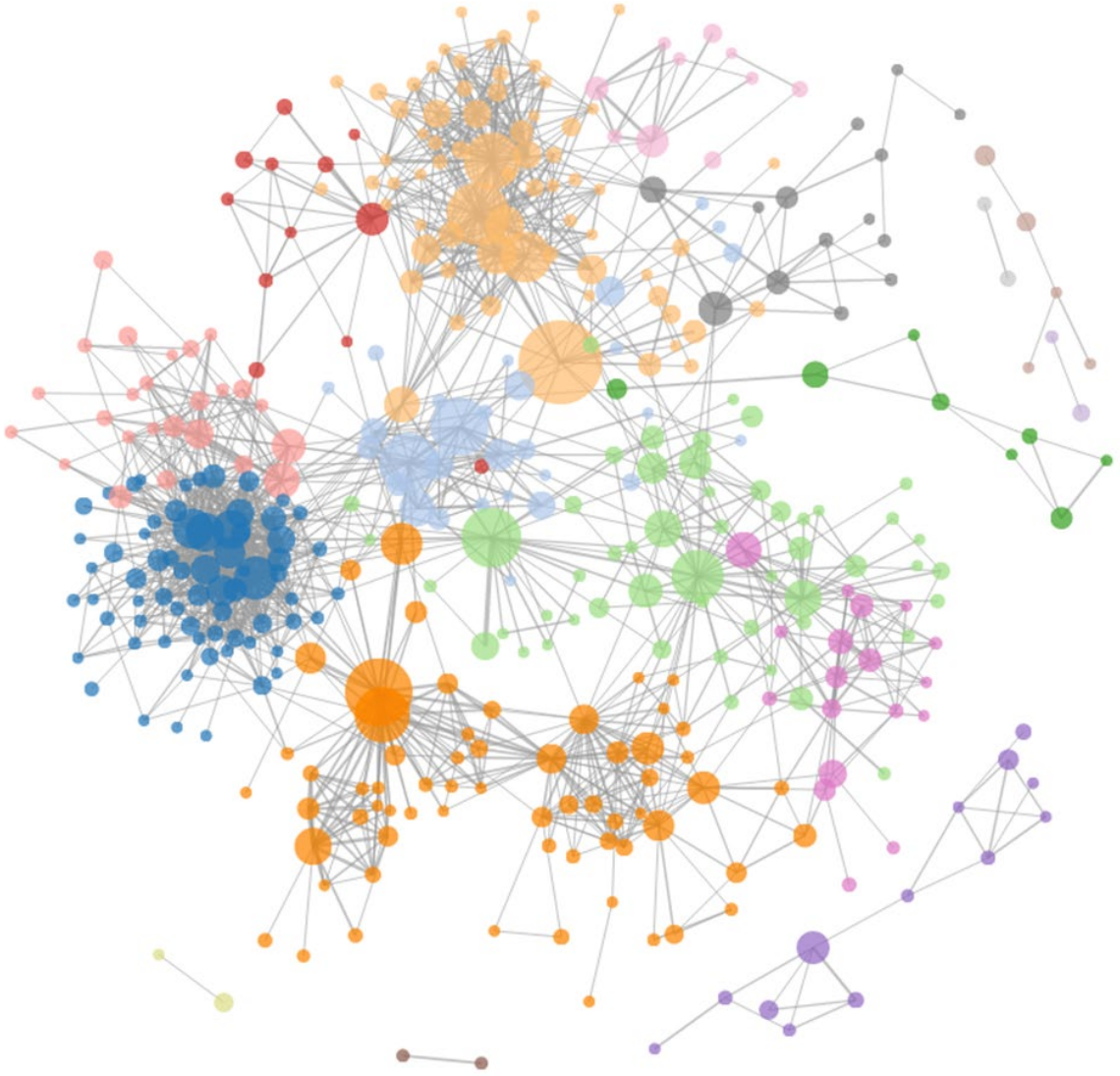

Transforming the Marine Transportation System Through Multimodal Freight Analytics

A Conference Summary of the Fifth Biennial Research and Development Conference

U.S. COMMITTEE ON THE MARINE TRANSPORTATION SYSTEM
MARCH 2019

This conference was organized with the Transportation Research Board (TRB). However, this summary document is not a report of the TRB or the National Academies of Sciences, Engineering and Medicine and has not been subjected to its official review procedures and processes.

