Social Science Evaluation of National Water Center Hydrologic Ensemble Forecast Service and National Water Model Output and Technical Support Services: Assessing Economic Benefits

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Executive Summary

Background: ERG developed a "Proposed Approach for Estimating the Economic Benefits of Enhanced Flood Forecasting Products and Services in the Freight Transportation Sector" in consultation with economists within the National Oceanic and Atmospheric Administration (NOAA) (hereinafter "economics team") in response to the Task Order entitled "Social Science Evaluation of the National Water Center Hydrologic Ensemble Forecast Service (HEFS) and National Water Model (NWM) output and Technical Support Services." This document describes the work associated with this portion of the Task Order.

Objective: The objective of this project was to develop a method to estimate the economic benefits of enhanced hydrologic forecasting products and services provided by the Office of Water Prediction (OWP) through advancements in the NWM. While focusing on one sector, the aim of this project was to develop a methodology that might be transferable across sectors so that, when OWP products and services are more clearly defined, the economic benefits across all users might be assessed.

Methods: To narrow the focus of the methodology development, the economics team examined one core partner group (transportation) for which economic benefits might be significant, and more easily quantified. Because the transportation sector is so large and diverse, and due to robust available data (Freight Analysis Framework [FAF]), we scoped the project to focus on how improved flood forecasting might mitigate operational losses and losses associated with products spoiled[1] because of delays or late deliveries across the freight movement sector (truck, rail and marine). We later refined the scope to focus specifically on the freight trucking industry.

The economics team then researched and brainstormed potential benefits of the NWM's advancements to the freight movement sector. Following this brainstorming period, ERG developed theoretical value chains, which were presented to freight transportation experts for feedback through a series of in-person meetings and phone interviews. The purpose of this feedback was to ground-truth our theoretical value chains and to better understand how the NWM's services might generate value to the freight trucking industry by improving operational and logistical decision-making.

Following initial engagement efforts, and based on the feedback that was received, the economics team refined the value chains and held two focus group webinars, followed by one-on-one interviews to understand how the industry would use these services for decision-making support given potential outputs of the NWM. The purpose of this round of engagement was to further ground-truth the value chains and, if possible, extract some initial feedback on the value of improved hydrologic forecasting services to operational decision-making in the freight trucking industry.

[1] Spoilage refers to both traditional "spoiling" (e.g., foods might spoil if delayed too long) and freight that misses a sensitive delivery window, and if delivered after that time, the freight cannot be used.

From this engagement, ERG collected useful information that can be used to guide future work to implement the valuation methodology described in this document. The following findings were extracted from this engagement:

- Industry experts validated the value chains regarding how the NWM could reduce operational costs and spoilage/revenue loss associated with flooding.
- Industry experts agreed that more accurate forecasting data within a few days of the event and better "real time" data (current information during the event) will help trucking companies avoid flooding hazards and more efficiently re-route freight to avoid delays and save time and money.
- Industry experts concurred that improved forecasts within 24 hours of route planning could help avoid operational losses. More accurate forecasts within 4-8 days prior to an event could inform logistics planning (e.g., routing, warehousing, and timing of major shipments) and would be particularly important for avoiding losses associated with large events (hurricanes in particular).
- The industry would best be served by NWM enhanced flood forecasting if it was integrated into existing navigation applications to *predict* impacted routes. This would provide more advanced warning compared to real-time information that applications now provide about road closures or traffic back-ups due to flooding.
- Depicting predicted flood inundation depth would be a major benefit. This information, when presented within the context of existing road/highway elevations (not just topography) would be very useful.

Recommendations

1. Further refine and tailor value chains for other transportation sectors: The value chains developed in this report should be applied to other sectors for refinements and tailoring. Developing theoretical value chains and then appropriately ground-truthing those value chains is the first step toward quantifying meaningful benefits.

2. Obtain data (through surveys, interviews or other sources) to complete a baseline calculation for economic loss: Step 3 of our methodology outlines some next steps for completing this baseline calculation. This effort can further ground-truth the connections between flood event sizes and delay times that the economics team has identified (e.g., small event can cause, at minimum, a three-hour delay; large event can cause delays between one-week to one-month). Additionally, this data collection effort could help to connect those delay times to economic losses (i.e., operational losses and spoilage/revenue losses). The NWM generates benefits to the freight trucking industry by providing enhanced flood forecasts to improve operational and logistics decision-making, and once delay-times are connected to economic losses, the economic benefits of the NWM's enhanced flood forecasts to the freight trucking industry can be estimated.

