Diagnosing the Marine Transportation System: Measuring Performance and Targeting Improvement

Conference Proceedings

The Committee on the Marine Transportation System

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Introduction

The Committee on the Marine Transportation System (CMTS), a Federal interdepartmental committee chaired by the Secretary of Transportation, and the Transportation Research Board (TRB) of the National Academy of Sciences hosted the 2nd Biennial Research and Development conference entitled "Diagnosing the Marine Transportation System: Measuring Performance and Targeting Improvement" from June 26-28th, 2012 in Washington, D.C. at the National Academy of Sciences. The purpose of the conference was to provide a forum to examine the use of performance indicators in marine transportation and waterways management through collaborative input from stakeholders. The first biennial Research and Development conference was entitled, "Transforming the Marine Transportation System: A Vision for Research and Development," and was held in Irvine, CA in 2010.

The conference was organized by a committee of Industry, academia, and Federal agencies along with members of the Research and Development Integrated Action Team (R&D IAT) of the CMTS. Over 130 conference participants from fourteen Federal agencies, as well as representatives from ports, industry, Non-Governmental Organizations (NGOs), and academia met and discussed the importance of developing a national strategic vision that will address how to measure and communicate performance of a freight transportation system that is modern, efficient, reliable and fully integrative of all modes of transportation, including road and rail. The marine transportation system (MTS) exists as a "system of systems" and stakeholders need to be fully cognizant of the economic, social, political, and environmental systems in which it exists.

One of the objectives from this conference was to develop a first ever framework to measure the performance of the national marine transportation system in the context of the overall supply chain. This conference summary report intends to meet this objective. In addition to key findings and outcomes of the CMTS-TRB conference, it will present a conceptual framework analyzing the performance of the MTS within the broader freight transportation system. It will also summarize existing performance indicators already in use by MTS stakeholders and government agencies as well as some of the metrics which still need to be developed in order to gain insights into the aspects of MTS performance deemed most critical by conference participants. Finally, the report will conclude with a description of research and development needs which must be addressed in order to gain new knowledge concerning myriad aspects of MTS performance.

Conceptual Framework for the MTS

In order to maximize MTS value to the nation and ensure an integrated, collaborative approach to its operations and future across all stakeholders, a data-driven, quantitative understanding of the myriad aspects of system performance must be obtained. This is an exceedingly difficult goal to obtain given the inherently political and distributed processes and policies that have historically been employed for MTS resource allocation. Furthermore, the CMTS is comprised of several dozen separate Federal agencies with purview over various portions of the marine transportation system, and each of these agencies must execute its respective mission according to its own legal, political, and organizational requirements. Because of this broad, distributed public and private stakeholder community, a framework is needed to foster and facilitate transparency, communication, and measurement.

Need for a systems-based approach

The MTS is comprised of more than just coastal and inland waterways, ports, and harbors. It is a critical part of the dynamic freight supply chain that continuously moves products through our country and across the world. It is a vast, intricate system with many types of users, vessel types, operating conditions, and usage patterns.

In order to maximize MTS value to the nation and ensure an integrated, collaborative approach to its operations and future across all commercial freight movement stakeholders, a data-driven, quantitative understanding of the myriad aspects of system performance must be obtained. This is an exceedingly difficult goal to obtain given the inherently political and distributed processes and policies that have historically been employed for the MTS. Furthermore, the CMTS is comprised of numerous separate Federal agencies with purview over various portions of the marine transportation system, and each of these agencies must execute its respective mission according to its own legal, political, and organizational requirements.

A final complication arises from the fact that MTS infrastructure planning and operation has historically been performed on a project-by-project basis, wherein projects (i.e. ports, waterways, locks and dams, etc.) are evaluated independently from one another using available indicators, though not necessarily those that best (or even adequately) convey system performance. Furthermore, portions of MTS infrastructure are also typically categorized according to project function(s), and also grouped regionally as part of large Federal organizational hierarchies (i.e. the U.S. Army Corps of Engineers (USACE) has 8 Divisions with 39 Districts organized by watersheds, the U.S. Coast Guard has 9 Districts based largely on state boundaries). So there are some inherent challenges to implementing a true systems-based strategy for the MTS, but it is hoped that many of these can be sufficiently overcome with the use of transparent, objective indicators which accurately capture the aspects of system performance that a broad Federal MTS policy would seek to establish.

For any transportation system, interdependencies between projects (i.e. components of the network) can be significant, and failure to take them into account can potentially lead to significantly sub-optimal operation and management. An example of this can be found in the navigation projects maintained by the U.S. Corps of Engineers. The USACE uses project-based performance indicators such as total annual tonnage to rank-order projects for funding prioritization. However, this approach does not directly take into account the fact that many commercial waterborne transportation movements transit multiple navigation projects while en route from origin to final destination. So while the origin port for a particular shipment of cargo may receive funding and therefore maintain an adequate level of service, other navigation projects transited by that shipment while en route may not (due to lower levels of total annual tonnage), thereby reducing the level of service and potentially affecting the MTS performance for the voyage as a whole. Because waterborne transportation routes are essentially confined to navigable inland rivers and dredged coastal channels, they are especially vulnerable to bottlenecking delays and outright closure if even one segment of the system (e.g. and inland lock chamber or coastal entrance channel) experiences an unexpected closure or reduction in performance.