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Conference Overview

The U.S. Committee on the Marine Transportation System (CMTS) collaborated with the Transportation Research Board (TRB) to hold the fifth biennial research and development (R&D) conference, "Transforming the Marine Transportation System through Multimodal Freight Analytics," in Washington, D.C. at the National Academy of Sciences on June 19-21, 2018. Over this three-day forum, 107 experts from government, industry, and academia shared and explored ideas about multimodal freight data and analytics that could potentially transform the way in which we assess and observe the marine transportation system (MTS). The conference program included three keynote addresses, three plenaries, ten breakout sessions, a student honor panel, and, for the first time in conference history, an interactive demonstration of four different researcher's work in an evening session. A complete proceeding of this conference is available from the National Academies of Science, Engineering and Medicine website.[1]

As with the previous iterations of this intimate R&D conference on the MTS, the 2018 conference closed with a summary session that integrated MTS research highlighted throughout the conference with discussions about how recommendations from the R&D community may be leveraged to support and inform policy. This summary details the key takeaways from this conference to inform the broader CMTS strategy for MTS-related R&D in the near future. The following presents the notable keynote thoughts and visions, a synopsis of each of the panel discussions, and the major points discussed in the many Technical Breakout Sessions. The document then identifies the specific gaps and needs the MTS stakeholders should be addressing to inform future research and policy prioritization.

Keynotes and Plenary Vision

The MTS touches all corners of our Nation's vast economy and is integral to the broader flow of freight across the globe. The important role of data related to the MTS was recognized as far back as 1994, when the National Commission on Intermodal Transportation recommended that the Federal government maintain existing data programs to collect freight activity data. Today, however, in the dawn of the Big Data Era, the full value of these datasets has been realized in tandem with an expansion of our collective capacity to collect and analyze large quantities of data. Taken together, data can expand our collective understanding of the MTS, such as identifying bottlenecks in the flow of freight across all modes of transportation, building system

[1] National Academies of Sciences, Engineering, and Medicine 2018. Conference Proceedings on the Web 22: Transforming the Marine Transportation System Through Multimodal Freight Analytics. Washington, DC: The National Academies Press. https://doi.org/10.17226/25336.

resilience and efficiency along every link of the supply chain, and, ultimately, optimizing the flow of goods and people across the MTS.

Keynote Address: Data and the Future of Transportation

Ms. Anne D. Aylward, Director of the U.S. Department of Transportation's (USDOT) Volpe Center, underscored how data can transform not just the MTS, but the larger multimodal supply chain. She offered three key areas to focus efforts over the next few years to transition the MTS and the multimodal supply chain into the era of Big Data:

1. *Communications, Coordination, and Capacity Building*: Ms. Aylward recommended better articulation and better alignment of goals around data collection and sharing, both within individual agencies and between the public and private sectors. This can only happen when best practices about information sharing have been identified and disseminated to all parties. The Federal government has a unique unifying role of bringing together the many partners across the MTS.

2. *Data Needs and Resources:* Establishing common data standards is critical to enabling seamless data sharing and efficient data collection across multiple parties. The challenge in data needs and resources today stems from a mismatch between private sector freight data resources and public sector practitioner needs. Public agencies may be limited by inadequate systems or data and limited personnel to handle data. Again, the Federal government, specifically, the USDOT, can play a role in sharing best practices and continuing to provide tools to support appropriate uses of data.