3. Work with state or local departments of transportation (DOTs) to quantify benefits: Step 4 of our methodology outlines some next steps for quantifying the benefits of the NWM. One approach to quantifying the benefits associated with reduced delays from improved flood forecasting services would

be to work with a state or local department of transportation (DOT). State DOTs could be recruited by working with the American Association of State Highway and Transportation Officials (AASHTO). State or local DOTs could potentially use improved flood forecasting information on an experimental basis to inform decisions about road closures. These DOTs could then provide feedback on the difference between the NWM products and services (e.g., lead time for road closures) compared to existing products and services. This feedback could then be translated to measurable changes (e.g., decreased delay time) which can be quantified as a benefit to the freight industry and calculated as an economic benefit based on data (see recommendation 2 above). There are some cities (e.g., Austin Texas, Boulder/Denver CO, Phoenix AZ), with whom WRSB has worked in the past and who have expressed interest in experimenting with new products. Working with them would provide more site-specific information and leverage existing partnerships.

4. Survey the industry or perform expert elicitations to quantify the benefits of the NWM: Step 4 of our methodology outlines some next steps for quantifying the benefits of the NWM. A key to quantifying benefits would be to survey or perform expert elicitations with the freight trucking industry to understand the difference that improved products could make in decision making and how those improved decisions translate into economic benefits. To do this, we recommend showing industry members both existing services and improved services within the context of hypothetical flood scenarios. This will enable industry members to base their responses on situational realities. This approach might best be done when the NWM outputs are more fully developed. To be meaningful to this user group, it would be most effective if the outputs could be demonstrated through integration into a navigation application so the industry could more easily relate to the information being provided and more accurately answer questions about how the NWM's products and services might inform operations and logistics decision-making.

Overview

ERG developed a "Proposed Approach for Estimating the Economic Benefits of Enhanced Flood Forecasting Products and Services in the Freight Transportation Sector" in consultation with economists within NOAA in response to the Task Order entitled "Social Science Evaluation of National Water Center Hydrologic Ensemble Forecast Service and National Water Model Output and Technical Support Services." This approach was developed to support the National Weather Service (NWS) Analyze, Forecast, and Support Office Water Resource Services Branch (WRSB), who works closely with the Office of Water Prediction (OWP), to develop improved hydrologic forecasting services to support core partners in the following areas: water supply, flood management, drought, water quality, agriculture, ecosystems, energy, emergency response and transportation.

Over the past two years, ERG has conducted extensive core partner engagement to define user needs for improved hydrologic forecasting products and services. Core partner input was used to develop prototype hydrologic forecasting products, which were then tested at stakeholder workshops. That input will be used to refine the products and develop a path for implementation.

This document describes the goal of this economic task, outlines ERG's approach, discusses the potential limitations of the approach, and summarizes deliberations and decisions made to refine the methodology we developed. Finally, this document describes the steps of the valuation methodology that ERG completed, findings gleaned from this effort and recommended next steps.

Goals and Outcomes

Goal: The goal of this work was to develop a method to estimate the economic benefits of enhanced hydrologic forecasting products and services provided by the OWP through advancements in the NWM. The economics team developed a high-level methodology that is transferable across sectors to eventually estimate economic benefits across all users of the NWM's products and services. The economics team focused the methodology on the freight trucking industry because: there are available data (via FAF); many high-value products are moved through the freight trucking industry; this sector crosses a range of hydrologic conditions (from streams with flash flooding to riverine flooding); and the freight trucking industry has more flexibility to use enhanced flood forecasts to adjust their decision-making process within a wide range of timeframes compared to other freight movement methods. Thus, there is an opportunity for enhanced flood forecasts to mitigate operational losses (delays) and spoilage/revenue losses (value of products spoiled because of delays or revenue loss because of late deliveries) by informing operational and logistics decision-making.

Outcomes of this project: The outcomes of this project are listed below:

1. A valuation methodology to estimate the economic benefits of the NWM's enhanced flood forecasting capabilities
2. Ground-truthed value chains describing how the NWM can provide benefits to the freight trucking industry
3. Industry input (both qualitative and quantitative) on how the NWM could potentially enhance decision making in the freight trucking industry
4. Recommendations for future research to continue to understand the economic benefits of the NWM

Methodology

ERG developed a methodology that could be implemented to assess the economic benefits of the NWM's enhanced flood forecasting capabilities. ERG implemented several of the initial steps of this methodology to test it, working within the constraints of available resources. The methodology and the steps that ERG completed to date are outlined in the sections below. For steps 3 and 4, ERG's economics team provided some "next steps" for completing the steps to the methodology. These are also embedded into the Recommendations section of this report.

Methodology to Value Economic Benefits of the NWM

For the reasons described above, the economics team focused specifically on the freight trucking industry. However, this methodology could be more broadly applied to freight movement (i.e., rail or barge) and other economic sectors. This is a four-step methodology that involved 1) brainstorming and developing value chains, 2) ground-truthing and revising the value chains based on industry feedback, 3) gathering and analyzing data to develop a baseline, and 4) quantify and calculate the measurable change.