The MTS within the national supply chain

The MTS does not exist in isolation, but is instead inseparable from landside transportation systems that move billions of tons of freight each year throughout the country. Therefore, in order to target MTS improvements so as to truly achieve maximum benefits to the nation, landside performance indicators and network considerations of the entire supply chain should be included within a systems-based strategy. To help address this need, there are several collaborations underway including a study being sponsored by the TRB National Cooperative Freight Research Program (NCFRP) and an effort between the CMTS R&D IAT and Oak Ridge National Laboratory (ORNL). The CMTS R&D IAT is working with ORNL, which developed the Freight Analysis Framework (FAF) under contract with the Federal Highway Administration. They are working on integrating the existing landside origin-destination freight flow trends available via the FAF with the U.S. Army Corps of Engineers' detailed Waterborne Commerce records. Figure 1 presents an example of the sorts of commodity flow data available via the FAF, and the relative contributions of the highway, rail, and waterway modes to the overall national freight picture.

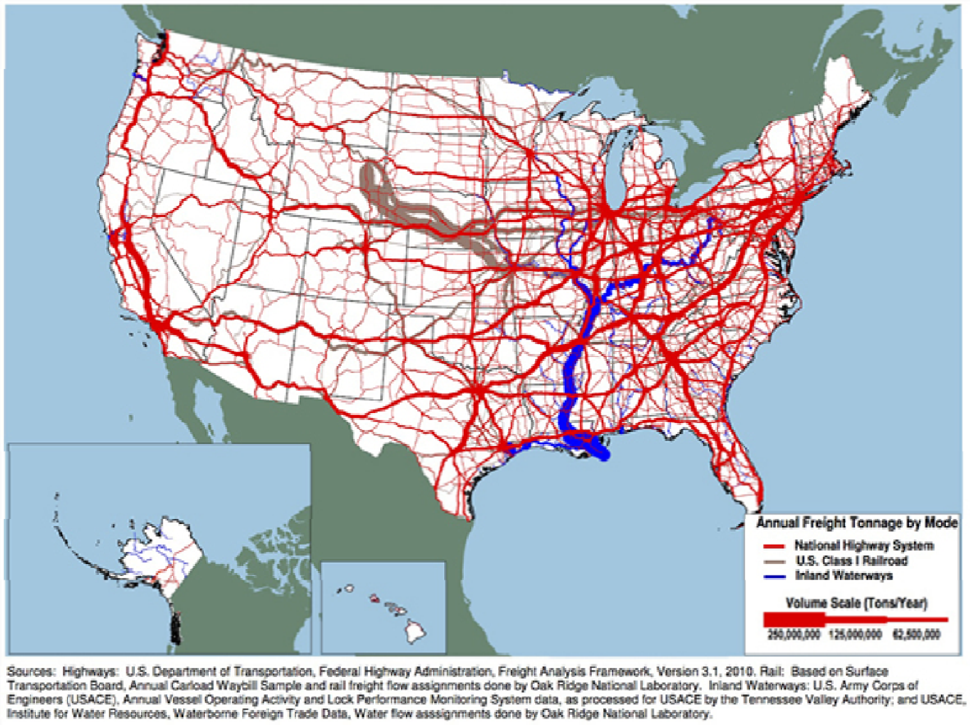

Fig. 1 – Freight Analysis Framework (FAF) national overview of total freight via inland waterways and landside modes

In contrast to the project-based approach to MTS planning and management mentioned previously, a "corridor-based" approach more fully captures the true nature of the freight transportation system in question. Rather than using performance metrics to analyze components of the MTS (e.g. individual ports, waterways, etc.) as discrete entities, a corridor-based strategy looks at primary origin-destination (OD) pairs and associated transportation routes. The levels of freight throughput (tonnage, monetary value of cargo, etc.) and other performance metrics for these corridors can then be compared to the costs of annual maintenance and/or capacity expansions of the component projects. The inclusion of cost considerations allows optimal project selection (for funding or other management action) through well-established portfolio analysis techniques.

In order to truly capture the contributions of the MTS to national wellbeing, this corridor-based conceptual framework must be extended to include landside modes of freight transportation. The national freight transportation system is comprised of millions of individual supply chains wherein commodities travel via various modes from their origin to final destination. Each segment of the supply chain therefore represents a link in a series system, and the overall performance of the supply chain is a direct function of the performance of each of the component modes. For example, the availability of a deep draft port for receiving cargo might be based on recent dredging decisions and the resulting likelihood of shoaling reducing channel depths below acceptable limits for shipping. It might also be a function of levels of congestion on the surface roads, Interstate highways, and rail connections in the immediate vicinity of the port. The challenge therefore becomes capturing these myriad performance measures from multiple modes of transport (e.g. shoaling likelihood in deep draft channels versus average highway speeds) within a single, consistent mathematical expression. In doing this, it may be helpful to consider some sort of modal neutral supply chain reliability parameter, or some overall level of service in terms of reliability, fluidity, or efficiency relative to ideal conditions. Regardless of how the performance of any particular supply chain is ultimately expressed, it should be coupled with some metric such as tonnage, ton-miles, or monetary value of cargo that conveys its relative significance within the overall freight system.

