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Standing Watch: Baselining Predictable Events That Influence Maritime Operations in the Context of the UN Sustainable Development Goals

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Abstract: The authors present a framework for assessing seasonal events that may influence maritime operations, seeking to tie in discussions about climate change adoption to maritime operational assessments. Most maritime-related research tends to focus on single events, such as a storm, but maritime systems operate within complex systems that have some predictable patterns. These predictable patterns due to natural events, such as weather and water levels, can influence operations, while other factors, such as cargo peaks or cultural activities, could also shape maritime systems. The growing focus on adopting human activities to the United Nation's Sustainability Development Goals means that system operations must be considered in their relationship to these broader goals. By integrating data from emergency management databases and weather information sources with other inputs, the authors created a matrix of regionally specific predictable events that may occur within a region by time of year that can be linked to the sustainability development goals. The matrix was vetted with various stakeholder groups to verify the information in the matrix. The main findings were that a seasonal event matrix is helpful as a reference for examining operational patterns in a river for various uses, such as training, operational planning, and emergency response coordination.

Keywords: maritime; seasonality; natural disasters; risk assessment; maritime operations

1. Introduction and Problem Statement

Mariners plied rivers, coasts, and oceans for ages, with corresponding risks to themselves, their vessels, and their cargo. Today, the maritime industry can access information about weather and other risks, and while things still happen, these risks, especially related to weather and climate, are understood. Nevertheless, there are new concerns about maritime systems being changed by climate change. While climate change occurs through "natural events", the human response is classified as "sustainability". For example, the United Nations, in seeking to address climate change, developed Seventeen Sustainability Development Goals (SDG).[1] While distinct regarding specific reporting elements, these goals contain overlap among the different groups. For example, using inland waterways to carry freight will reduce emissions compared to rail or truck, and it will also lead to the adoption of cleaner and more efficient engines. Both items are included under Goal 9, "Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation," and Goal 12 "Responsible consumption and production". Concerns over pollution from maritime accidents are related to Goal 14, which is to conserve and sustainably use the oceans, seas, and marine resources for sustainable development.

There appears to be no framework to look at the potential for seasonal events based on predictability, especially regarding waterways and maritime systems, to examine changing climate activities seasonally to baseline if and how different events shape communities and, thus, their sustainability goals. This paper examines diverse events, focusing on seasonality, to provide a baseline to identify the seasonal nature of known risks at regional and maritime-domain levels. These will be developed through a desktop scan to identify known data points with seasonal or predictable patterns. Once the information was collected, it was presented to local maritime specialists to

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consider the merits of a seasonal classification structure. This approach identifies what should be quantified, not necessarily developing a deterministic probability while providing a framework to discuss shared events to improve planning for events. The paper has the following structure: a literature review that develops the theoretical framework for focusing on predictable events in the maritime sector to manage operational risks better. (The authors also seek to list that not all events are "bad", and placing navigation within a context of human activities can provide additional insights into localized activities.) In the methodology section, the authors discuss the structure used in developing the SEM model through regional and industry definition, creating a predictable event taxonomy, which was then populated using secondary data and desktop scans. The last step was stakeholder validation of the SEM to see if the work was accurate and if it assisted in framing the predictable risks within a region. The results show a regional comparison, in addition to a comparison of the Orleans Parish, Louisiana, and Warren County, Mississippi, to highlight the nature of broad regional patterns and localized events within a region.

2. Literature Review

The United Nations developed Seventeen Sustainability Development Goals (SDGs) to address climate change.(United Nations, Department of Economic and Social Affairs, 2015) These seventeen goals broadly address how climate change will influence the biosphere and the role of maintaining stewardship goals related to environmental resources, such as fisheries and marine habitat, while sustaining human flourishing, especially in historically improvised areas. While distinct regarding specific reporting elements, these goals contain overlap among the distinct groups, for no human activity is isolated from other activities, as highlighted by the Stockholm Resilience Center's wedding cake, where biosphere activities serve as the basis for the second layer of equity and the top layer of economics.(The SDGs Wedding Cake, 2016)

Natural disasters are not a minor problem, and climate change is assumed to make these disasters more prevalent and expensive to address.(Auffhammer, 2018) Between 1998 and 2017, disasters from climate or geophysical events resulted in an estimated 1.3 million people killed and 4.4 billion injured or homeless. While most deaths and human losses were from earthquakes and tsunamis, extreme weather events caused 91% of the reported disasters.(Centre for Research on the Epidemiology of Disasters (CRED) et al., 2018) forecasts are that these events will only increase over time, leading to more disruptions to human activities related to food production, quality of life, and supporting industries, such as navigation. There is a growing focus on looking at natural disasters in the context of climate security.(Niklas Bremberg et al., 2022) As such, there is one SDG focused on climate change, SDG 13, with the goal of "Take urgent action to combat climate change and its impacts". These include reducing human loss from sea level rise and storm events, but other SDG groups also seek to address natural disasters by building more resilient communities (SDG 12)

To assist in this goal, the United Nations developed the SENDAI Framework for Disaster Risk Reduction in 2015 to integrate existing agreements on climate response.(Sendai Framework .:. Sustainable Development Knowledge Platform, n.d.) The SENDAI seeks to achieve the following outcome: "The substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries". Rather than outline what risks are, the SENDI framework listed four priorities: Priority 1: "Understanding disaster risk", Priority 2: "Strengthening disaster risk governance to manage disaster risk", Priority 3: "Investing in disaster risk reduction for resilience", and Priority 4: "Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction".