The steps below outline the proposed methodology. We have also identified steps we have completed during this project and those that could be implemented as part of future work.

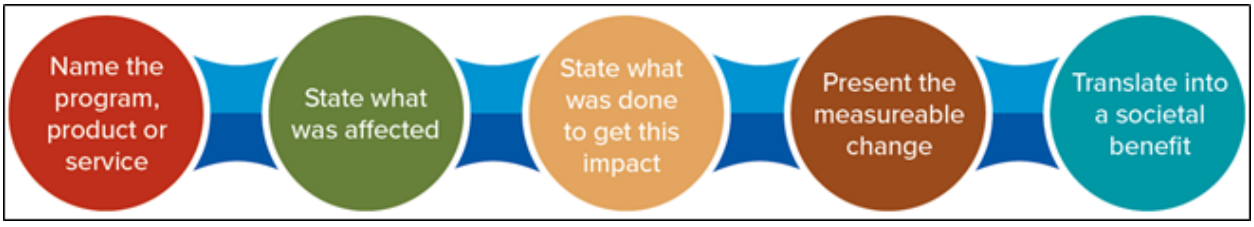
Step 1. Brainstorm Benefits and Develop Theoretical Value Chains

ERG completed this step during this project. Below, we first provide some background on value chains and how they could more generally be applied to describe and estimate the benefits of the NWM. We then present the steps we took toward brainstorming and developing value chains specific to the freight transport industry for trucking.

Background on Value Chains

Value chains clearly and defensibly show how value is generated and translated into a monetizable benefit. The value chain approach also aligns with NOAA's Chief Economist Office recent approach on other valuation efforts. This section presents the high-level method that we applied (and could be applied to all sectors to determine the benefits of the NWM). Figure 1 below presents a value chain to show the path to connect the NWM to a societal benefit.

Figure 1. Steps in developing a value chain to calculate an economic benefit



For each benefit, we developed a value chain to connect the NWM to that specific benefit. This provided an important linkage between the NWM and an industry-level benefit and is similar to a logic model. At a high-level, this is how we applied the value chain to the NWM.

1) The first (red) circle (name the program, product, or service) is the NWM.
2) The second circle (green) is the industry, organization, built environment, people, or other entity impacted by the program or service (i.e., who is benefitting).
3) The third circle (cream) is the mechanism by which the NWM is impacting the entity (e.g., the NWM improves decision making for a group to help avoid damage, increase safety, save time).

4) The fourth circle (brown) is the measurable change (or delta) resulting from impacts from the NWM. This typically requires the following:
    a. Step 4a: Establish a quantitative baseline (e.g., the lost time or damage in the absence of the NWM).
    b. Step 4b: Calculate the new measurement relative to the baseline that results from the NWM impacting the entity (e.g., lost time or damage in the presence of the NWM)
    c. Step 4c: Calculate the change / delta (i.e., Step 4b - Step 4a)
5) The fifth circle (blue) is the valuation strategy to turn the measurable change into a benefit in terms of dollars. This step likely requires an economist and could use a wide variety of market (e.g., avoided cost, increased revenue, increased production, travel cost, hedonic pricing) and non-market (e.g., contingent valuation / willingness-to-pay) methodologies depending on what needs to be calculated.

Brainstorm Benefits and Draft Theoretical Value Chains

The economics team brainstormed some potential benefits of the NWM's flood forecasting capabilities to the freight industry. Tables 1 and 2 (see "Results" section) present two theoretical value chains we explored through research and discussions with contacts in the freight transport sector.[2]

Step 2. Ground-truth and Revise Value Chains Based on Research and Initial Expert Feedback

ERG attended the Transportation Research Board (TRB) Annual Meeting, which includes thousands of transportation experts across industry, government, academia, and nonprofits. At the meeting, ERG attended sessions and subcommittee meetings related to freight movement and held conversations with experts after the sessions and during the poster session. We attended the following sessions related to freight transportation and/or flooding:

- Transit, Freight, and Logistics Modeling Subcommittee Meeting
- Inland Waterway Transportation Challenges and Path Forward
- Freight Surveys Subcommittee Meeting
- Freight Rail Transportation Committee
- Liner Shipping Routes and Schedules under Uncertain Weather and Ocean Conditions: A Robust Optimization Approach
- Assessment of Travel Delay, Value-of-Time and Potential Safety Impacts of Truck Route Diversion using VISSIM Micro-Simulation Model
- Current Research in Agriculture and Food Transportation

In addition to conversations with experts at the TRB Annual Meeting, we scheduled longer conversations with several of these experts. Those follow-up consultations were performed by phone in the weeks following the meeting and focused on the value chain for calculating economic benefit and decision-making during flood events. ERG interviewed individuals from the following organizations and institutions:

[2] These are most applicable to the freight trucking sector but could be broadened or slightly tweaked to potentially capture benefits to rail or barge.