Indicators for the MTS

Existing Indicators

Results from the conference shows that there are a number of indicators that are currently used by Federal agencies and industry for measuring aspects of MTS performance within their purview and for targeting improvement of their operations, respectively. Some indicators are region specific. For example, ports frequently develop their own indicators which are not always used at other ports. For the sake of brevity, all of those indicators are not listed here. The indicators listed below are from the major Federal agencies which manage, operate and are influenced by the MTS and are published in official reports and/or available via inquiry to agency staff.

As evident from the table below, there are many indicators being used currently, but they tend to measure individual agency/industry performance concerns and do not provide a total system perspective. What is needed are indicators that measure performance and provide visibility and understanding of the MTS performance as it relates to the other modes of transportation and the overall supply chain.

Table 1. MTS Performance Indicators Currently in Use.

Agency/Industry	Focus Area	Indicator
Saint Lawrence Seaway Development Corporation (SLSDC)	Navigation	% of days in the shipping season that the U.S. sector of SLSDC locks are available
U.S. Department of Agriculture	Navigation	# of barges carrying grain through inland waterway locks
U.S. Army Corps of Engineers	Navigation	Navigation Channel Availability
	Navigation	Scheduled and Unscheduled Lock Closures
	Navigation	Navigation System Risks
U.S. Coast Guard	Search and Rescue	% people in imminent danger saved (in maritime environment)
	Search and Rescue	% rescue assets on scene within standards
	Search and Rescue	Asset availability
	Aids to Navigation	Aid availability
	Aids to Navigation	% of aids to navigation serviced on time
	Aids to Navigation	# of navigational accidents
	Marine Safety	# deaths and injuries
	Marine Safety	# of navigational accidents
	Marine Safety	% cargoes inspected for certain dangerous cargoes
	Ports, Waterways, and Coastal Security	MTSA facility inspections rates and NOVs/penalties
	Ports, Waterways, and Coastal Security	MTSA facility compliance rate with Transportation Worker

		Identification Credential Regs.
	Ports, Waterways, and Coastal Security	Maritime terrorism and security risk reduction
	Alien/migrant Interdiction Operations	# undocumented migrants interdicted
	Drug Interdiction	Removal rate within the maritime zone
	Defense Readiness	Cutter Readiness
	Defense Readiness	Readiness Assessments
	Icebreaking	# of days critical waterways are closed to commerce due to ice
U.S. Environmental Protection Agency		Million indicator tons of carbon equivalent emissions from marine spark-ignition and marine diesel engines
The Maritime Administration		Annual Shipment Weight
		Annual Twenty-foot equivalent unit[1]
		Total capacity of all calls (total indicator tons of all ships loaded to water line)
		Total (tanker, product, crude oil, container ship, dry bulk, roll-on roll-off container, motor vehicle, gasoline carrier, combination vessel, general cargo vessel) calls and capacity
		U.S. waterborne trade (million indicator tons)
		Average vessel size per call at U.S. ports
		Containership Calls at U.S. ports, Post-Panamax and other
		Containership Calls at U.S. ports by size
		Average Age of vessels per call at U.S. ports
Industry Reported: Kirby Inland Marine		Delay days
		Revenue per ton-mile
		Ton-miles
		Towboats operated
Industry Reported: American Commercial Lines		Stationary days reduction for covered hoppers
		Turn rate per 10,000 liquid barges

[1] TEU is a nominal unit of measure equivalent to a 20’ x 8’ x 8’ shipping container.

		Average working capital as a percent of revenue
Industry Reported: Maersk Line	Key Performance Indicators in the following areas:	Energy
		Safety
		Daily Running Costs
		Cooperation (Best practice sharing)
Railroad Operators[2]		Cars on line
		Train Speed
		Terminal Dwell
All users[3]		Average length of haul
		Operating Ratio
		Revenue per ton-mile
		Tonnage (total, all loads)
		Ton-miles or barrel-miles
		Terminal dwell time or empty miles factors

The Saint Lawrence Seaway Development Corporation

The Saint Lawrence Seaway Development Corporation is the U.S. Federal agency responsible for constructing, operating and maintaining the U.S. owned segment of the St. Lawrence Seaway that runs between Montreal and Lake Erie. This includes 2 of 15 locks in this part of the seaway. They measure performance in their system by calculating the percentage of days in the shipping season that the U.S. sectors of the St. Lawrence Seaway locks are available (Table 1).[4]

The U.S. Department of Agriculture

The U.S. Department of Agriculture which develops agricultural policy in the United States has one indicator that relates to the MTS, specifically, they measure the number of barges carrying grain that travel through inland waterway locks (Table 1).[5]

[2] Railroad operators who disclose their performance indicators from this source include: BNSF Railway, Kansas City Southern, Canadian Pacific, Norfolk Southern, CN, CSX Transportation and Union Pacific.
[3] Cottrell, 2008.
[4] Personal communication, SLSDC, Marvourneen Dolor.
[5] Personal communication, USDA, Nick Marathon.