However, there is a need to clarify better risks and how these risks tie to specific industries, many of which have robust planning and response capabilities. The challenge is that risks need to be evaluated in the context of awareness and planning, which depends upon agreeing on what risks exist and how to communicate about these risks within the respective location. Listing the disasters is not enough; this information requires engagement with local groups planning and responding to these disasters. Furthermore, this engagement with locals supports Sustainability Goal 17,

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Partnerships for Goals, which focuses on data and institutional sharing. There is a need to reconsider how risks are assessed locally and nationally and, by extension, their effects on other sustainability goals. However, how should local groups compare their activities to SDG goals, especially as they relate to changing weather patterns?

Climate change is expressed in terms of shifting weather patterns.(Shaftel, n.d.) The problem is that everyone knows the weather, but costs are associated with addressing shifting weather patterns and sea level rise. As the costs associated with responding to natural and man-made events increase, there is a growing demand to incorporate risk-based assessments in both the public and private sectors, partially through technology collection but also through better forecasting, big data, and cooperation. However, as the relationship between climate change and security/adoption merges, climate change influences the nature of natural disasters, food security, and general community well-being.

The challenge is that weather patterns are changing, and while it is necessary to talk about aggregate rises in world temperature, these effects are more apparent in the spring and fall transitional months.(Abrahamsson & Håkanson, 1998; Collazo et al., 2022; Zhou, 2024) As such, these assumptions concerning a "typical" seasonal event may change the relationship to human ecosystems. To address the fact that "everyone understands seasonal weather patterns", a monthly framework should conceptually be accessible as a starting point to assess risk within a community. As such, the assumption that people understand basic weather patterns is not necessarily consistent when asked to report about weather phenomena at a very localized level. Part of this could be familiarity, which leads to false risk assumptions, but as is always the case, surprises can often occur with tragic consequences.

There is a role here for monitoring and near forecasting events, such as weather patterns, to determine if resources are needed and, if so, where they may be deployed.

Mariners plied rivers, coasts, and oceans throughout the ages, dealing with potential risks to themselves, their vessels, and their cargo. Today, the maritime industry can access information about weather and other risks, and while events still happen, these risks, especially related to weather and climate, are understood. However, climate change concerns will influence new concerns about maritime systems. Generally, these concerns have been about rising sea levels, changing port infrastructure, and water variability for inland navigation. Barros, et al, developed a crosswalk between inland navigation and broad sustainable goals so that the focus of this paper will be more narrowly related to sustainability goals and seasonal events.(Barros et al., 2022)

This effort is not the first study to propose looking at waterways monthly, as these items were outlined regarding Central Europe, including water levels and operational limitations.(Meißner et al., 2017). While Meißner, et al., study focused on waterway levels, this focuses more on examining seasonal events, of which water levels are but one element. Furthermore, other studies have considered changing Arctic conditions, a climate-related seasonal pattern, or sea ice for the Great Lakes, which adds to mariners' exposure to cold weather events while also putting pressure on mitigation strategies.(Chen et al., 2020; Richard D. Stewart & Daniel L. Rust, 2022) The challenge is that maritime disasters tend to focus on singular events related to weather but assume all events contain a human factor element.(Adumene et al., 2022) This focus on assessing and mitigating risks, especially in managing vessel operations, has served the industry well. However, some concerns are that changing climate patterns will influence human work patterns and lead to more exposure to natural disasters.(Camuffo, 2019)

Conversely, the changing nature of water levels may also put pressure on the availability of inland navigation to provide reliable service. As such, changing water levels may lead to a mode shift to other less environmentally friendly modes.(Banks, 2024) So, while this may be seen as a natural disaster discussion, other operational considerations are not considered "disasters" but will be shaped by changing climate activities on a seasonal basis.

This is not to say that maritime researchers have not categorized various risk and disaster events in other settings. Many papers propose risk trees sorted by different phenomena, such as the 4 M (Man, Machine, Medium, and Management) approach used by Tao, et al., who developed a matrix

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of four Main areas where marine risks can be organized. Their four categories are centered around operational constructs, such as crew (fatigue, negligence, poor training), Ship (component failure, navigation problems), Channel (dimensions, depth, shoaling), and finally, the environment (fog, rain, and societal events, which includes other vessels.) They developed twenty events clustered around five broad categories: crew unsafe acts, ship mechanical failures, harsh channel conditions, adverse weather conditions, and social/ economic environments. The groupings were used to develop a static model to assess transportation risks associated with the shipment of spent nuclear roads in Asia. Other studies have used risk models to examine channel safety (, seafarer operations ((Wang & Fu, 2022), and collision management(Ozturk & Cicek, 2019).

