Paper 77 - Performance Measures for the Marine Transportation System of the USA

KRESS, Marin; DIJOSEPH, Patricia

U.S. Committee on the Marine Transportation System; U.S. Army Engineer Research and Development Center

Email (1st author) marin.m.kress@usace.army.mil

ABSTRACT: This paper describes an initial assessment of the U.S. Marine Transportation System (MTS) using publicly available data from authoritative sources. Seventeen measures across five categories of assessment were identified (economic benefits, capacity and reliability, safety and security, environmental stewardship, resilience). Graphs for ten measures are included in this report. In conclusion, it is possible to make a high-level assessment of U.S. MTS performance, but gaps in data reporting and analytical capacity still exist. Suggestions for future research include identifying sources of intermodal freight data and the development of improved measures for environmental stewardship and security.

1 INTRODUCTION

1.1 *Motivation for project*

Many stakeholder groups in the United States (U.S.) are interested in the performance of the marine transportation system (MTS) which includes coastal and inland waters. Interested groups, each with different priorities and questions, include government entities, commercial and recreational users, and non-governmental organizations. However, there is no single authority for information on all aspects of waterways that comprise the MTS. This makes it difficult to find information on different elements of MTS performance. This project brings together public data, available on the internet, on different aspects of MTS performance using multiple authoritative sources and then presents that data in a unified way so that all stakeholders can have the same information.

1.2 *MTS data providers in the United States*

In the United States there are many Federal agencies with maritime-related responsibilities, ranging from law enforcement to trade data collection. U.S. Federal agencies with major maritime roles include the Coast Guard (USCG) (safety and law enforcement)[1], the National Oceanic and Atmospheric Administration (NOAA) (science and charting)[2], the Department of Transportation (statistics and regulations) [3], and the Army Corps of Engineers (USACE) (regulations, operations and maintenance, and dredging) [4]. These agencies, and others, produce relevant maritime data as part of their routine activities, but such data is not necessarily collected at the same spatial or temporal scale. At present there is no single repository for collecting these data to produce a holistic assessment of the U.S. marine transportation system. There are initiatives to make all U.S. government data more discoverable through websites such as the Data.gov and Marinecadastre.gov websites, however the Data.gov website is not specific to the MTS [5]. Data.gov does not archive data, but provides links back to individual Federal agency websites where data is stored. The Data.gov process requires agencies to submit information and metadata about available datasets and then routinely check back with Data.gov to make sure that the links are still active. As more Federal data sets are published and made discoverable the ability to understand and assess MTS performance should improve.

1.3 *Previous PIANC work on this topic*

This project builds upon an organizational framework published by the World Association for Waterborne Transport Infrastructure (PIANC). The PIANC report, Performance Measures for Inland Waterways Transport (2010), identified three general purposes for performance measures (operational, informational, for reference) and nine thematic areas (infrastructure, ports, environment, fleet and vehicles, cargo and passengers, information and communication, economic development, safety, and security) [6]. Of these areas, the categories selected for this project are economic benefits, capacity and reliability, safety and security, environmental stewardship, and resilience. Two notable differences exist between the suggested PIANC framework and this project. The first is that this project did not include an evaluation of specific private assets such as port property or vessels because of the wide variety of establishments and the lack of data available to develop measures that then could be applied in a standardized way. Many ports are privately run and in competition with each other for business, there is little incentive to publish anything except required data. The second is that this project focused on commercial operations and did not include data for recreational waterway users even though in there are important economic benefits from recreational activities, especially in areas that are heavily economically dependent upon tourism.

1.4 *General description of performance measures*

This report proposes that an ideal MTS performance measure can be collected locally, using the same method across all areas of responsibility, so that comparisons could be made at the local or regional level and that national summaries could be easily compiled. All measures should relate to specific goals for the MTS so progress can be measured. In the absence of official goals it is important to provide a baseline understanding of the current system, including where data is missing. When designing performance measures to measure progress is it key to distinguish between output-based measures and outcome-based measures. Output-based measures identify information about the use of resources [7]. Examples of MTS related output measures include number of containers loaded and unloaded at a port, amount of sediment removed from a channel, or the number of vessel inspections completed by regulators. Outcome-based measures identify how well an organization is meeting stated goals and objectives; these types of measures are often more relevant to the general public [7]. Examples of MTS outcome measures include the number of vessel accidents, average tons per vessel transported through a specific channel, and average travel time between two ports. Both output and outcome-based measures are necessary to evaluate a system; they work in tandem to support analysis of how a system's structure is contributing to its functional goals. Since the MTS is geographically expansive and subject to both environmental and human influences there will always be regional differences in challenges and priorities.