3. *Planning and Decision Making*: Alongside better communication to stakeholders, better communication is integral to make sure that findings from advanced analysis of freight flow are incorporated into existing required planning processes. Showcasing successful innovations that incorporate multimodal freight modeling, such as the U.S. Navy and Volpe's Maritime Safety and Security Information System[2] and the Alternative Fuel Transportation Optimization Tool[3], can convey the importance of collecting and sharing freight data. Additionally, data-driven reports such as the Bureau of Transportation Statistics' annual Port Performance Freight Statistics Report[4], mandated by the Fixing

[2] Maritime Safety and Security Information System (MSSIS) (2014, January 16). Retrieved from https://mssis.volpe.dot.gov/Main/

[3] Volpe National Transportation Systems Center. (2015, September 1). Alternative Fuel Transportation Optimization Tool: Description, Methodology, and Demonstration Scenarios. Accessed from https://rosap.ntl.bts.gov/view/dot/12233

[4] Bureau of Transportation Statistics. (2019, January 15). Port Performance Freight Statistics Program Annual Report to Congress 2018. Accessed from https://www.bts.gov/port-performance-reports-to-congress

America's Surface Transportation (FAST) Act, provide valuable avenues to translate data into policy. Here again, the Federal government has a unique role among marine transportation stakeholders to develop tools, write reports, and steward data critical for the MTS.

Keynote Address: FMC Supply Chain Innovation Team Initiative

Commissioner Rebecca Dye, of the Federal Maritime Commission (FMC), provided first-hand examples of how the supply chain might be optimized through changes to the supply chain process. These recommendations stemmed from the FMC's Supply Chain Innovation (SCI) Teams Initiative, which brought together small working teams of port directors and other high-level industry leaders from multiple industries along the supply chain. These teams were tasked with first identifying one supply chain process innovation that would make the supply chain more reliable and efficient, and then to develop a private sector implementation of this process innovation. From the report, Commissioner Dye shared two key recommendations:

1. *Enhanced Visibility of the International Supply Chain*: All six import and export SCI Teams agreed that enhanced visibility of the international supply chain could improve the global supply chain, by providing increased reliability and resilience.

2. *Timely Access of Specific, Critical Pieces of Information:* While more data is integral to understanding the wider network of supply chains, operators within the supply chain require access to timely, relevant, accurate, and discrete pieces of information. For example, most shippers need to know when a container is available. Timely access to this information can minimize port congestion, cutting down on emissions from idling trucks and needlessly long waits for truckers.

FMC released its SCI Teams Initiative report in December 2017 and recommended the development of the National Seaport Information Portal, which would deliver key information to actors along the supply chain in a single, one-stop shop.[5] Such a portal would allow actors to better align their operations with adjacent links in the supply chain and provide a wealth of information as the Nation looks to build its multimodal freight flow model across the various modes of transportation.

[5] Federal Maritime Commission. 2017. "Supply Chain Innovation Initiative Final Report". https://www.fmc.gov/assets/1/Page/SCITFinalReport-reduced.pdf

Plenary I: Perspectives Driving MTS Freight Analytics

The first plenary of the conference identified a multitude of challenges facing the advancement of MTS freight analytics. Some of the major challenges identified by panelists include the interoperability of data, consistent and appropriate granularity of data, and the scarcity of local data available to inform "last mile" details. These gaps are closely related to the ongoing need to understand how disruptive events can cascade through the transportation system and supply chain.

Speakers acknowledged that while more data are required to meet these existing gaps, new ways of incentivizing data sharing without compromising private interests, cybersecurity, or system integrity must also be adapted. Speakers recommended compiling and sharing of best practices on data sharing to overcome this hurdle.

Alongside data sharing, speakers also acknowledged that many components of the supply chain are continually being optimized. For example, many ports have limited ability to expand further on land, and therefore must find other ways to keep up with the increasing influx of cargo, which often includes increasing efficiency and productivity of existing facilities, updating existing practices and digitizing many practices where possible. While such changes may be port-, facility-, or operator-specific, compiling and sharing these practices may further optimize the supply chain.