One of the challenges is the need to discuss risks, either from a performance metric, as in the SDG Goals, or to develop risk assessments, as in the case of maritime operations. While most events have a seasonal pattern, these events are not necessarily identified as such. For example, in the National Risk Register, except for volcanos, earthquakes, and tsunamis, the case could be made that the other fifteen variables may possess some seasonal element. Other databases, such as the International Disaster Database and the recent Geocoded Disasters extension, do not include a seasonal element but annualized data.

Part of this could be based on the taxonomies used in disaster management, which can have seasonal and non-seasonal patterns. The PERIL System includes Geophysical, Hydrological, Meteorological, Climatelogocial, Biological, and Extraterrestrial.("IRDR Peril Classification and Hazard Glossary," 2014) Meteorological Hazards, Hydrological Hazards, Geohazards, Environmental Hazards, Chemical Hazards, Biological Hazards, Technical Hazards, and Societal Hazards are the family tree outlined in the SENDAI structure. (Hazard Definition and Classification Review, 2020) While not all events are seasonal, their relationship to climate change may be. Also, this broad view of hazards is based on an event with measurable human loss of life or property; navigation-related disruptions may be "too small" for consideration. Focusing on several metrics concerning metadata about various data sources, Mazin, et al, concluded that no single database covers all information in a manner that may satisfy national/local disaster research needs.(Mazhin et al., 2021)

Building on Mazin, et al.'s criticism of global disaster databases, this study acknowledges a time bias (in this case, annualized information and not seasonal), and an accounting bias, where risks, especially maritime-related, are quantified concerning exposure. However, people respond to "real events" and plan according to their perceived uses, regardless of the risk taxonomy used.

There is no way to decouple navigation actions from other human activities, such as fishing, water supply, agriculture, or ecological management. While waterways are essential, these other activities should be treated not as risks but as events, not all of which are "bad" or result in loss of life or property. Cultural events may draw large crowds but are seen as a net positive from a wellness and economic perspective and are a component of the Sustainability Development Goals for supporting communities.

In any planning assessment, there is a need to classify what to include before any empirical work occurs, as failing to do so may result in ignoring things that may not be "quantified". As such, it may be essential to consider the timing of predictable events to improve communication within a location. Risks can occur anytime and are caused by many factors, such as human error, component failure, or a natural disaster. These events should be documented and included in a risk profile as needed. The challenge is to get agreement on events that are likely to happen, to ensure that communication pre-event, during the event, and post-event occur, and that vessels and facilities can recover. Such information can assist in developing better algorithms for "smart" maritime operations/ports, which may not be able to handle local variations but also for system optimization.

The literature review suggests a lack of structure to categorize local actions within the context of national activities and, by extension, events that may be subject to pressures from changing weather patterns, so there is a need to look at the nature of those changes from a static baseline of traditional Disaster structures.(Wisner & Alcántara-Ayala, 2023) For example, databases/reports will discuss risks and events annually. However, nothing is broken down monthly to assist planners and

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operational decision-makers related to transportation activities, although many of these events may possess a seasonal element.

The challenge is defining what area to study and how to narrow those choices into a more definitive framework that can be used by a single industry, in this case, navigation, in the context of local events that may seasonally influence operations.

There seem to be two parallel but overlapping needs to examine how changing climate influences human activities, which includes navigation. While broad in scope, the focus is on natural disaster response, which comprises both planning and adoption and occurs locally. Nevertheless, climate change and the corresponding need for adoption are one component of the Sustainability Development Goals (Climate Change 13), but the consequences of changing seasonal weather patterns may influence other SDG goals. Conversely, maritime operations treat weather as just one of the many events that may occur.(Figure 1.) The research gap occurs as both areas see the need to address seasonality as a component regarding planning, but neither has a framework for assessing predictable, known events that may occur throughout the year. There are different reasons for this occurrence, but the gap exists.

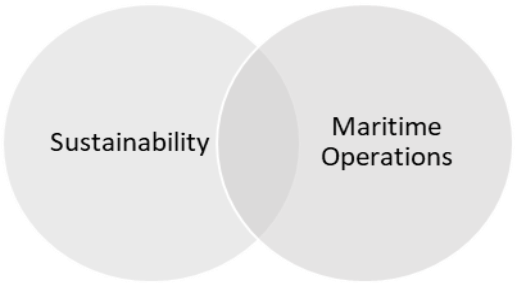

Figure 1. The Gap Between Sustainability and Maritime Operations.

This gap, represented by the middle-shaded area, recognizes that sustainability goals and maritime operations could benefit from baselining predictable, seasonal events. As such, through the development of a Seasonal Event Matrix (SEM), the authors suggest such a framework could provide a starting point for a unified perspective of the predictable events within a specific maritime system that can be linked to some elements of the Sustainability Development Goals.

The authors developed a seasonal event matrix for this study in the United States of Alabama, Louisiana, and Mississippi based on event taxonomies and desktop scans. The second step was to validate this work by receiving input from stakeholders concerning the usefulness of the information for examining seasonal variation in operations.