The U.S. Army Corps of Engineers

The U.S. Army Corps of Engineers (Corps) is responsible for operating a huge portfolio of navigation assets including 12,000 miles of inland and intracoastal navigation channels, and 238 lock chambers at 192 lock sites[6]. Performance indicators established by the Corps comply with requirements established by the Office of Management and Budget which helps to determine the prioritization of funding requests for Corps projects. The Corps measures performance on their navigation infrastructure by looking at three different indicators: navigation channel availability (the length of time of delays at locks and dams), scheduled and unscheduled lock closures, and navigation system risks (Table 1).[7]

The U.S. Coast Guard

The U.S. Coast Guard (USCG) has broad responsibilities to protect homeland security and the maritime environment. It also conducts maritime law enforcement, performs search and rescue operations and maintains inland, coastal and offshore aids to navigation. The USCG maintains nearly 51,000 aids to navigation including buoys, day marks, fog signals, beacons, and radio towers for short-range navigation (Department of Homeland Security, 2012). It also maintains aids used for longer-range navigation, including DGPS (Differential Global Positioning System). Performance indicators used by the Coast Guard can be found in Table 1.

The U.S. Environmental Protection Agency

The U.S. Environmental Protection Agency (EPA) is charged with protecting human health and the environment. Under their purview, they are charged with reducing emissions from oceangoing vessels. The EPA has divided programs for reducing marine engine emissions into two broad categories: (1) marine spark-ignition engines, including outboard engines and personal watercraft, as well as gasoline-fueled sterndrive and inboard engines and (2) marine diesel engines, including auxiliary engines

[6] U.S. Army Corps of Engineers, *Information Paper*, December 2010.
[7] U.S. Army Corps of Engineers, *Navigation Strategic Vision*, 2012.

and both recreational and commercial propulsion engines. They measure overall performance in million indicator tons of carbon equivalent emissions (including nitrogen oxides, hydrocarbons, carbon monoxide and particulate matter) from these engines (Table 1).[8]

The U.S. Maritime Administration

Many of the performance indicators used by the Maritime Administration (MARAD, Table 1), can be found in the *U.S. Water Transportation Statistical Snapshot* (Maritime Administration, 2011). Ports exist in private/public partnerships and due to the wide variety of circumstances and ways in which they operate; they use many different performance indicators. The Maritime Administration keeps a statistical database with statistics regarding more than 300 ports. These statistics, though not necessarily performance indicators, are reflective of performance in the marine transportation system.

Industry Reported

Although many indicators used by industry are not publicly released, some indicators have been such as those used by Kirby Inland Marine[9], American Commercial Lines[2], and Maersk Line[5] can be found in Table 1.

Maersk Line uses Key Performance Indicators (KPI) to measure operational efficiency on their ships in the following areas: energy, safety, daily running costs, and cooperation (best practice sharing).[10] Seven major railroads (BNSF Railway, Kansas City Southern, Canadian Pacific, Norfolk Southern, CN, CSX Transportation and Union Pacific) post three of their performance indicators online weekly to improve communications: cars on line, train speed, and terminal dwell[11].

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[8] Environmental Protection Agency, "Diesel Boats and Ships," http://www.epa.gov/oms/marine.htm and Alan Stout, EPA, personal communication.
[9] Kirby Inland Marine, Press Releases, http://www.kirbycorpjobs.com/en/releases/search.asp
[10] Maersk, July 15th, 2012 Press Release, "Maersk Ships Save US$ 90-million on Energy Using KPI"
[11] See http://www.railroadpm.org/

<u>All users</u>

There are a number of performance indicators that are used by many, if not most, providers in nearly all freight transport modes (Cottrell, 2008). In developing performance indicators that reflect the entire intermodal, freight transportation system, it preferred to utilize indicators that are already in use by all modes (see Table 1).

The indicators listed here are used by Federal agencies and by industries which participate in the MTS. Port-specific indicators are not listed. There are some performance indicators that are standard at coastal ports (e.g., tonnage, TEUs, $-value of cargo, etc.) while other metrics are port-specific due to the heterogeneous nature of cargo shipments, facilities, and carriers across ports and geographical regions. Ports and carriers are reluctant to reveal cargo profiles for competition as well as confidentiality reasons. Because of these reasons, ports have developed highly individualized methods for measuring and defining success of their operations. The implementation of widespread performance measurement will necessitate either standardization across ports and cargo types, or the development of new indicators.

The same challenges exist when trying to compare across modes. Traditional network measures have been unused for across-mode comparisons, likely because of lacking data and/or computational resources. Other measurement limitations exist, including controlling for and incorporating factors that are out of the control of managers, such as policy changes. Measurements must also have a time component as many investments (such as capitol costs) have time variables.