Plenary II: Reaching the Vision: Advancing Multimodal Freight Network Analytics—The Challenges and Opportunities

In this plenary, speakers expanded upon the data challenges outlined by the first plenary. One major challenge is the lack of consensus about what to measure along the supply chain, and what measurements are most important for the construction of a multimodal freight model. Alongside this are a lack of standard analytical methods to measure end-to-end supply chain performance and bottleneck identification and a lack of metadata requirements for probe data. Additionally, marine transportation is often seen as a bookend to the supply chain, rather than an integral link, and much work remains to integrate maritime data with other modal data.

Several logistical challenges loom as well, including the convergence of multiple data streams from different sources and the challenge of aligning datasets collected with different methodologies or classified differently. This challenge is especially problematic as the expansion of sensors, probes, and interconnected devices are applied to freight activities.

Panelists recommended developing standard definitions and standards to ensure harmonization across all parties within the supply chain and analysts working to optimize the supply chain. Uniform definitions of commodity classes and levels of service across all freight

modes and standards for probe metadata can ensure that the swell of Big Data created by the supply chain and multimodal freight network is best utilized to optimize the system. Additionally, such standardization also enables the data to be repurposed beyond immediate operation logistics and incorporated into long-term planning and research.

Panelists further recommended utilizing data visualization tools to share and convey Big Data related to the supply chain. One such example was travel time contour maps which focused on modal connections. Panelists also encouraged conference participants to not simply collect more data, but to seek out the specific, discrete types of data to inform shippers and other operators within the MTS.

Plenary III: The Value of Multimodal Freight Network Analytics—Making the Case through Scenarios

In a system as complex as the multimodal freight system, scenario planning is a vital process tool to understand how changes might ripple through the system. Speakers shared different perspectives on the scenario planning process; how it is used by Federal agencies, U.S. military, private corporations, and researchers; and considered how scenario planning might be expanded to enhance the multimodal freight network.

Scenario planning can be used to examine how disruptions to the MTS might impact the supply chain, and the converse, how land-based disruptions to the supply chain might impact the MTS. Speakers encouraged the consideration of both natural and man-made disruption scenarios at multiple levels of impact to capture the full complexity, in both scale and interconnectedness, of the freight system. Local level scenarios are especially important tools as they provide regional granularity and can enable the incorporation of rich, local knowledge into larger planning processes.

Keynote Address: Blockchain and Freight Transportation

Mr. John Kingston, Head of Public Engagement for Blockchain in Transportation Alliance and executive editor of *Freightwaves*, shared his perspective on the role of blockchain to distribute information digitally without copying the information. First widely used for cryptocurrency applications (e.g. Bitcoin), blockchain is a promising new technology that could transform the supply chain and the MTS. Each step or process in the supply chain may be recorded as a transaction in the blockchain, a digital ledger, accessible to all parties in the system. While this mechanism of data sharing provides some unique cybersecurity advantages, such as being a more difficult system to hack, blockchain also brings with it serious data privacy concerns,

owing to its transparent ledger structure. Blockchain is an emerging technology, but without further standards its role in the multimodal freight network and the MTS remains unclear.

Takeaways from Technical Breakout Sessions

Data Analytics

Maritime and Freight I, II, & III

Three separate breakout sessions were devoted to discussions of maritime and freight data analytics. Various emerging technologies can be harnessed to describe and understand freight and maritime activity and improve operations and decision-making, but data challenges remain. For example, access to data for daily operations remains a problem, as does the integration of more traditional data sources with novel probe data sets and advanced analytics. Access to high quality data also enables the use of models as valuable decision making tools.

The challenge of safely sharing data remains a major obstacle in harnessing the full power of maritime and freight datasets. Speakers recommended the development of methods to anonymize data so that the information could be used to inform public policy without negatively affecting business. This data-sharing challenge is not unique to maritime transportation, however, and the maritime sector and the public entities that support this sector are poised to develop and demonstrate best practices for public–private policies and data exchanges.