3. Methodology

The research, recognizing the importance of supporting communication and feedback, provides a framework for combining publicly available information with local knowledge. Based on the earlier work, the paper builds upon the question of known seasonality events.[2] However, as the focus is on developing a hazardous identification process relevant to the four realms, it is essential to start with the traditional Emergency Management Risk concerns and then add elements tied to the other three areas. This structure maintains the broad Emergency Management role, which is expanded to identify specific monitoring and operational needs.[1]

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[1] This approach would be considered a "preassessment" activity as related to the guidance document released by the Cybersecurity and Infrastructure Security Agency. In the guidance, there is

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The broad methodological outline is

1. Define the study area
2. Develop the event categories and data to include in the Seasonal Event Matrix,
3. Populate the SEM with posted information, initially from national sources but supplemented by desktop scans and local knowledge,
4. Validate the information with various regional stakeholders.

3.1. Define the Study Area

The first step is to define the scope and scale of the domain. Risk managers look at broad events that may occur, including events that happen but may not occur in a specific area. For example, earthquakes, snow, wildfires, and tsunamis occur worldwide, but not in all places. A coastal community may have different flooding events than an inland region. While meta-studies focus on specific events over larger geographies, broad events over broad areas require some limitations to prioritize risk considerations. The focus on a single area helps to eliminate the inclusion of things that have limited changes occurring in a region and provides a framework when adding various databases into the work effort and stakeholder engagement.

This study uses the Central Gulf (the U.S. States of Alabama, Louisiana, and Mississippi). The Gulf Coast is classified as a subtropical climate.[4] It has hot, humid summers with mild winters. Due to its location between the Gulf of Mexico and the Continental United States, many boundary fronts move through the Region, especially in the Spring and Summer months. The region also experiences hurricanes in the late summer into the fall.

The Central Gulf is home to some of America's most significant maritime clusters, including six of the Nation's top 15 tonnage ports.[5] There are over 2.3 trillion short tons of cargo moving by barge and ocean-going vessels through the region..[6] The three states have many deepwater and inland ports along significant waterways (Gulf Intercoastal Waterway, Mississippi River, Tennessee-Tombigbee, Black Warrior, and the Red River). According to the U.S. Army Corps of Engineers, there are over 2600 docks and almost 50 locks.[7] It is in the center of the Nation's Energy Corridor, the most significant US Grain export system, but the region is also home to advanced manufacturing in aviation and transportation. As there is a nexus between counties, where most Emergency coordination occurs to waterways, there are 213 Counties and Parishes in the Central Gulf area, providing some diversity regarding estimating more localized events.

3.2. Define the Risks/Events to Include in the SEM

The next step is to develop a regional event category hierarchy. So, once the study area was determined, the SEM requires examining seasonality to predict known risks. [2]There appears to be no definite structure concerning classifying risks, primarily based on predictable (seasonal) probability. For example, high water conditions generally occur in the Spring for inland waterways. However, some waterways experience high water conditions due to rain events in coastal areas due to storm surges. As such, seasonality is related to many elements, which assist in identifying the risk and the potential source of forecast knowledge of an event, such as weather forecasts. While annual data or

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framework concerning how to identify a marine system and /or terminal and the some resources concerning information related to assessing risks. [3]

[2]This paper talks about predictability, which this paper is defined as the season upon which an event may occur, or a general understanding of when an event will occur. It is not defined as a statical probability, which for this paper is a quantified estimation that an event will occur. In some ways, probability may be considered changeable, based on the appropriate timeframe, such as the probability that something will occur over the course of a year, or the probability that an event will occur within the next week, are much different. Oftentimes, this concept of annualized probability ignores the ability to the potential known timing of these events.

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other general information is available, the lack of a time definition does not address the risk's actual "cost/effect" or the potential for an event to become multi-hazard if other independent events occur simultaneously.

The initial focus is the development of an event profile based on nationally available statistics. In Appendix Table A1, the National Risk Index, produced by the Federal Emergency Management Agency, lists eighteen natural hazards at a county level.[8] As expected, some natural hazards, such as avalanches and volcanic activity, are not likely to occur in the study area. While the model estimates annual risk, for this purpose, the focus is on the events likely to occur over a year, so the annualized information needs to be disaggregated seasonally. [3]

For this paper, eight categories were developed based on their linkages to known, seasonally occurring events[4].

Ecological: Events that occur naturally, from migratory animals to other regulations or permits that mitigate the potential for biological risk or ecological degradation. The challenge with this structure is one of definition. Hydro-sociology lists human engagement as related to water resources, but there is no clear distinction concerning how to organize and consider water resource management.[9,10] This can also be applied to other items, such as diseases or pathogens. Also, there is a discussion about biological as a pathogen framework or health risks, such as by the United Nations Office for Disaster Risk Reduction, so it would be considered a subset of the ecological system.[11] However, this term also includes the role of ecological stewardship, where restrictions can limit operations to protect ecologically sensitive areas, such as bird rookeries or marine mammals. [5] However, there are several studies linking climate change to ecological changes.[12,13]. This is group most tied to the various United Nationsl Sustainability Goals related to SDG 13, Climate Change.