The conference demonstrated that it will likely be necessary to create new indicators for use across government agencies and industry, as well as create indicators that describe and seek to understand the system as a whole and how the MTS supports the overall supply chain. This will necessitate working across the Federal government, industry, academia, ports and state and local agencies.

Research and Development Needs

Indicator Identification and Development

A strong takeaway from the conference was that in order to identify appropriate indicators for measuring performance of the MTS it is first necessary to determine end goals. For example, is indicator identification needed in order to provide improved services to customers? To efficiently make use of limited investment dollars? To create a healthier environment and a stronger economy? The more explicit the end goals are the more useful they will be for guiding MTS management decisions and long-term planning efforts. For example, rather than setting vague, overly-general, or hard-to-determine goals such as a "healthier environment" , a more explicit and therefore useful goal for MTS performance will set quantifiable thresholds, set according to relevant scientific studies, for MTS environmental impacts such as air emissions and discharges to water.

As MTS performance is monitored against national policy goals, it is also necessary for chosen indicators to be straightforward and that they resonate with the broad spectrum of MTS stakeholders and the public at large. Different goals and indicators will be needed for communicating with different stakeholder groups. For example, the general public will likely be more interested in indicators that track the number of jobs a port brings to a community rather than more obscure measures of port efficiency such as the number of crane lifts per hour. Whenever possible, the more technical metrics which are already widely accepted within MTS stakeholder groups should be disseminated in terms that are more likely to resonate with the public at large. For example, a projected increase of *x* million tons of cargo at a port could instead be publicly described in terms of the *y* new jobs in a community that increase is expected to support. Reconstituting indicators in different terms is also a possibility. For example, it may be possible to determine how many vehicle deaths were averted by shipping freight via barge rather than via trucks. This sort of calculation would help determine the worth, value and performance of the marine transportation system relative to other modes.

Indicator development cannot proceed without data. The MTS has frequently been described as data rich. However, in developing certain indicators, it may be determined that we are not in possession of specific data that we need or the data that we possess may not be in a useful format. Data collection and storage is expensive, and, as much as possible, we should strive to use existing data to develop indicators and search for means to share data in formats that are useful and accessible.

The coastal MTS system is difficult to measure as a complete whole. Ports are unique in nature due to geographical characteristics, commodity types, and geographical reaches that they serve. Developing indicators that are applicable across the inland waterway system, on the other hand, is possible due to the homogenous characteristics of the system. However, interface issues that exist on the coastal system exist on the inland system as well. Technology and funding limitations, as well as the challenges of sharing data among many different players, are present across the entire MTS.

When measuring the impact of our infrastructure, we must also consider that the effects of our operations may stretch much farther than the project's geographical boundaries. Studies that show the geographical reach of MTS operations convey the value of the MTS to the nation and could be used to justify increased funding for infrastructure construction and maintenance. Additionally, these studies should be able to propel infrastructure proposals forward that consider the system as a whole.

Data Gaps

We continue to struggle to identify indicators and goals that are important for private industry. The conference provided a platform for industry to present their perspective and use of indicators, so there was a good exchange and discussion. The railroad system in the United States is privately owned and operated. Ports exist in public-private partnerships and what each port considers important for its operations varies widely. Additionally, shippers, carriers, and manufacturers all have different priorities and goals and it is not in their missions to provide data regarding performance to the public sector. It will be necessary to develop performance indicators that take their priorities into account and describe the system, not individual components.

Needed Indicators

Developing and using performance indicators to assess performance across the whole system will require addressing these challenges. The first step is to determine what questions one wants answered. For example, there are fundamental differences between ports that move primarily bulk cargo and those that move high value, containerized cargo. However, in determining performance it may be possible to class ports based on those with similar characteristics and then compare across classes. Other characteristics that could be classed are similar commodities and similar international ports served.

Developing performance indicators that seek to understand and reflect the entire transportation system requires understanding the connections between modes. This may include mapping the type and amount of cargo that moves from water to road or rail, documenting the times and days of the week when congestion occurs or developing corridors of freight movement in the Nation. Similar to how freight movement is mapped on the highways, mapping marine corridors would reveal geographical areas of potential interest and investment. Ideally, marine corridors would also be able to be linked to rail and road corridors to understand inter-mode freight movement. R&D should focus on mapping and understanding these corridors as well as determining what new corridors might be developed if alternatives were available.

Much of the data and priorities of private industry remains confidential information. However, data sharing between the Federal government and private industry is improving. It may be necessary to create new connections with private industry to gain access to their data in order to improve the delivery of public services. If that is not possible, it will be necessary to create research methodologies that can provide insight into trends (such as the types and amounts of cargo that moves through ports) without divulging confidential information. Some of these methodologies have already been created but widespread use across the nation is not yet underway.

When developing indicators, we must acknowledge uncertainties in both indicators and data. R&D should develop methodologies to incorporate uncertainties into decision-making and also understand how data-poor or data-lacking indicators affect our final decisions. Uncertainties should be adequately communicated to decision-makers and stakeholders in a way that facilitates decision-making and helps them understand the implications of the lack of data.