2 METHOD

2.1 *Using existing public data*

This research has two elements, 1) internet-based research for existing public data sets and 2) the acquisition of Automatic Identification System data from the U.S. Coast Guard for vessels travelling on inland waterways and the generation of travel time estimates. This project started with a meeting of experts from multiple maritime disciplines to identify areas of MTS performance that would be of interest to many groups. There is not a standard set of goals for MTS performance, but there are areas of clear national interest (e.g., zero accidents, reduce pollution, improve resilience). These broad national interests were used to guide the first year of research and data discovery.

An original list of suggested performance measures narrowed down to topics which had publicly available data from authoritative sources. This research resulted in seventeen performance measures from every category except 'security' for which no comprehensive public data has yet been identified. A subset of the seventeen measures is presented and discussed in section 3.

2.2 *Using archived AIS data from the U.S. Coast Guard*

This project used archived AIS data for the year 2013 to develop travel time estimates for specific port pairs along the Ohio River to demonstrate AIS analysis capabilities (for full methods see [8]. Briefly, the four ports used were Cincinnati, Ohio; Louisville, Kentucky; Evansville, Illinois; and Cairo, Illinois (where the Ohio River flows into the Mississippi River). In 2013 not all commercial vessels on inland waterways were required to use AIS, however enough vessel records were available to generate a sufficient sample size for this initial research project. Origin and destination areas were set for each port using latitude and longitude. Any commercial vessel that broadcast a signal within both areas was included in the sample, but samples were separated according to upstream or downstream travel.

3 FINDINGS

3.1 *Vessel Travel Time Estimates*

The results of the travel time estimate calculations are shown in Table 1, with the 25th, 50th, and 75th percentile travel time for the population of vessels included in the sample. These estimates can now be used to examine the impacts of lock closures or river conditions on the travel times for commercial vessels. This method will be applied to include more port pairs along the Ohio and Mississippi Rivers, other inland waterways of the U.S., and coastal ports.

Table 1. Travel time estimates for origin and destination pairs along the Ohio River in 2013, calculated using archived 2013 AIS data from U.S. Coast Guard.

ORIGINS	Travel Time (Hours) 25th percentile **50th percentile** 75th percentile	DESTINATIONS: Cairo, IL	Evansville, IL	Louisville, KY	Cincinnati, OH
	Cairo, IL		30.1 **36.9** 50.2	69.3 **84.1** 109.9	95.7 **115.9** 149.8
	Evansville, IL	21.4 **25.9** 38.6		33.5 **40.3** 50.6	59.9 **72.1** 90.6
	Louisville, KY	47.1 **56.0** 78.5	22.2 **25.8** 32.7		21.5 **28.1** 32.4
	Cincinnati, OH	65.3 **77.4** 108.8	40.4 **47.3** 62.9	14.8 **19.0** 24.5	

3.2 *Economic benefits to the United States*

The entire MTS provides significant benefits to the U.S. as a conduit for both national and international trade. Inland waterways are important transportation routes for grain and agricultural exports as well as energy commodities including coal, petroleum products, and other bulk commodities [9]. In 2013 the MTS was used to import and export goods worth billions of dollars (Figure 1), the value of imports and exports moved by water in 2013 surpassed pre-recession levels. The MTS was also used to import and export millions of kilograms worth of goods (Figure 2). The role of inland waterways in the transportation of goods within the US is significant, in 2012 there were over 565 million short tons of domestic commodity shipments (defined as having both domestic origin and destination).[9] The first round of MTS performance measures were not designed to identify specific benefits from inland waterways, coastal, and Great Lakes trade. However, relevant information is available from the U.S. Army Corps of Engineers Waterborne Commerce Statistics Center and will be consulted for future performance measures development [10].