The role of USDOT is limited largely to broader transportation policy and planning efforts along with making targeted MTS-related investments in infrastructure such as facilities, connections, and cranes. The most beneficial near-term focus for USDOT may be enabling better connectivity between links along the supply chain.

Inland Waterways

Inland waterways are benefiting from the expansion of multimodal freight analytics, leveraging existing, publicly available datasets to assess inland waterway system performance at locks and across the whole system. Data combined with the right analytical lens can help operators and planners understand the role of a single lock in the wider inland system, the shipper's cost burden from lock closure, traffic patterns through a lock system, and rail capacity along a comparable corridor. Trip data from U.S. Army Corps of Engineers and the waybill data can be used to evaluate the state of the U.S. inland waterway system and its ability to respond to disturbances. Automatic Identification System (AIS) data shows valuable promise as a tool to establish baseline travel times and monitor how the entire inland waterway system responds following many kinds of disruptions.

Port Performance

Ports are integral nodes in the intermodal supply chain, and AIS information can, and is, being used in novel ways to shed light on port operations, evaluating port mobility and efficiency. Ports are also using emulation to simulate operations in their terminal operating systems to build and synchronize jobs and tasks at the port.

Decision Support

Resilience

Analytics of the freight system can inform decision makers in the aftermath of a disaster, and the MTS plays an especially critical role in economic and community resilience both pre- and post-disaster. As in the case of Puerto Rico during the 2017 hurricane season, resilience of data and information systems can be as important as the resilience of the physical infrastructure itself. For example, while the San Juan port was opened quickly, data on port status and the location of freight were difficult to find, breaking the supply chain at a critical moment. As with Puerto Rico, because island seaports and airports are the lifelines to response and recovery in an island environment, it is important to have the detailed data needed to accurately model impacts. The lack of funding, lack of risk awareness, fragmented governance, geographical constraints, and communication challenges stand in the way of taking action to enhance resilience across the Nation's MTS.

Managing Flows

Data and advanced analytics are integral to managing and optimizing flows through the supply chain and for monitoring performance of the system. The U.S. Army Corps of Engineers is working on a platform to share data between public and private sectors. Additionally, standards for data quality and standard methodologies for collection and data analysis are critical to ensuring the interoperability of data.

Safety

Enhancing the safety of the MTS is of utmost importance, yet there is a lack of available near-miss/accident causation data in the maritime domain. This necessitates proxy methodologies and qualitative analysis to determine correlations, trends, and predictions and to solve for data gaps. The U.S. Coast Guard's (USCG) Marine Information for Safety and Law Enforcement (MISLE) database has tremendous opportunity for deeper mining and analysis, especially if it can be coupled with AIS data, to understand near-misses. Careful analysis of the system before and after regulation implementation has the potential to evaluate regulation efficacy, (e.g. Subchapter M implementation), but translation for policymakers is required to incorporate into rulemaking justification and adoption of best practices for waterway safety.

Environment

Big Data is being harnessed to understand the environmental impacts of marine transportation. AIS data, in conjunction with private vessel data and USCG data for modeling maritime air emissions, has been used for the monitoring of spatial and temporal emissions from maritime sources. Analyses of these data have led to multi-attribute performance measures, which have highlighted opportunities for modal shifts for intermodal maritime cargo to minimize air emissions and optimize energy efficiency. While there is excitement that data collected may expand opportunities for environmental analysis, concerns about the quality of the underlying data abound. For example, AIS data must first be scrubbed of 'ghost' and erroneous data, otherwise any ensuing analysis will be invalid.