- Bureau of Transportation Statistics
- Federal Highway Administration
- I-95 Corridor Coalition
- Texas A&M Transportation Institute
- University of Texas, Austin Department of Civil, Architectural and Environmental Engineering
- Gemini Shippers
- Association of American Railroads
- Michigan Tech Transportation Institute

We also researched literature to assess these value chains. In one article about the use of weather forecasting information, the Chief Information Officer at the freight broker C.H. Robinson stated,

"Think about the ripple effect a large-scale weather event like a hurricane can have on supply chains throughout a region. When shippers and carriers can be predictive and prescriptive, they can take actions to lessen the impact to supply chains and their businesses. Shippers can work to find alternative options to ensure their products still reach their customers, while carriers can move capacity out of the impacted area before drivers and trucks become stranded. These types of movements could prevent impacts in the immediate area but also throughout the supply chain."[3]

Step 3. Gather and Analyze Data to Develop a Baseline and Calculate Measurable Change

During this project, ERG conducted initial research into this step, and we provide recommendations on how best to conduct these steps in future efforts.

As discussed above, this methodology is designed to eventually capture the baseline operational losses (freight delays) and spoilage/revenue losses (value of products spoiled because of delays or revenue loss because of late deliveries) based on improved hydrologic forecasting. This approach outlines the recommended datasets and high-level sequence of steps to estimate the average annual losses at the national level to the freight sector due to flooding. This also presents data challenges we have identified as we have explored data availability in each step. For these steps we have primarily focused on the trucking industry. Based on conversations with experts in the barge and railroad industry, they may be more limited than the trucking industry to improve decisions based on improved flood information from the NWM.

Step 3a: Gather and Analyze Freight Movement Data

The Freight Analysis Framework (FAF), maintained by the U.S. Department of Transportation, Federal Highway Administration, is an enormously rich dataset. FAF captures total flow, domestic, import, and export freight movement, capturing 42 commodity categories (i.e., live animals/ fish, cereal grains, meat/ seafood, tobacco products, logs) classified at the 2-digit level of the Standard Classification of Transportation Goods (SCTG). The movement of these 42 commodity types are captured across eight

[3] Truckers Benefit from Weather Forecasting Technology. "https://www.ttnews.com/articles/truckers-benefit-weather-forecasting-technology"

total modes of transportation (i.e., truck, rail, water, air). FAF measures these commodity movements by commodity tons, ton-miles, and total values. Finally, FAF offers relatively granular spatial data, offering national totals, state specific data, and over 100 FAF zone-specific areas typically based on areas where substantial amounts of freight are moved through (e.g., Charleston, SC; Mobile, AL; Orlando, FL).

Outlook, Challenges, and Limitations: We recommend the use of FAF data to estimate a dollar-per-day value by commodity and freight type. By calculating dollar-per-day of freight moved through certain areas, one can develop a better understanding of the potential for losses associated with delays due to flooding. FAF data do not provide the route taken; rather, they provide the destination and origin. Thus, while one would have a general sense of how freight is moving, the lack of route-based data presents challenges and limitations to connect flooding in specific locations to the FAF value moved per day between origin and destination. Additionally, freight movement can be seasonally dependent and the annual FAF dataset would not account for these variations.

Step 3b: Estimate Losses Associated with Delays

In Step 3a, we present a method to show the value of freight moved per day from each origin to each destination. Using this data, we explored whether one could estimate losses associated with delays of varying lengths. For example, the losses with a 6-hour delay, a 1-day delay, a 2-day delay, etc. to estimate losses associated with commodity delays of varying lengths. These two types of losses could include: operational losses from delay (down time is money lost to paying employees) spoilage/revenue losses (value of products spoiled because of delays or revenue loss because of late deliveries).

"Spoilage" or Revenue Loss Data: Outlook, Challenges, and Limitations. The experts that we interviewed confirmed that shippers and trucking companies experience losses from delays. Examples of this include agricultural or food products spoiling because of delays; delays causing negative impacts to a supply chain because the company could not deliver them in time; and trucking companies losing their revenue based on an agreement to deliver products in a certain amount of time.

The harmonized system used to categorize freight is broad as food products are grouped into "cereal grains," "other agricultural products," "animal feed," "meat and seafood," "milled grain products," and "other foodstuffs." For meat and seafood, one could develop estimates of the percent spoil based on certain delays by using information from the United States Department of Agriculture (USDA) to estimate the length of time before refrigerated meat and seafood might spoil.[4] The goal would be able to estimate the percent lost for each commodity type based on a certain delay. For example, about 15 percent of the value of meat and seafood is lost with a 2-day delay.

Next Steps: Continue to look for datasets from USDA to develop estimates for spoilage rates for food products.