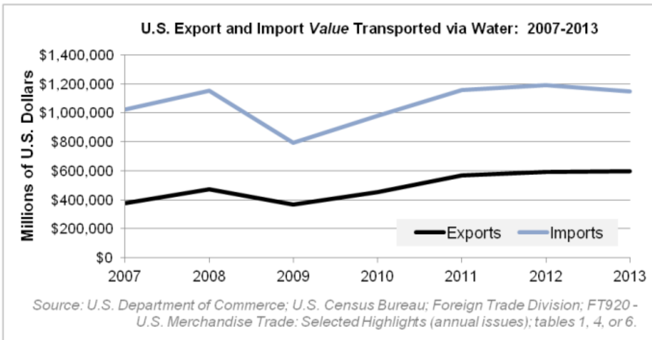

Figure 1. U.S. Export and Import Value Transported by Vessel: 2007-2013. Source: U.S. Department of Commerce; U.S. Census Bureau; Foreign Trade Division; FT920 - U.S. Merchandise Trade: Selected Highlights (annual issues); tables 1, 4, or 6.

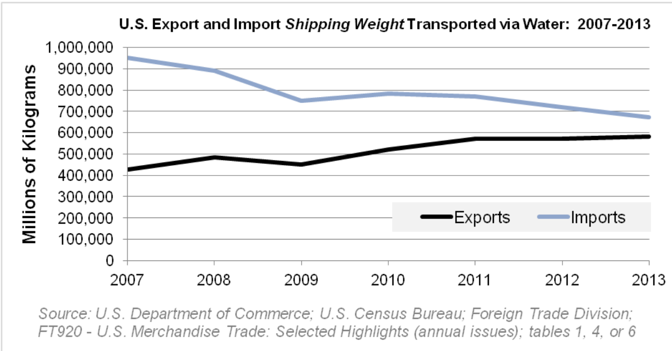

Figure 2. U.S. Export and Import Value and Shipping Weight Transported by Vessel: 2007-2013. Source: U.S. Department of Commerce; U.S. Census Bureau; Foreign Trade Division; FT920 - U.S. Merchandise Trade: Selected Highlights (annual issues); tables 1, 4, or 6.

The Inland Waterways Trust Fund (IWTF) was established in 1978 to help pay for construction and maintenance of navigation infrastructure on the U.S. inland and intracoastal waterways [11]. As shown in Figure 3, between 2002 and 2009 disbursements from the IWTF exceeded revenues, indicating that there were more demands for construction funding than the IWTF was able to supply. Although changes were made to the IWTF as part of legislation passed in 2014 it is too early to tell if they will result in closer alignment between IWTF revenues and disbursements [12].

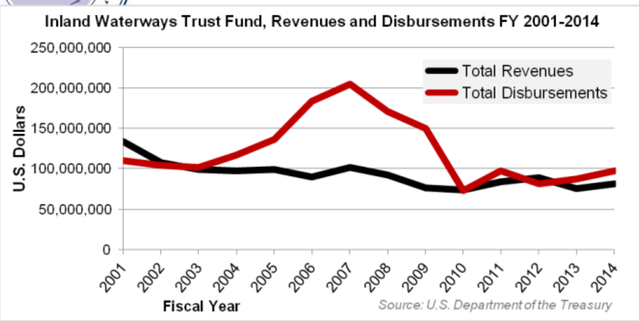

Figure 3. . Inland Waterways Trust Fund, Total Revenues and Disbursements, Fiscal Years 2001-2014. Source: U.S. Department of the Treasury.

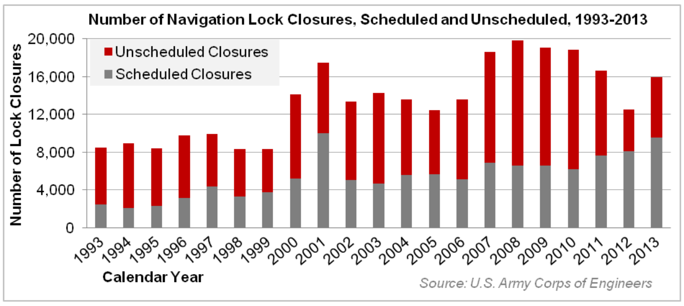

Figure 4. Number of navigation lock closures, scheduled and unscheduled, 1993-2013. Source: U.S. Army Corps of Engineers.