Similar to being able to account for uncertainty, we must determine how we can measure and account for risk in our indicator development and utilization. Not only do we need to learn how to analyze risk, but we must determine ways in which we can communicate and manage risk. There are a number of different methods able to account for uncertainty and risk including multicriteria decision-making analysis and conceptual models. These should continue to be used and developed for making investment decisions.

Critical to the successful development and use of indicators is frequent interaction and communication with potential affected stakeholders. As the utilization of indicators can determine the scope and type of project that is developed, it is also necessary to engage stakeholders in the development of indicators. This may mean developing new, or utilizing exist, stakeholder outreach techniques to reach and communicate with affected stakeholders.

Developing Measurement and Modeling Capabilities

As emphasized multiple times at the conference we are “data rich and information poor.” While we do not lack for data, in general, in the MTS, several participants identified the existence of data gaps. It will be necessary, moving forward, for us to determine what those data gaps are and what will be necessary to remedy them.

Model capability is evolving to predict the most efficient movement of cargo through modes. Besides continuing to improve and optimize these models to determine the best movement of cargo through the country and the world, it is also necessary to determine the goals that seek to be optimized in these models. For example, are we hoping to gain the greatest reliability at the lowest energy intensity possible? Is increased marine highway utilization the goal? Quicker delivery of cargo? Recognizing that not all goals can be met when choosing the optimal route of freight, it is necessary to choose the variables of most interest before models can be developed and run.

Model development has advanced to enable the ability to track the consequences of moving freight between and among modes. Certain limitations exist in modeling movement (including geographical and data restrictions) which should be investigated.

Management decisions must also recognize that certain uses/movements on the MTS may have precedent or require special concern. For example, shipping toxic or hazardous materials may require more scrutiny applied to movement. Additionally, national security concerns may need to take precedent in certain locations or at certain times.

Currently, there are many data and measurement services available to inform ship operators (e.g. Automatic Identification System (AIS), LOMA, tide gages, Physical Oceanographic Real-Time System (PORTS), etc.). Many of these capabilities are in the process of being integrated, but many incompatibilities and inconsistencies exist between these databases. Efforts to integrate and standardize should continue. The ability of AIS to track vessel movements will allow more efficient and effective delivery of Federal services and further investigation into how it can be utilized to improve operations should continue. For example, future capabilities may include the development of predictive tools that are able to provide hydrodynamic modeling and river system optimization.

The data collection required to develop indicators should, as much as possible, be automated, ferried and stored in databases that are easily accessible for all those who need access to it. The easier it is to collect, store, and access data, the more likely it will be for the indicators developed to be used and applied to decisionmaking. Indicators that require costly, labor-intensive or time-intensive collection of data will likely become "snapshot" indicators that only tell us about the operation of a system at one moment in time. Although this may be useful in some cases (especially for indicators that are determined to be crucial, though difficult to measure), in many other cases, it is likely that this will lead to indicators that fall out of use quickly. The more data collection and analysis can be automated, the more likely the development and use of indicators will be.

In addition to the collection and use of real-time data, archived data continues (and will continue) to be useful. Analysis of archived data reveals trends as well as elucidates areas of potential concern. Thus, it is necessary for archived data to be well managed and easily accessible. As datasets are merged between and across agencies naming (as well as other) inconsistencies have been found which impair integration efforts. Continued coordination and communication will address these issues and create datasets that should yield valuable historic data.

Visual, spatial data should continue to be utilized in communicating indicators and goals. Visual data (seen through a dashboard) is easy to relate to stakeholders and policy makers who may not be familiar with the technical details of indicators. Spatial data helps us target infrastructure needs as well as determine the spatial extent and impact of investments and improvements to the MTS.

One challenge identified at the conference was determining the state of our current infrastructure. Determining infrastructure state is essential to understanding how the system is performing. When performing condition assessments, it has proven difficult to understand how structural integrity impacts the functionality of a structure. Research should continue to seek to understand how to determine the appropriate functional life of our MTS infrastructure.

Determining Important National Indicators

Results from the conference and sub sequential efforts show a range of indicators that may be used to describe the MTS. We have divided them into categories that follow the CMTS "National Strategy for the Marine Transportation System: A Framework for Action."

1. Economic Benefits to the Nation

- Amount of Federal, state and local taxes generated ($)
- % of Gross Domestic Product (GDP) contributed to by marine transportation (advantage, exports, domestic)
- # of jobs generated (direct, indirect, and induced in transportation services and in goods manufacturing)
- Cost of not investing or delayed investment ($)
- Amount of private investments based on transportation assets ($)
- % of production cost of goods attributable to marine transportation ($)
- Total value of trade (in and out, internationally)
- Amount of value added to goods ($, pre vs. post transportation and processing)

- Cost of living advantages due to imports ($)
- Amount of Harbor and Inland Trust Funds ($)
- Producer Price Index (PPI)