[4] https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/safe-food-handling/refrigeration-and-food-safety/CT_Index

In addition to food products, experts and research revealed some industries, such as electronics and retail, rely on just-in-time delivery to reduce needed warehousing space, so delays impact their supply chain. Similar to above, the broad harmonized system categories limit how accurately we can identify industries where delays would impact supply chains. Furthermore, the agreements trucking, rail, and barge companies have with shippers are often proprietary. Industry folks indicate that some build in penalties for delays, but these vary, and sometimes these contracts include clauses for weather events, and sometimes they do not. One of the experts noted they have been in the industry for many years trying to understand these contracts but have not been able to gain much insight due to the proprietary nature of the contracts shippers and trucking companies develop.

Next Steps: Consider convening a focus group of up to nine shippers to provide some broad estimates for losses by categories based on examples of storm events provide context and to highlight the difference between existing and improved products. This would need to be done in a way that does not reveal business-sensitive information.

Operational Loss Data: Outlook, Challenges, and Limitations. BLS Occupational Employment Statistics (OES) data provide the hourly mean wage for truck drivers ($21.80)[5], rail conductors ($30.89)[6], and captains, mates, and pilots of inland water transportation vessels ($42.56)[7]. Using these rates, one can calculate the operational losses after calculating the hours or days of delay. Theoretically, this is a more straightforward loss to estimate for known delays. The challenge for this calculation comes in the next step when determining the hours of delay due to events.

Some other useful information related to these losses:

- For Hurricane Harvey, the cost of hiring tractor trailer from Dallas to Houston increased, on average, 66% from the week before Harvey.[8] This reflects the additional time and logistics associated with moving through flood-impacted areas. It also includes a component of increased fuel prices from the hurricane impacting oil refining in the Gulf of Mexico. Nationally, the average rate for dry vans **increased $1.90 per mile**, which incorporates fuel prices.
- Market surcharges due to hurricane activity in 2017 (Harvey, Irma, and Maria) led to a total cost of $673,000. The **Average Cost Per Load went up by $159.58** (11%) after Hurricane Harvey and the Average Cost Per Mile increased by 15%.[9]
- Hurricanes brought prolonged delays. Looking at the data, we can see that average transit days went from 2.65 to 2.95, which is an increase of 10.17%.[10]

[5] https://www.bls.gov/oes/2017/may/oes533032.htm
[6] https://www.bls.gov/oes/2017/may/oes534031.htm
[7] https://www.bls.gov/oes/2017/may/oes535021.htm
[8] https://www.wsj.com/articles/hurricanes-disrupt-freight-sector-send-rates-soaring-1504735610
[9] https://www.supplychain247.com/paper/hurricanes_transportation/zipline_logistics
[10] https://www.supplychain247.com/paper/hurricanes_transportation/zipline_logistics

- "There was a **5.5 % increase in spot freight rates** across the US. After Hurricane Harvey struck concomitant with 72% loss of loads from Houston. Spot rates expected to increase to as high as **$4.55 per mile**, particularly in areas that are in the hurricane's path."[11]

Step 3c: Connect Delay Times to Event Sizes

We explored connecting events of certain sizes to a certain length of delay (e.g., a 500-year flood causes five days of delays). Here are some data we found from this research that will help to estimate baseline losses associated with events.

- Hurricane Harvey closed the Port of Corpus Christi for **one week** and barge, rail, and trucks into the area.[12] The article also noted "more than $100 million in petrochemicals, wind energy equipment, even agriculture goods sail through the port each day."
- Hurricane Isabel in 2003 closed a major Norfolk, VA through way for almost four weeks, and it closed ports at Norfolk, Portsmouth, and Newport News.[13]
- Conversations with industry indicated that small flood events can easily cause at least a 3-hour delay due to increased traffic.

Outlook, Challenges, and Limitations. Based on the literature and discussions with FHWA and BTS, we found certain size events impact different regions to largely varying degrees. Flooding associated with larger hurricanes may shut down ports from about one week to one month. This information can be used to estimate the range of losses based on the length of time the impact occurs, and the extent to which advanced, and more specific forecasting information might avoid impacts. Similarly, one interviewee indicated that, "even a small flood event will cause a minimum of a three-hour delay. Once the water clears, drivers are often stuck in stacked traffic."

Step 3d: Calculate Baseline Losses from Flooding

"Case Example" Losses: Develop estimates for select FAF regions. For example, if there is a storm of "X" magnitude that caused a "Y" day delay in Charleston, SC, one could estimate potential losses. The next step would be to develop some case example estimates to help provide some compelling examples of the losses to provide more context about the potential for improved flood forecasting to mitigate some of these losses.

