from which to calibrate the International Waterway Network. Similarly, large archives of AIS data is already being used in collision-prediction models. This data would serve to better benchmark exact congestion levels within ports, near-miss situations and high resolution port transit tracks. Archiving AIS data received in the Gulf of Mexico oilfields would be an interesting exercise to see how often shipping lanes are adhered to for vessel transits. Once more short-sea shipping services are offered and shipping schedules are established, the network could be used for performance tracking.

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