2. Capacity

- % of infrastructure utilization
- % of ship slots used (berth occupancy and # of ships)
- Degree of channel width/depth utilization
- # of lock and channel closures not due to "nature"
- Throughput measure
- Fluidity of the system (average time/unobstructed time)
- Unexpected/expected lock downtime
- % of ship channels at project depth/width
- # and severity of congested nodes
- Load/unload times
- Wait times

3. Safety and Security

- % of population exposed to HAZMAT risk
- # of ship accidents (collisions, allisions, groundings)
- Safety/security comparison to other modes of transportation
- # of ports that meet required security standards
- # of injuries (personal injuries, deaths) per 1,000 trips
- # of serious security incidents
- % of at-risk vessel cargos inspected before entry into U.S. ports
- # of boating accidents per 1,000 trips

4. Environmental Stewardship

- % of industry using clean technologies (biofuels, new engines, ballast water treatment technology)
    - % usage of "clean" marine engines/age of marine engines
- Amount of dredged material used for beneficial use
- % of brownfields remediated
- Air quality/GHG emissions from MTS operations
    - Fuel/energy usage per amount transported
- Acreage and type of habitat restoration
- Acreage and type of habitat/land creation
- % of projects incorporating climate change considerations into planning
- % of ports/waterways with impaired water quality
- Impact of no action on other modes, congestion, air quality

- Performance index for Health of the Coast
- Carbon footprint/transportation energy use
- % or # of invasive species expansion into new waterways
- % capacity of disposal sites/% of ports without adequate disposal areas
- # of whale strikes, turtle takes and interactions with other threatened and endangered species

5. Resilience and Reliability

- Cost of delaying projects (inflation, reengineering, benefits foregone, accelerated deterioration)
    - Time it takes to go from permit to project completion
- Impacts of project failure on jobs, taxes, property values, remediation
- Available alternate capacity during disruption
- Travel time index (reliability measure)
    - Percent above the average travel time that you would need to add into your travel time to be on time 95% of the time
- % of time not available due to unscheduled closures
- % of time at reduced capacity and/or efficiency (planned or not)
- # or % of critical infrastructure in immediate danger of failure as a result of underfunding
- # or % of critical infrastructure not functional as a result of underfunding
- Recovery time after disasters (days)
- System vulnerability to bottlenecks and widespread closures/delays
- Value to national defense due to redundancy (unused capacity)

6. Miscellaneous

- Non-transportation benefits (e.g. drinking water, industrial cooling, hydropower)
- Traffic that can't be rerouted (e.g. oil refineries, steel and power plants)
- With and w/o MTS conditions (e.g. congestion, safety, economic benefits)
- Community impacts/livability (e.g. trucks in neighborhoods, air quality, community buy-in)
- Availability of money for maintenance

Based on feedback from conference participants and other engaged professionals in the field, these indicators were then divided into (broad) categories that described why they haven’t been created and/or what would be needed to create them. R&D should focus on developing the methodologies, collecting the data or otherwise developing the technologies that will elucidate the calculation of these indicators. Developing indices or families for indicators may also be possible.

Requires Study

- Number and/or value of private investments made to fund transportation assets
- Value added to goods (pre- vs. post- transportation and processing)
- Cost of living advantages due to imports
- # or % of critical infrastructure not functional as a result of underfunding and # or % of critical infrastructure in immediate danger of failure as a result of underfunding
- Available alternate capacity during disruption of MTS operations

Complicated/Difficult to Calculate

- Jobs generated (direct, indirect, induced) in MTS operations
- Cost of not investing or delayed investment
- Load/unload times of freight cargo
- Wait times to unload cargo
- Amount/type of habitat creation and/or restoration (including wetlands, marshes, etc.)
- Safety/security comparison to other modes of transport
- Impact of no action on:
    - Other modes of transportation
    - Congestion
    - Air quality
- System vulnerability to bottle necks and widespread closures/delays

Potential confidentiality issues

- % of ports that meet required security standards
- # of serious security incidents
- % at risk vessels cargos inspected before entry into US ports
- Value to national defense due to redundancy (unused capacity)

Done by someone else already?

- Use of clean technologies (e.g., biofuels, new engines, ballast water treatment technology)
- % of ports using climate change considerations (such as changes in water temperature, water level, ice cover, etc.) in project planning

Needs new measurement methodology

- Related air quality/green house gas emissions

Could be done but isn't being done currently

- Travel time index for marine freight movement
- With and w/o MTS conditions (congestion, safety, economic benefits)

- Impacts of project failure on jobs, taxes, property values, remediation, other variables of concern
- Cost of delaying projects (inflation, reengineering, benefits foregone, accelerated deterioration) - lost of service, cost of moving from permit to construction, depends on type of project, prioritize investments over portfolios