3.3 Capacity and reliability

On U.S. inland waterways many vessels travel significant distances between their origin and destination. For example, the Tennessee River stretches over 600 miles, the Ohio River over 900 miles, and the Mississippi River extends over 1800 miles [9]. The ability of vessels to engage in long-distance transportation on inland waterways is heavily dependent upon navigation locks; locks which have seen an overall increase in the cumulative duration of closures and the number of closure events over the past decade (see Figures 4 and 5). Unscheduled closures of navigation locks are considered more economically disruptive because they reduce or eliminate the response time available to commercial users. Since 2001 total inland waterway tonnage has varied between 1.2 billion to 1.4 billion tons per year, indicating a steady demand for this mode of transport and thus a continued need for maintenance funding. There is uncertainty over the scale of future maintenance needs for inland navigation infrastructure, while the number of lock closures fluctuates from year to year, any single year between 2000 - 2013 had more total closures than any single year from 1993 – 1999 (see Figure 4), indicating a system-wide increase in maintenance needs.

There is stakeholder interest in being able to estimate the cost from a single closure at a specific lock, but such calculations would depend on multiple factors such as time of year, duration of closure, and number of shipments delayed. Some of this data is collected by a Lock Performance Monitoring System (LPMS) run by USACE and could be queried to develop performance measures on this topic [13].

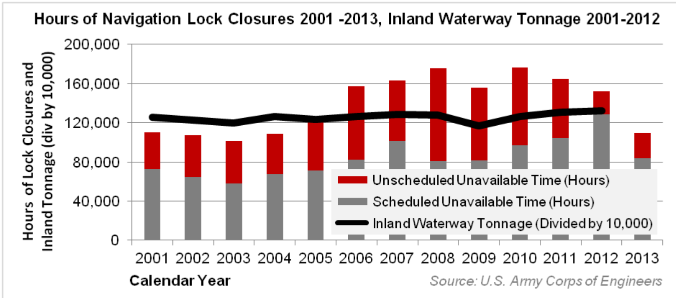

Figure 5. Hours of navigation lock closures, scheduled and unscheduled, 2001 - 2013, and annual inland waterway tonnage (divided by 10,000) from 2001-2012. Source: U.S. Army Corps of Engineers. Inland Waterway Tonnage defined as having an origin or destination in inland regions including the Great Lakes system.

3.4 Safety

Despite the variety of hazards associated with commercial maritime operations in U.S. waters, the number of casualties associated with commercial operations in U.S. waters has been relatively stable over the past decade, as shown in Figure 6 and 7. Figures 6 and 7 do not separate out inland events from coastal events, but further analysis of USCG data might allow for that distinction. There were no performance measures identified for ‘security’, but research on that topic will continue into the future.

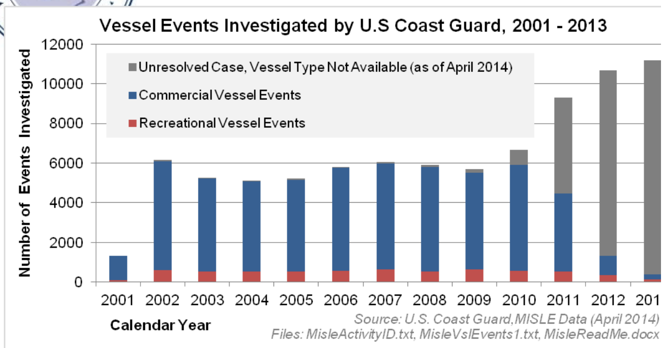

Figure 6. Number of vessel events investigated by USCG, 2001 - 2013. Source: U.S. Coast Guard, Marine Information for Safety and Law Enforcement (MISLE) files.

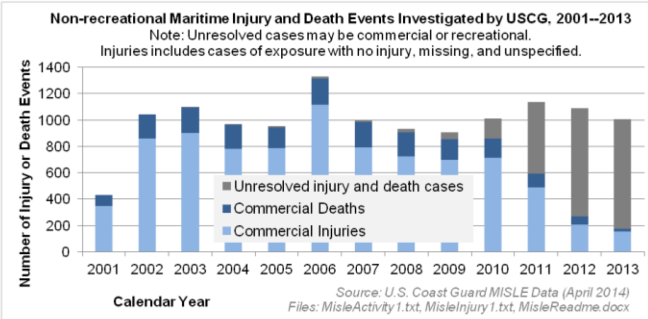

Figure 7. Marine casualties associated with commercial operations, 2001 - 2013. Source: U.S. Coast Guard, Marine Information for Safety and Law Enforcement (MISLE) files.