National-Level Aggregation: FAF provides a complete national dataset. In future work, it will be possible to "roll up" the baseline losses associated with freight moving to and from each FAF region to the national level. This will require incorporating event probability by magnitude, which could be pulled

[11] http://oceanstarinc.com/impact-of-hurricane-season-on-freight/

[12] https://www.caller.com/story/news/local/2017/08/31/harvey-2017-port-corpus-christi-reopens-lucrative-ship-channel/621746001/

[13] Shital A. Thekdi, and Joost R. Santos. "Supply Chain Vulnerability Analysis Using Scenario-Based Input-Output Modeling: Application to Port Operations." Risk Analysis, Vol. 36, No. 5, 2016

from storm probability databases. This would help develop average annual losses for each FAF region then sum across all regions[14] to develop a national estimate.

Outlook, Challenges, and Limitations: In the short-term, one could develop baseline losses for a handful of regions. One challenge in doing this would be defensibly connect weather or water events with delay times and then to operational losses that would be appropriate for a given region.

Step 4. Quantify and Monetize Measurable Change

Once we understand the baseline loss, we need to quantify how information from the NWM could lead to enhanced decision making. That enhanced decision-making would lead to a measurable change, which we could then monetize.

The general sequence of steps needed to quantify and monetize the measurable change include:

1) Understand the behavior change associated with the NWM outputs, including when (the thresholds of flood extent or type of event) the NWM would lead to such change and what those associated actions are.
2) Quantify the measurable change from the behavior change (e.g., the number of operational hours saved with taking a new route, the percent of certain product types that would no longer spoil as a result of those decisions)
3) Monetize the measurable change (e.g., Apply an operational dollar-per-hour value to hours no longer lost, apply a dollar-per-pound value for commodities that would no longer spoil).

The economics team focused on understanding how decision making in the industry could be improved given the outputs from the NWM. We formulated questions to begin to understand steps 1 and 2 above given potential outputs of the NWM.

ERG developed and hosted two webinars and held several one-on-one conversations with relevant freight trucking, shippers, and logistics companies to better understand how the NWM may inform decision-making and to identify gaps to be addressed in future work. Our industry-engagement approach is outlined in the section below.

Freight movement is a particularly competitive and sensitive industry, and small competitive advantages can determine economic viability. The economics team gained a deep understanding of the necessary level-of-effort to engage industry-members in future work. We have documented our recruitment efforts below to inform future work.

[14] We will prioritize this by starting with regions moving the most freight as resources may limit whether we can pull storm event probability for all 100+ regions of the FAF. We will provide some context about our final estimate (e.g., this covered 85% of freight moved and excluded X, Y, and Z regions so this is somewhat of an underestimate).

Webinar Recruitment[15]

Leverage Existing Connections: ERG engaged 6 relevant contacts from the Transportation Research Board's (TRB) Annual Meeting via email with the goal of identifying industry experts who could attend the webinar. Of the 6 contacts emailed, three responded. Of the three respondents, only one was able to provide an industry contact (who ultimately did not make the webinar).

EPA SmartWay Email Blast: EPA SmartWay agreed to publish the webinar invitation link in the EPA SmartWay's monthly newsletter, which was released to approximately 3,700 SmartWay partners just over two weeks prior to the webinar. About 3 out of 3,700 contacts on this SmartWay list attended the webinar.

Cold Email and Call Recruiting of Freight Trucking Associations and Companies: ERG conducted research and identified another 40 individuals employed by freight trucking companies or freight trucking associations. We invited these 40 individuals to attend the webinar and to send notice to their association members (if applicable). ERG emailed these 40 individuals two weeks prior to the webinar. Three individuals responded to our initial emails (and one responded to a follow-up email). Two out of four respondents (trucking association leadership) agreed to send the webinar information to their association members. One person noted they could not attend, and the fourth respondent indicated they did not want to circulate the information during their company's driver appreciation week.

As follow up, ERG extracted publicly available phone numbers for individuals who had not responded to our initial email. ERG called 24 individuals and left 17 voicemails. After leaving a voicemail, ERG followed-up with the individuals via email and re-sent the webinar link. In some cases, if a phone number was faulty or a number was not listed, ERG called a colleague of the initial email recipient. Finally, ERG followed-up via email with 11 individuals for whom numbers were not listed, numbers were faulty, or a number for another company representative could not be found. This process took place between 9/4/2019 and 9/6/2019

Summary: In total, 35/40 individuals (in addition to the about 3,700 SmartWay partners [8/27] and the initial 6 emails sent [7/22]) received between two and three communications from ERG with registration information about the webinar between 8/30 and 9/6. Two individuals indicated they sent the webinar invitation and information to their association members.

Post-Webinar Recruitment

ERG conducted post-webinar engagement efforts with a refined focus on logistics companies to setup one-on-one conversations to fill gaps as the webinar focus group conversations focused on the truck carriers.