Cultural: Regionally celebrated events or during their celebration may influence landside or waterway access. Culture includes other human activities influencing maritime operations, such as kayaking or fishing tournaments. These are not considered risks in the traditional event planning framework but have implications for managing crowded spaces and deploying if an event should arise. Tied to SDG 1, 11, 12

Fluvial: Events determined by water movement, such as river flooding, currents, sediment transport, or other factors that influence the condition of waterways and channels. Some of these, such as flooding, are generally considered in most disaster management groupings, although they ignore the implications of navigation. Thus, a separate group was created, but it is represented by several studies related to navigation risks to water.. André Robert's "River Processes" is an excellent resource regarding how fluvial systems work.[14] These are tied to SDG 13,

Geotechnical: Events related to land structures, such as landslides or avalanches, could be tied to seasonally related events. [6] While usually not associated with navigation risks, landsides, especially in island communities, can have significant disruptions, such as in Southeast Alaska.[15,16] Landslides may be seasonal, driven by precipitation, soil conditions, and temperature, and

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[3] Other events, such as terrorist attacks, active shooters, but also component failure, such as pipeline rupture, reflect an uncertainty that may not necessarily have a seasonal element.

[4] The events are also classified by the predominant Three E's of Sustainability: Economics, Equity and Environmental. Those topics are discussed elsewhere.[2] The list of all events, categorized by their initial Realm of responsibility is listed in the Appendix Table 3. As with any classification, there may be differences concerning why things more in certain areas, but the focus of this risk is tied to both the nature of the event and a perception concerning where the risk notification and communication will start the response process.

[5] This elements will often be included in environmental assessment reports.

[6] Based on the National Risk Index there are avalanche risks in the region, but there are landslide risks. However, the author was not able to determine a causal relationship between seasonality and landslide events in the region.

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forecasting tools have improved, but challenges remain regarding warning and near-time prediction.[17,18] tied more to SDG 13, as not predictable events

Maritime: Events related to maritime operations, such as cargo, fishing, recreational boating, ferry operations, or other users that depend on access to maritime activities. This maritime category may also include planned military operations or exercises. Again, there are two main areas of research: the assessment of generalized risks, [19–21], or more specific risks based on either specific cargo types, such as containers, [22,23] or regional operations, such as the Arctic.[24,25] Generally, these treat ongoing operations as having specific events but do not consider other users or cargo peaks as predictable. One could argue that technology and other events can improve terminal operations. However, there may be concerns over mitigating peak traffic demand through a terminal, such as in bulk terminals.[26] It is also not uncommon for vessel operations to be restricted to one-way or daylight-only operations for safety reasons due to various factors, which can restrict "traffic" but does not necessarily close a port or waterway. Tied to SDG 9

Metrological: Events shaped by weather conditions, such as wind or hail. (For most natural disaster events, these elements list various weather events. Generally, weather patterns are well known, but despite this knowledge, it remains a constant challenge to address perception, storms, temperatures, and other related events or even prepare for an incoming storm system. Nevertheless, the Weather is the Weather. Tied to SDG 9

Non-Seasonal Natural Events: Natural events outside of a predictability pattern may have significant disruptions when they occur, such as earthquakes or volcanic activity. Tied to SDG 12 comunites and equity.

Other Events: These events occur but are not predictable, such as an oil spill, active shooter, or space debris in any seasonal structure, but are generally caused by human activities. The Other Events category provides a placeholder for these events but is not included in their diversity and breadth of scope. Also, some of these activities are exclusively within a particular realm, so their inclusion here may not be warranted. However, these elements were not included in the SEM due to their inability to be categorized as seasonal events based on the NOAA Storms or National Risk Index databases. As such, these elements can influce varius events, such as SDG 14, etc.

Finally, based on the authors' experiences and the literature, these categories were overlaid with a corresponding element regarding closures. For example, the port is closed when some events, such as a hurricane, occur.[27] Other events, such as fireworks, may partially close the river for a few hours[28]. That does not mean the whole port region shut down; it is simply the designated fireworks area. Also, Mardi Gras (Carnival) is a significant culture event, and while navigation continues, there may be localized congestion, leading to traffic delays. Other events, such as termite swarms, are annoying but do not necessarily close operations down. Thus, the authors estimated three categories regarding closures: full closure, partial closure/restrictions (waterway or landside), or likely limited or no restrictions on commercial freight movement. These three categories are based on the authors' own experiences. Few events shut down an entire port complex, as water-related activities do not mean landside activities can not occur, or the opposite, where a terminal may be closed, but the waterway and other facilities can still be serviced by marine traffic. Finally, there appeared to be no definition of what constitutes a partial or full/complete closure or disruption, although there are plenty of lists of related risks in the maritime domain, but ultimately, disruptions are dependent upon the risk tolerance of the affected parties.