Maritime Applications of Big Data and Machine Learning

Blockchain and machine learning applications may be leveraged to improve logistics and research of the maritime domain, but this action will require access to multiple, accurate, and complete data streams. It was suggested that a natural-language user interface might be one solution to allowing better access to and analysis of transportation data. Access to consistent and quality data was a unifying theme across the presentations, as were concerns about cybersecurity, given the amount of proprietary data sought for these data-intense applications. While Big Data and machine learning are very promising, a key pitfall about the collection was noted; AIS data on ships and GPS data for trucks are not as complete as anticipated, with subsequent limited utility for informing key decisions.

Identified Research, Development, and Technology Needs

Enhanced Data Access and Integration

TRB-CMTS R&D Conference presenters and participants identified a number of existing challenges revolving around data. For data to be incorporated into multimodal freight analytics, data must be:

- *Interoperable*: Freight data must be interoperable between different modes of transportation. There are currently many roadblocks that limit the interoperability of freight data today, ranging from the plurality of methods used to collect data across different modes of transportation, to the logistical challenges of aligning and merging multiple streams of data.

- *Accessible*: Freight data must be accessible to the analysts in need of data to inform decision making. Data must be able to transcend the IT firewalls between public and private partners, between different levels of government (e.g. city, county, state, and Federal), and between Federal agencies. Access to these data must be balanced with the need to minimize security risks and protect proprietary information.

- *Complete and Accurate*: Complete and accurate data are key pillars to support a high-fidelity freight flow model and to transforming the MTS. In the age of Big Data, there is an abundance of data available, but questions remain over the accuracy of the data. Probe datasets, such as AIS, can be plagued with data gaps and inaccurate information from improperly filled in fields or from challenges aligning with other data sets. Additionally, the dearth of local observations and last mile details limits the scope of this work, and there are challenges with disaggregating large data (from national and regional levels) to a finer scale.

The CMTS' Maritime Data Integrated Action Team (Data IAT) is actively working to address the challenges of sharing data within the Federal government, including the specific challenges associated with historical AIS data access. The Data IAT is currently working to facilitate the identification, archiving, linking, and integration of authoritative data from agencies with equities in maritime transportation data. Access to interoperable and shareable authoritative data will assist CMTS member agencies in making timely and well-informed decisions that enhance the capabilities of the MTS as well as fulfill strategic analysis and reporting requirements.

Additionally, while many participants identified the need for more data to enhance all aspects of analysis, it should be noted that operators within the supply chain have distinct and separate

data needs. FMC Commissioner Dye recognized this in her keynote address, noting that the timely access of specific, critical pieces of information is often the most important data requirement to optimize the flow of freight through the supply chain.

Recommendations

1. **Further work is needed to modernize and harmonize data collection, sharing, storage, and application practices, and leverage existing best practices throughout the process.** Numerous speakers at the CMTS TRB R&D Conference urged that the best practices around data collection, sharing, and stewardship be shared between operators along the supply chain and between government partners. Additionally, experts recommended the development of data and metadata standards, as well as standard terminology, to make data inherently more interoperable and better suited for further post hoc applications beyond freight applications.
2. **There must be better communication with stakeholders along all parts of the supply chain to meet the data needs of operators.** Developing means of communicating, such as FMC's proposed National Seaport Information Portal, may be one direct way to ensure communication up and down the supply chain, as well as providing researchers with a single, merged data stream of relevant freight datasets.

Challenges Facing Multimodal Freight Network Analytics

While access to and quality of data are major obstacles facing multimodal freight network analytics, other challenges remain as analysts work to compute the multimodal freight network. These challenges include:

- *Lack of standards:* The lack of standard analytical methods and data quality standards compounds the logistical challenges of merging multiple data streams to accurately reflect the complex network of freight flow. Multiple types of data from multiple differently-sized data streams, including multiple types of probe data, are required to support multimodal analytics. Developing standard analytical methods to measure end-to-end supply chain performance and bottleneck identification could transform how the MTS and wider supply chain is evaluated and how disruptions to the supply chain are quantified.