3.5 Environmental Stewardship

MTS environmental stewardship considerations span estuarine, freshwater, coastal, and offshore areas that vary greatly in their physical and biological conditions. MTS environmental considerations are complex because they span the air, water column, and benthic environments which MTS operations can impact. Preliminary measures that pertain to some of these environmental sub-types have been identified. Vessel pollution incidents impact the water column. The vast majority of recorded pollution incidents (Figure 8) are associated with oil pollution, but total numbers include chemical, other, and unspecified events. Figure 8 does not include pollution incidents associated with on-shore maritime facilities, those numbers are recorded in a separate file available from USCG.

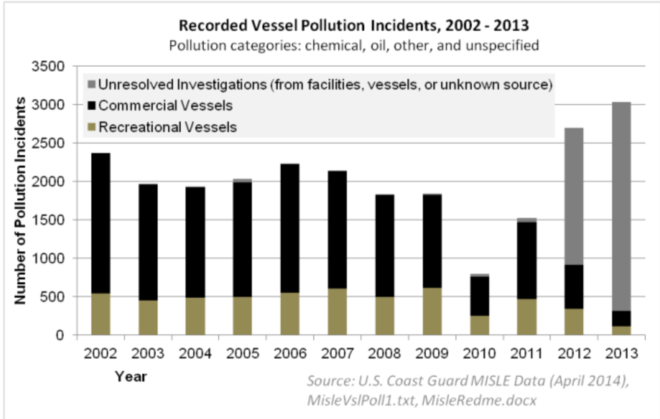

Figure 8. Recorded Vessel Pollution Incidents, 2002 – 2013. Source: U.S. Coast Guard, Marine Information for Safety and Law Enforcement (MISLE) files.

Federal navigation channel maintenance activities (e.g. jetty reconstruction, dredging, and dredge material placement) present their own types of environmental stewardship considerations. Short term environmental considerations are often focused on local benthic and water column environments during construction. However, longer term environmental stewardship might consider the potential relationship between these activities and habitat creation or loss. For sediment dredged out of channels by USACE, there is no distinct trend of increasing beneficial use of this material. Both the percentage and cubic yardage of dredged materials used for wetland nourishment dropped from 2008 to 2013; however, there was a general increase in the cubic yardage and percentage of sediments used for beach nourishment over the same time (see Figure 9). The ability for a project to re-use dredge material depends on sediment type, location, cost, and permitting requirements. The aggregated national totals shown in Figure 9 indicate that overboard and open water placement (red bars) is still a widely used placement method. One caveat to this interpretation is the limitation on the level of detail available in dredge material placement records as well as regional discrepancies in defining what qualifies as beneficial use. It is possible that more refined data categories for dredge material placement would reveal different trends. More detailed geographical data would be needed to assess the creation of specific habitat types from beneficially reused sediments.

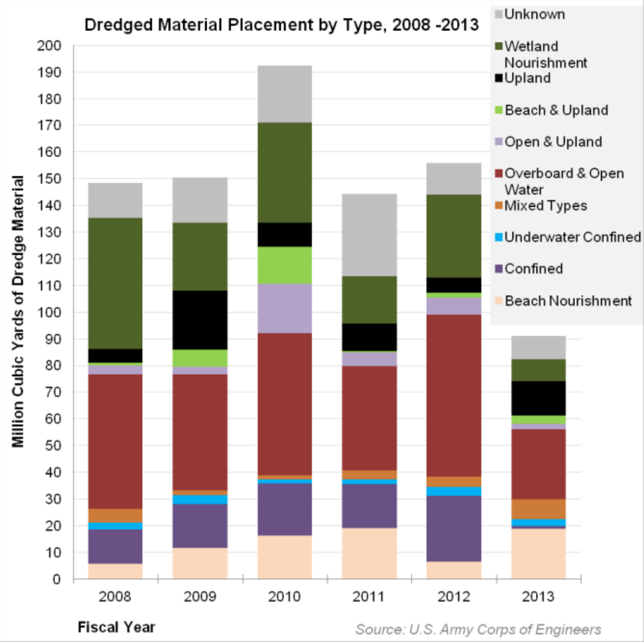

Figure 9. Dredge Material Placement Methods and Volume, 2008 to 2013. Source: U.S. Army Corps of Engineers.