These categories helped consider what events should be added to the SEM structure. Including cultural or environmental regulations in the context of events, and not necessarily risks, was an important engagement tool for local stakeholders. The anticipation was that they did not see these events as risks, but they did see where they could influence their business operations and the interaction among different events over the year.

3.3. Develop and Populate the SEM Model

The third step is to populate the matrix based on readily accessible databases, focusing initially on weather events, to be supplemented with the other data elements through a desktop scan. There

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are two main focus areas: national risks and local events, each requiring a different data processing approach, but before any events were included, a basic regional framework was developed. The work was put into Excel, expecting that users would not require additional software to use the SEM, nor was there assumed to be a prohibitive learning curve for users who wish to modify the current information.[7]

National Risks

The initial integration step was linking the National Risk Index with the U.S. Army Corps Master Docks Plus database. This data join effort provided a framework for integrating a baseline of information on navigation systems, such as waterways, docks, locks and dams, and where commercial navigation occurs. The National Risk Index included all counties and parishes in the region, but only the county and the events were included for this purpose. Finally, areas identified as coastal zones were identified based on the respective State coastal zone plan.

Weather is reported on a monthly matrix at a location, with record temperatures and precipitation posted.[29] Such graphs provide basic climate information regarding temperature or rain events, t but does not present all the weather-related events that may occur, such as the type of precipitation, the duration and severity of a storm, or other information. Such information needs to be supplemented with other data sources. The question is where one finds other information. The NOAA Storm Database was used to examine these elements to develop a seasonal estimate for each county/parish in the study area, as it reports information monthly and at a county level. The information can provide a means to organize a baseline climate event profile. The Storms Database uses the following definitions related to weather activities[30]. "An Episode is an entire storm system and can contain many events." An Event is an individual type of storm event." (Thunderstorm Wind, Hail, Tornado, and Flood are events). However, there are some concerns about using the data as a quantitative source.[31] For some elements, the actual County FIPS reported events occurring in different counties/parishes, such as coastal flooding in Northern Louisiana, or an event is reported at the discretion of the local weather service station. So, the data can provide a good proxy of regional activities, but there were some allowances in the SEM based on these classifications. Nevertheless, the information helps examine seasonal weather events at a county level across the region and is so.

The monthly summary for the three states between 2006-2022 shows that most of these events follow a seasonal pattern.(Appendix Table A2) Spring into Summer is when most storm-related episodes and events occur, but strong storms and tornados happen year-round. Some elements were dropped from the metrological category, such as seiches, which were so infrequently reported that it was unclear how to validate their occurrence. Also, drought is an accumulated lack of rain and can affect water levels. However, due to the region's ordinarily heavy precipitation, droughts are different than in other places, making them hard to quantify on a seasonal basis, especially as droughts may span multiple months and occur in seasons of heavy rainfall.[32] Finally, the authors could not find a consistent regional database that reported river stages monthly at a county level, so they estimated these based on generalized knowledge.[8] The National Risk Index items were thus

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[7] SEM summarizes the raw data into an Excel Pivot Table that users can manipulate.7 The Columns reflect months when an event will likely happen if it did occur, while events that have no discernable month are listed as non-seasonal. A "notes column" allows users to retain information on particular activities not included in the pivot table. The structure was deemed the easiest to maintain/revise and did not require additional software.

[8] There are several data sources on water conditions, such as the National Weather Service on flood conditions [33,34]. For example, the Mobile District of the U.S. Army Corps of Engineers lists many resources related to monitoring water to support navigation.[35] As such, riverine flooding was listed as non-seasonal as it can happen year round.

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disaggregated by month to develop the national-level weather-related SEM, but some elements, such as earthquakes, remain in the database but are listed as non-seasonal.

Localized Events

The authors conducted a desktop scan to supplement the national data with local information and identified additional seasonal risks.[9] For example, fog is an issue for regional navigation. Fog data were not listed for Louisiana in the Storms database, but it is a concern.[36] Other known events were added to provide additional elements of system events that may influence operations seasonally. These are listed below in Table 1 and came from various sources, such as local emergency responders and discussions with stakeholders.[10]

Table 1. Review of other Categories/Events that Occur in the Region Not Reported in the National Risk Index (Source: Authors).

Category	Event	Notes	Seasonality	Source
Ecological	Flighted Spongy Month Complex	Vessels arriving from the Far East must be inspected for egg masses to prevent	May to October	[37,38,38]
Ecological	Termite Swarms	Terminates can cause considerable damage, but often that damage is observed after the "swam" occurs. The swarms are very annoying to workers doing work outside at night. Generally, the swarms occur along and south of the I-10 corridor.	May	[39]
Ecological	Wildfire	Wildfires occur throughout the region, but swamp fires can lead to heavy smoke. A swamp fire combined with heavy fog led to a significant traffic incident in the greater New Orleans area.[40]	Typically from fall into Spring, although they may occur year-round	[41,42]
Cultural	Christmas Bonfires	Bonfires are lit along the river to "guide Poppa Noel" to visit Children on Christmas Eve. There is localized congestion.	Christmas	(*Festival of the Bonfires – Cajun Style*)
Cultural	Fireworks	Limited Fireworks in downtown New Orleans. The Coast Guard provides notifications through the Federal Register.	The Mississippi River by Jackson Square is closed for fireworks on the 4th of July and New Year's Eve.	([44]

[9] In some ways, these localized events could be considered as a result, but were listed here, due to the mix of desktop scan and feedback during the development process.

