MarTREC
Maritime Transportation Research & Education Center

MarTREC UTC Project Information Form
USDOT Tier 1 University Transportation Center
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Project Title: Network Science-based Analysis of the US Marine Highway Network and a Random Graph Model for the Intermodal Port Network

Project Abstract (Brief Description): Marine highways in the US correspond to navigable waterways that run closer to major interstate roads in the country. Unlike the US Interstate road network and the airport network, the US marine highway network (MHN) and the US marine intermodal port network (MIPN) have not been analyzed and no results have been so far reported in the literature. We model the MHN as a graph whose vertices correspond to the marine highways and there exists an edge between two vertices if the corresponding marine highways intersect each other. We propose to analyze the MHN using algorithms for community detection, cluster analysis and centrality assessment to identify the critical marine highways and their intersection points (intermodal ports) that could potentially be a bottleneck whose capacities need to be enhanced. Each marine highway serves one or more inland ports and/or coastal ports that are equipped for intermodal transportation. To avoid traffic congestion, especially in scenarios of evacuation, we would prefer not to overload any particular intermodal port across a marine highway. From a Network Science standpoint, no port in an MIPN will be overloaded if the MIPN exhibits the characteristics of a random network. We propose to build an MIPN of the US marine intermodal ports such that two ports are connected (i.e., a marine transport service could be deployed between the two ports) if the "waterway distance" between the ports through the marine highways is within a threshold. Such a marine transport service could ease the existing congestion in the interstates and rail roads between the two intermodal ports/cities. In this pursuit, we propose to develop a binary search algorithm to determine the smallest possible value for the threshold waterway distance contributing to a random network-like MIPN topology (referred to as US-MIPNrand).

Describe Implementation of Research Outcomes - Tasks for PO-1: We propose to determine the edge betweenness centrality (EBWC) values for the links in the MHN and rank the intersection points (links between two marine highways) with respect to their role as bottleneck links in the network. We will determine the recently proposed (by the PI) Neighborhoodbased Bridge Node Centrality (NBNC) tuples of the marine highways on the MHN to rank and identify the marine highways/bridge nodes whose capacities need to be enhanced to facilitate congestion-free passage of traffic originating across the clusters to which the bridge nodes are connected to. Tasks for PO-2: We will implement the Brandes' algorithm to determine the betweenness centrality (BWC) of the marine highways in the MHN as well as determine their degree centrality (DEG). We will determine the Kendall's concordance-based correlation coefficient for the normalized (DEG, BWC) values of the vertices in a DEG vs. BWC coordinate system to theoretically examine whether or not marine highways with fewer intersections need capacity enhancement. Tasks for PO-3: Given the distance matrix between any two intermodal ports, we propose to develop a binary search algorithm that could be used to determine the (minimum) threshold waterway distance that can be setup as the cutoff to decide the presence or absence of links (construed as marine services) between any two intermodal ports. We will choose a target value and run through the algorithm in iterations to determine the minimum waterway distance beyond which the value of the MIPN will be above the target. The corresponding random network-style MIPN will be referred to as US-MIPNrand. Tasks for PO-4: We will use the raw data of the waterway distances between the intermodal ports in the Gulf Coast states and run the binary search algorithm for PO-3 to determine a random network-like MIPN (referred to as Gulf-MIPNrand) whose variation in node degree is within a chosen target value for. We will extract a sub graph (comprising only of the intermodal ports in the Gulf Coast

states and the associated marine highways) of the US-MIPNrand network constructed based on the same value used. If for all the targeted values, the randomness index values of the sub graphs are closer to the randomness index values of Gulf-MIPNrand, we can conclude the sub graph of a real-world random network (the US-MIPNrand network) is also a random network
Impacts/Benefits of Implementation - The proposed research addresses the need to identify efficient, resilient and sustainable maritime and multimodal transportation infrastructure. PO-1 and the associated tasks would directly help to enhance the resiliency and sustainability of the maritime infrastructure by identifying the bottleneck maritime highways and the bottleneck intersection points (intermodal ports) so that their capacity can be enhanced. PO-2 and the associated tasks would contribute to enhancing the efficiency of the maritime infrastructure by suggesting the low-degree maritime highways that would need capacity enhancement on the basis of their betweenness. PO-3 and the associated tasks help to identify the marine transport services that could be implemented between the inland ports that are not efficiently used. PO-4 and the associated tasks focus on the Gulf Coast states (including Mississippi) to enable innovative routes for freight transportation among the inland ports in these states. Both the POs-3 and 4 and the associated tasks would address the need to consider the transportation challenges of the lower socio-economic and rural communities (in the form of marine transport services that could be setup between inland ports) so that they can be better connected to the rest of the world. All the four POs and the associated tasks are aimed at optimizing resource allocation, minimizing congestion points and maximizing transportation efficiency.
Web Links: martrec.uark.edu
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