[15] See Appendix A. Who we Engaged? for a list of individuals we contacted during our recruitment and engagement process. This list does not include all 3,785 SmartWay program partners who received a notice in the SmartWay monthly newsletter.

ERG downloaded the EPA SmartWay partner list and filtered the sheet to include only logistics and truck carrier companies in the United States. From this list of 2,983 companies, ERG randomly selected companies and conducted research to identify and obtain contact information for relevant personnel at each company. ERG emailed over 40 people at 14 different companies. Of the individuals contacted, two people responded and scheduled interviews. One was a very large package delivery company with thorough insights about the logistical aspects and route planning. Another contact was a short-haul carrier with logistics insight and a good sense of the overall trucking supply chain (from shipper to truck carrier to client).

Results

Value Chains

Tables 1 and 2 present our validated value chains for this project. These were primarily ground-truthed with the trucking component of the freight transport industry but could potentially be broadened to incorporate rail and barge.

Table 1. Value chain of the NWM reducing spoiled or late delivered goods

Name the service	The NWM…
What was affected	… will help the freight transport industry reduce the amount of product spoiled or delivered too late…
What was done to get impact	… by providing forecasting and real-time data that allows drivers to avoid bad routes or change the pickup timing to avoid delays…
Measurable change	…reducing the amount of spoiled goods or those delivered too late for use by [X amount or Y%] ...
Benefit	…translating to a cost savings of [$Z] for trucking companies.

Table 2. Value chain of the NWM reducing time lost because of traffic from flooding

Name the service	The NWM…
What was affected	… will help the freight transport industry reduce time in traffic from flooding…
What was done to get impact	… by providing forecasting and real-time data that allows drivers to avoid bad routes or change the pickup timing to avoid delays…
Measurable change	…reducing the amount of hours lost in traffic to trucking companies by [X amount or Y%] ...
Benefit	…translating to a cost savings of [$Z] for trucking companies.

Findings from Research and Engagement with the Freight-Transport Sector

Value Chain Validation

- Experts generally agreed with the value chains. Whether using rail, truck, or barge, experts noted that if the NWM can provide improved long-term flood forecasting (week or two out) at a more detailed spatial level, shippers of products can take actions to lessen the impact on the supply chain such as moving products earlier or moving inventory to other distribution centers that will not be impacted by flooding. Shippers of products could also re-allocate drivers time by

having them focus more time on driving before flooding events and do more work at the warehouse during large flood events.

- Our research also supported these value chains. In one article about trucks use of weather forecasting information, the Chief Information Officer at the freight broker C.H. Robinson stated, *"Think about the ripple effect a large-scale weather event like a hurricane can have on supply chains throughout a region. When shippers and carriers can be predictive and prescriptive, they can take actions to lessen the impact to supply chains and their businesses. Shippers can work to find alternative options to ensure their products still reach their customers, while carriers can move capacity out of the impacted area before drivers and trucks become stranded. These types of movements could prevent impacts in the immediate area but also throughout the supply chain."*[16]

What Industry is Using Now for Decision Making

- Large carriers and logistics companies are incorporating significant amounts of technology into their load planning. Many of these companies use Transportation Management Systems (TMSs); incorporating flood forecast information into these TMSs would be extremely useful, especially past 24-36 hours. Technology is helping to increase intelligence of entire supply chain which massively impacts the freight transportation industry.
- Industry-members rely on the following for traffic information: TruckMap, Trucker Path, CoPilot Truck, Sygic Truck Navigation, Waze, Google Maps, Word of Mouth (radio communication with truckers and dispatch centers), and State 5-1-1 transportation and traffic information telephone hotlines.
- Industry-members rely on the following for weather information: National Weather Service information at the state or local scale, State and/or local Department of Transportation, forecast information from private companies or sources such as Weather.com and Accuweather, and Local weather/news sources.
- Some logistics/freight companies have their own meteorologists.

Feedback on how the NWM could be most useful to the industry

- It would be helpful if these forecasts showed flooding relative to road elevations in addition to topography. Raised roads might be unaffected in some areas that are flooded.
- It would be useful to have information integrated with a mobile traffic application.
- State and local DOTs would be interested in improved flood forecasting products, and one way for this to benefit the industry might be for DOTs to disseminate the information on roads that could likely be impacted by flooding, and obtaining information from State DOTs on metrics such as timeliness of road closures, which can then be translated into economic benefits.