[10] Table 1 was structured to serve as a repository for additional events that may be added to the SEM Model to maintain a log of the source of the event.

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Cultural	Mardi Gras	Carnival Season begins on January 6 and extends to Mardi Gras (Fat Tuesday). While the navigation and transportation systems continue to operate, traffic will be heavy by parade routes, and hotel space will be limited also.	January -March	Local Knowledge[45,46]
Cultural	Unauthorized Fires	Fires are set in unauthorized areas, leading to fires at various piers along the river.	December -March	Interview with New Orleans Fireboat Captain
Maritime Operations	Saltwater Silt Construction	Occasionally, low water periods allow saltwater to come up the Mississippi River, which can damage drinking water access. The Corps of Engineers is responsible for mitigating this, typically by building a saltwater dam in the river.	June	[47]
Fluvial	Low Water	The Mississippi River drains the Central U.S., and water levels are predicated on snow melt and precipitation events. Traditionally, the fall is the low water period. Other waterways may be influenced by coastal or rain events.	Fall	[48–50]
Fluvial	High Water	Traditionally, Spring is the high-water period in the Mississippi River. Other waterways may be influenced by coastal or rain events.	Spring	Local Knowledge
Fluvial	Lock Inspections	The Corps is responsible for locks and dams on federal waterways. Usually, locks are inspected during low water conditions.	Low water periods – the elements listed here are placeholders, as the United States Corps of Engineers (USACE) notifies partiers concerning any expected/unplanned facility closures/closures	[51]
Maritime	Inbound Containers	Containerized inbound shipments arrive in anticipation of the Holiday shopping season.	The holiday rush typically occurs in August and ends in the first week of December.	US Trade Information [52]

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Maritime	Ferry	There are several ferry services in the State of Louisiana, operated mainly by the LA Department of Transportation. However, there are execution ferries to Ship Island in Mississippi and a ferry in Alabama.	Year-round, except for the Ship Island Ferry, which runs from March to October	[53–55]
Maritime	Grain Shipments	Mississippi River is one of the Nation's grain export corridors. Shipments by barge and train arrive at the end of the harvest and are shipped out of the port.	September – February	US Trade Information [52]
Maritime	Vessel Cruise	Ocean-going Vessel Cruise	Year-round in New Orleans, but seasonal in Mobile	Resources from the City of Mobile and the Port of New Orleans[56,57]
Maritime	Dinner Cruises	Local dinner and excursion vessels	The New Orleans Steamboat Company and the Creole Queen run two services	[58,59]
Maritime	River Cruises	Inland Shallow draft vessels	Year Round south of St. Louis	[60]
Maritime	Military Cargo	Ports dedicated to supporting Military operations through the National Ports Readiness Network	Year-round	[61]
Metrological	Marine Fog	Marine Fog is caused by warm air moving over colder water, resulting in advection fog.	Typically, it starts in late fall and ends in early Spring	[62–64]

Stakeholder Engagement

The final step is to solicit stakeholder review. The authors identified stakeholders to review this, which included various federal agencies (U.S. Army Corps of Engineers, the U.S. Coast Guard, the National Oceanic and Atmospheric Administration), the region's ports, several trade associations, and other local maritime specialists. It was stressed that this work is more exploratory and not a specific guidance or recommendation. The authors met with various groups to solicit their comments and concerns, some of which were added as events within the SEM model.

4. Results

The goal is to develop a single monthly matrix for all users to understand their expectations concerning access and usage of the waterways. So, the first question is, does seasonality matter? While the region has hot, humid summers and mild winters, there are changes due to metrological events. However, many events occur monthly throughout the region due to water levels and cultural events. Finally, an event does not necessarily mean a full or partial maritime system closure, as the incident may only pertain to a specific terminal or waterway segment.

The second question is whether the matrix presents the information in an easy-to-understand format. The balance remains on capturing this knowledge while not penalizing the lack of exactness nor diminishing the ability to communicate the seasonal nature of a waterway system to

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inexperienced staff or non-maritime stakeholders interested in understanding regional risks. Thus, the monthly matrix is designed for non-specialists but should also be relevant to the maritime operator.