Conclusions

1. **Data:** As many conference participants recognized, we are data rich and information poor. One of the most crucial first steps in developing and implementing meaningful performance metrics is to develop a comprehensive inventory for the data that we do possess. Additionally, we must find ways to utilize the data that we already possess in new ways to meet our goals perhaps by combining across data sources to patch together more complete datasets or use for analysis to create a hybrid proxy. The restrictions on data sharing that exist due to confidentiality concerns (among others) continue to hamper efforts. We should continue to investigate ways in which to share data more freely while preserving industry confidentiality.
2. **Goal setting:** Before creating and utilizing performance indicators it is necessary to determine our desired end state. For example, are we hoping to use performance indicators to better target nationwide freight transportation investments? Do we want to decrease unscheduled closures of port facilities and locks? Goals and priorities should be explicitly stated in a national document so the goal, data, and indicator calculation may be understood and transparent to those using it.
3. **Determining scale:** Different indicators matter more on different scales. For example, the amount of time it takes to offload a container from a vessel matters at the port and shipper level but matters little at the National level. On the other hand, the amount of brownfields remediated matters a lot at the National level but little at the port-specific level. At this time, Federal agencies involved in the MTS have performance indicators that consider factors that

they control but do not consider the interdependencies of their operations with other agencies and industry. National priority setting and performance indicator development must find a way to account for and consider scale.

4. **Align Federal activities with national goals (from Item 2 above):** MTS member agencies need to ensure that their activities will result in changes in performance that can actually be detected by the chosen metrics. Though this may seem like an obvious point, due to the complexities inherent in MTS operations, it is seldom the case that performance indicators track directly with Federal investments and operational decisions. For example, an increase in the Corps' O&M dredging budget, and commensurate increase in overall channel availability, does not guarantee that annual waterborne tonnage totals (nationally or regionally) will necessarily increase. In fact, tonnage totals could still go down depending on broader global and national economic forces. Likewise, increased search and rescue activities on the part of the US Coast Guard do not guarantee reductions in marine casualties, again owing to broader trends and considerations. MTS decision makers need to have realistic expectations concerning the anticipated results of funding decisions and operational strategies meant to address performance objectives that are defined by indicators.

5. **Stress the importance of the MTS to overall national wellbeing:** The MTS does not exist for its own sake, but instead plays a vital role in supporting U.S. standards of living and overall quality of life. Just as the MTS is comprised of myriad component parts that are nonetheless interdependent and that function as a system, so too is the MTS fully integrated with the broader US economy. The vital role played by the MTS in supporting the U.S. energy, agriculture, transportation, and manufacturing sectors (among others), areas of the economy not typically associated with marine transportation, needs to be highlighted in the performance indicators and publicized whenever possible. R&D should' better quantify and understand the

contribution of the MTS within the overall US freight network, with future work slated to include the intermodal supply chains that increasingly span the globe.

The development and implementation of MTS indicators will require the participation of a wide range of stakeholders and partners. It will require the understanding of the entirety of the system and the best ways its performance can be optimized. Finally, it will require innovation and creativity in conducting new research and developing new technologies to facilitate better performance of the system. With targeted investments and better use and allocation of limited resources, we will continue to develop better performance metrics for the marine transportation system.

For more information on performance indicators and the MTS, please see the following resources:

Committee on the Marine Transportation System. 2008. "National Strategy for the Marine Transportation System: A Framework for Action." Available at http://www.cmts.gov/downloads/National_Strategy_MTS_2008.pdf.

Committee on the Marine Transportation System. 2012. "A Compendium of Federal Programs in the MTS." Available at http://www.cmts.gov/Resources/Compendium.aspx.

Committee on the Marine Transportation System. 2013. "Marine Transportation System Data Portal." Available at http://www.cmts.gov/Resources/DataPortal.aspx.

Cottrell, W.D. 2008. "Performance Indicators Used by Freight Transport Providers." Available at http://leonard.csusb.edu/research/documents/1011FinalReport.pdf.

U.S. Department of Homeland Security, Office of the Inspector General. 2012. "Annual Review of the United States Coast Guard's Mission Performance (FY 2011)." Available at http://www.oig.dhs.gov/assets/Mgmt/2012/OIG_12-119_Sep12.pdf.

U.S. Department of Transportation, 2013. "DOT Budget and Performance Fiscal Year 2014." Available at http://www.dot.gov/budget/dot-budget-and-performance.

U.S. Department of Transportation, Maritime Administration. 2011. "U.S. Water Transportation Statistical Snapshot." Available at http://www.marad.dot.gov/documents/US_Water_Transportation_Statistical_snapshot.pdf.

National Cooperative Freight Research Program. 2011. "NCFRP Report 10: Performance Measures for Freight Transportation." Available at http://www.trb.org/Publications/Blurbs/165398.aspx.

PIANC (The World Association for Waterborne Transport Infrastructure). 2010. "PIANC Report No. 111: Performance Indicators for Inland Waterways Transport, User Guideline." Available at http://www.pianc.org/edits/articleshop.php?id=1001110.

U.S. Army Corps of Engineers. 2012. "U.S. Port and Inland Waterways Modernization: Preparing for Post-Panamax Vessels." Available at http://www.iwr.usace.army.mil/index.php/us-port-and-inland-waterways-modernization-strategy.

More information on the conference can be found at http://www.trb.org/Conferences/Metrics2012.aspx. Conference proceedings can be found at http://onlinepubs.trb.org/onlinepubs/conferences/2012/Metrics/Program.pdf .