Operational Losses

- Small flood events can cause a significant (e.g., 3-hour) delay. Even if water clears quickly, stacked traffic will cause delays.
- Carriers typically incur operational losses due to flooding delays. These losses include:
    - Increased payment to drivers for additional hours

[16] Truckers Benefit from Weather Forecasting Technology. "https://www.ttnews.com/articles/truckers-benefit-weather-forecasting-technology"

    - Increased fuel costs
    - Increased mileage on vehicles (depreciation of equipment and associated maintenance costs)
- Large freight trucking companies and logistics networks are often very fluid. Some are good enough to operate on 12-hours of advance notice, but 24-hours would be extremely ideal. Large companies operate 24/7 so there would be a lot of value in this product to entire trucking and transportation segment.
- Hours of service limitations for drivers. These limitations dictate how many hours drivers can drive each day over eight day stretches. It usually takes drivers 10-hours of non-driving for their hours to fully "reset." If a delay pushes a driver to the end of their eligible hours, losses can be compounded by waiting for driver hours to reset.
- Depending on the size of a business, companies can often plan alternate routes 12- to 36-hours ahead of time.
- Industry experts also agreed that more accurate forecasting data within the next few days and better real time data will help trucking companies avoid flooded roads and more efficiently re-route to avoid delays and save time.

"Spoilage"/Revenue Losses

- This information could be used to "soften" costs by providing the carrier with information to communicate with customers as a good faith measure. This communication can result in further avoided costs. For example, customers or warehouses may not need to hire shift to unload freight if they know in advance it will be delayed.
- Using extra hours on one shipment, due to delays from flooding, might delay the driver's subsequent shipments if they need to wait for their hours to reset due to the extra time spent on one shipment due to flooding. This might result in lost revenue from delaying other shipments.
- Enhanced flood forecast information would be especially useful for carriers who haul perishable and/or refrigerated freight.

Warehouse/Restaging

- Companies with advanced predictive capabilities usually need about 3-4 days' notice to re-stage warehouses or make inventory decisions.
- Companies with less advanced predictive capabilities usually need about 7-8 days to make changes.

Recommendations

1. Further refine and tailor value chains for other transportation sectors: The value chains developed in this report should be applied to other sectors for refinements and tailoring. Developing theoretical value chains and then appropriately ground-truthing those value chains is the first step toward quantifying meaningful benefits.

2. Obtain data (through surveys, interviews or other sources) to complete a baseline calculation for economic loss: Step 3 of our methodology outlines some next steps for completing this baseline calculation. This effort can further ground-truth the connections between flood event sizes and delay

times that the economics team has identified (e.g., small event can cause, at minimum, a three-hour delay; large event can cause delays between one-week to one-month). Additionally, this data collection effort could help to connect those delay times to economic losses (i.e., operational losses and spoilage/revenue losses). The NWM generates benefits to the freight trucking industry by providing enhanced flood forecasts to improve operational and logistics decision-making, and once delay-times are connected to economic losses, the economic benefits of the NWM's enhanced flood forecasts to the freight trucking industry can be estimated.

3. Work with state or local departments of transportation (DOTs) to quantify benefits: Step 4 of our methodology outlines some next steps for quantifying the benefits of the NWM. One approach to quantifying the benefits associated with reduced delays from improved flood forecasting services would be to work with a state or local department of transportation (DOT). State DOTs could be recruited by working with the American Association of State Highway and Transportation Officials (AASHTO). State or local DOTs could potentially use improved flood forecasting information on an experimental basis to inform decisions about road closures. These DOTs could then provide feedback on the difference between the NWM products and services (e.g., lead time for road closures) compared to existing products and services. This feedback could then be translated to measurable changes (e.g., decreased delay time) which can be quantified as a benefit to the freight industry and calculated as an economic benefit based on data (see recommendation 2 above). There are some cities (e.g., Austin Texas, Boulder/Denver CO, Phoenix AZ), with whom WRSB has worked in the past and who have expressed interest in experimenting with new products. Working with them would provide more site-specific information and leverage existing partnerships.

4. Survey the industry or perform expert elicitations to quantify the benefits of the NWM: Step 4 of our methodology outlines some next steps for quantifying the benefits of the NWM. A key to quantifying benefits would be to survey or perform expert elicitations with the freight trucking industry to understand the difference that improved products could make in decision making and how those improved decisions translate into economic benefits. To do this, we recommend showing industry members both existing services and improved services within the context of hypothetical flood scenarios. This will enable industry members to base their responses on situational realities. This approach might best be done when the NWM outputs are closer to final. To be meaningful to this user group it would be most effective to demonstrate the capability for these services to be integrated into a navigation application so the industry could more easily relate to the information being provided and more accurately answer questions about how the NWM's products and services might inform operations and logistics decision-making.

Appendix A. Who we Engaged?

During our preliminary expert engagement, we spoke to 9 individuals (2 Government, 3 association representatives, 2 academic, 2 industry). During the webinar and ground-truthing phase, we sent recruitment text via monthly newsletter to EPA SmartWay (3,700+) partners and emails to 80+ additional individuals at trucking and logistics companies and associations. During this phase we engaged 5 individuals (1 association, 1 insurance company, 1 state government, 1 small truck carrier, and 1 large freight carrier and logistics company) through webinars and phone calls.