3.6 Resilience

Resilience, and how best to measure it in the context of the MTS, is an evolving concept. For many people the term resilience brings to mind an image of community being able to survive a natural disaster such as a flood or hurricane. Within USACE, resilience is defined as "the ability to prepare and plan for, resist, recover from, and more successfully adapt to the impacts of adverse events" [14]. The age of a navigation structure can indicate its physical condition, which in turn may be an indicator of its resilience to environmental stressors such as strong flood waters and debris. All structures will have different weathering stressors, maintenance needs, and potential weak points based on their design and construction. The value of thinking about the MTS from a resilience standpoint is the emphasis on learning from past events (such as Superstorm Sandy that affected the northeastern part of the U.S. in 2012) in order to prepare and plan for future disruptions. Figure 10 shows the number of USACE-owned or USACE-operated navigation locks opened by decade, starting in the 1830s. From Figure 10 it is apparent that most USACE-owned locks are over fifty years old, however this is not necessarily indicative of poor physical or functional rating. More nuanced measures, based on resilience goals for different types of infrastructure, remain to be established.

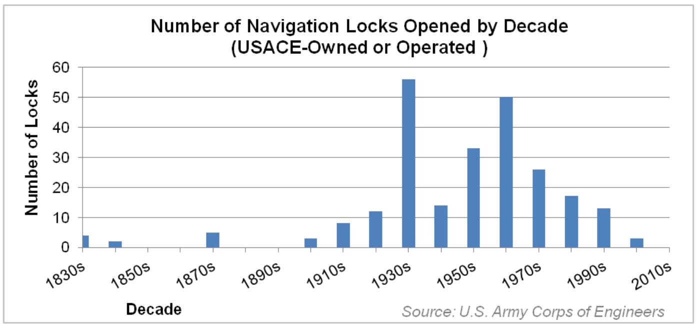

Figure 10. Decade of opening for USACE-owned or operated navigation locks: 1830s-2010s. Source: U.S. Army Corps of Engineers.

4 DATA GAPS AND FUTURE RESEARCH

This project has shown that it is possible to use existing data to create a high level overview of MTS performance within the U.S. Other countries with an interest in monitoring and assessing their own MTS performance might wish to engage in a similar project. If authoritative data are not available (from government or other sources), then efforts to make such data public, or available to authorized researchers, could be considered. If monitoring systems are being designed, then procedures for automatic reporting and data sharing should be included Bringing together different pieces of information will not automatically make the MTS more efficient or resilient, but it is a step towards establishing a shared understanding of current conditions and potential areas of improvement. For the U.S. MTS there are data gaps in multiple areas, notably the security category for which no appropriate MTS-specific data sources were located. In the environmental stewardship category more robust data on topics such as the role of the MTS in spreading invasive species through inland waters would improve analytical capabilities. For the capacity and reliability category better insight into how freight shipment travel across other transportation modes (road and rail) before or after using the MTS, this would support the development of an intermodal network model. Data gaps also exist for privately owned assets such as port property. Future work will include continued research and data sourcing for all of these categories, as well as developing a website where these data and interpretive graphics can be automatically updated. Future work will also include expanding the travel time atlas (Table 1) based on AIS data and analysis of the effects of different environmental factors such as river level.

5 CONCLUSIONS

The data presented here were published by U.S. federal agencies with a role in maritime transportation. Making authoritative data publicly available and easily discoverable is fundamental to a transparent performance assessment of the MTS. Different stakeholder groups will have different goals and questions about performance, the most valuable performance measures will be those that can serve multiple users. This research identified an initial set of seventeen performance measures for the MTS of the United States and presented data for a subset of those measures. These measures were related to broadly accepted goals such as zero accidents, zero pollution, etc. Further research is needed to query these datasets for more region-specific data that could then be used to guide strategic future investments in MTS infrastructure.

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