- *Lack of common terms and definitions*: Analysts and supply chain operators use different terminologies, compounding the challenges of communicating across sectors. Today, there is a lack of common definitions of commodity classes and levels of service across different levels of government and modes of transportation. Analytics and data terminology, too, can be challenging, as new advanced analytics are unveiled and new types of probe data come into use. It is of paramount importance that sector-specific

and modal-specific jargon is limited to better ensure communications across different components of the supply chain.

- *Harnessing the full potential of probe and sensor data:* Probe and sensor data, such as AIS, have the potential to answer what was unthinkable just years ago, and as autonomous and automated technologies enter the transportation sector, it is important that methodologies be developed to extract critical, quantitative data from probes across all modes of transportation. Data visualization is a powerful means to examine probe and sensor data; however, these visualizations, such as heat maps, can maroon and isolate complex data sets from further analysis.

Recommendations

1. **Standard analytical methods should be developed to ensure appropriate and consistent application of freight data analytics.**
2. **A lexicon of standard terms used in freight, transportation, supply chain, and data analytics should be developed to better enable communication across sectors.**

Opportunities

Presenters at the CMTS TRB R&D Conference highlighted several opportunities to advance the use and quality of multimodal freight network analytics, including:

- *Incorporation of scenario planning*
  Scenario planning allows planners to look at how land-based localized impacts could ripple across the MTS and vice versa. Analysis of both natural disaster and man-made scenarios and events at local and national levels can capture the full complexity of the freight system. Scenario planning in conjunction with multimodal freight analytics can provide analysts with further insights about system resilience, performance, and interconnectedness.

- *Incorporation of cutting-edge technologies*
  There has been a flurry in the development of advanced analytics in the past few years. Incorporation of natural language processing, blockchain technology, and cloud computing into multimodal freight analytics can ease access to data and connectivity of data. Additionally, operations stand to be greatly improved through model-guided optimization, such as the optimized ship routing and accurately calculating costs of moving away from business-as-usual operations.

- *Merging of data streams for analysis beyond the MTS*
  One ongoing theme in Big Data is the application of data for post hoc purposes. Researchers at the conference presented several innovative ways where data collected for safe and efficient flow of freight through the supply chain may be leveraged for

environmental management support tools (such as the merger of AIS with USCG datasets to model air emissions from maritime sources) or public health support tools (such as the multi-attribute performance analysis for intermodal maritime cargoes). Further and expanded use of maritime and freight datasets may shed light on other adjacent fields, while also highlighting the greater value of the MTS.

- *Development of methodology inventories*
  The field of multimodal freight analytics is ripe for the review and inventory of commonly used methods. Such an inventory would better enable researchers to validate their findings and better understand the uncertainty associated with their models. Furthermore, such an inventory can allow for analytical methods to cross-pollinate between different sections of the supply chain and different modes of transportation, creating a test bed community for like-minded analysts. This may be especially valuable as automated technologies become incorporated into other modes of transportation. Lessons learned from working with AIS data, for example, may greatly inform analysts working with data generated from autonomous surface transportation, accelerating change across the entire transportation field.

Summary of Conference Recommendations

The 2018 TRB CMTS R&D Conference highlighted some of the tremendous progress happening across the field of multimodal freight analytics. However, a single, uniting multimodal freight model is still beyond the R&D horizon. Integral components of a future national multimodal freight model are still being developed, and steps may be taken to advance this effort that would also enhance the wider efficiency of the MTS. Distilled recommendations from this conference include:

- Modernize, harmonize, and standardize data collection, sharing, storage, and application practices and policies to better enable the sharing of data across various entities along and within the supply chain and outside observers.
- Develop a common working lexicon of terms used in discrete modes of transportation and freight flow analytics.
- Enhance the visibility of the MTS by prioritizing communication efforts with stakeholders, policy makers, and the wider public.
- Incorporate scenario planning into MTS analyses to understand implication of both man-made and natural disruptions.
- Apply data generated by the MTS to other interdisciplinary studies.
- Develop an inventory of methods used in multimodal freight analytics and other supply-chain studies.

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