The final table of the initial categories and events of the SEM for the States of Alabama, Louisiana, and Mississippi is shown in Figure 6. As expected, these natural disasters are represented, but local knowledge also shows a broader overview of generalized risks/events within the three states. Users can manipulate the data by selecting specific counties/parishes, waterways, navigation, and coastal systems. As expected, Meteorological events occur in every county/parish, but from an event matrix, 101 counties or parishes have navigation activities as reported by the USACE.[7]

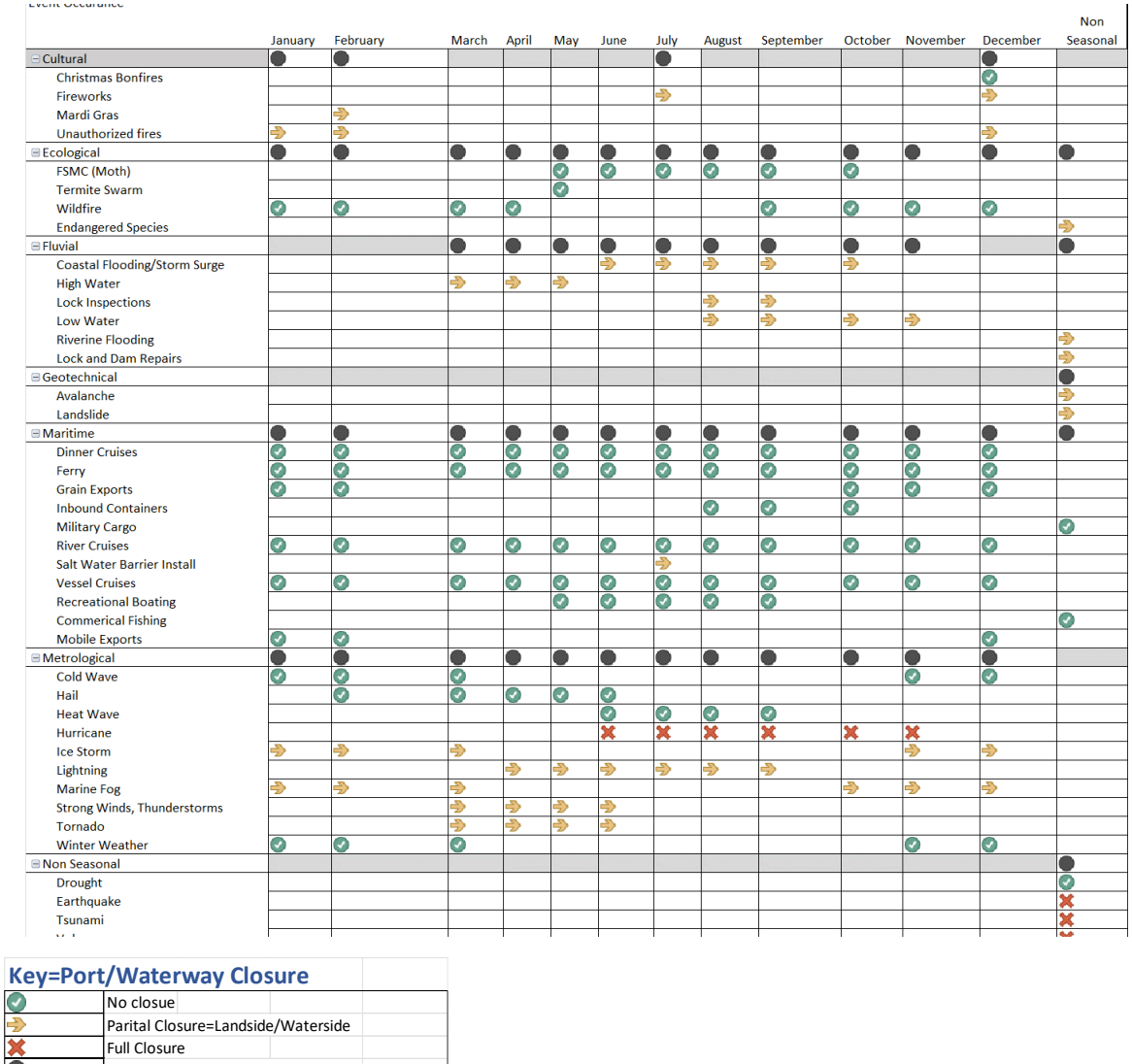

Figure 6. Monthly Matrix of FEMA and NOAA Storms Database and Other Datasets Integration.

To test the usefulness of this SEM approach, the authors recognized the need to evaluate the difference between two port areas within the region. Two different counties/parishes were considered: Orleans Parish, Louisiana, and Warren County, Mississippi.(A SEM output for Mobile County, Alabama, was outlined elsewhere.[2]) Orleans Parish ranks as one of the U.S.'s top tonnage ports. It handles a mix of breakbulk (steel, rubber, metals, and coffee), project cargo, containers, and bulk products through 118 publicly and privately owned docks and terminals.[7] There are over 380,000 residents in 2020, according to the U.S. Census. Warren County is located roughly 300 miles upstream along the Mississippi River, home of the Port of Vicksburg, with a population of 44,700.[65] The port handles a mix of bulk and break-bulk products, such as metals, alumina ores, wood pallets, grains, and fertilizer, through the 36 docks reported in the county. Both ports handle barge services, but the

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Orleans Parish services ocean-going vessels. As such, Orleans Parish gets exposure to both coastal activities and events specific to deep-sea navigation. Warren County, located further north, will experience the same broad regional weather events but not the same marine-related risks due to its navigation sector and infrastructure.[11] The SEM results for New Orleans are shown in Figure 7.

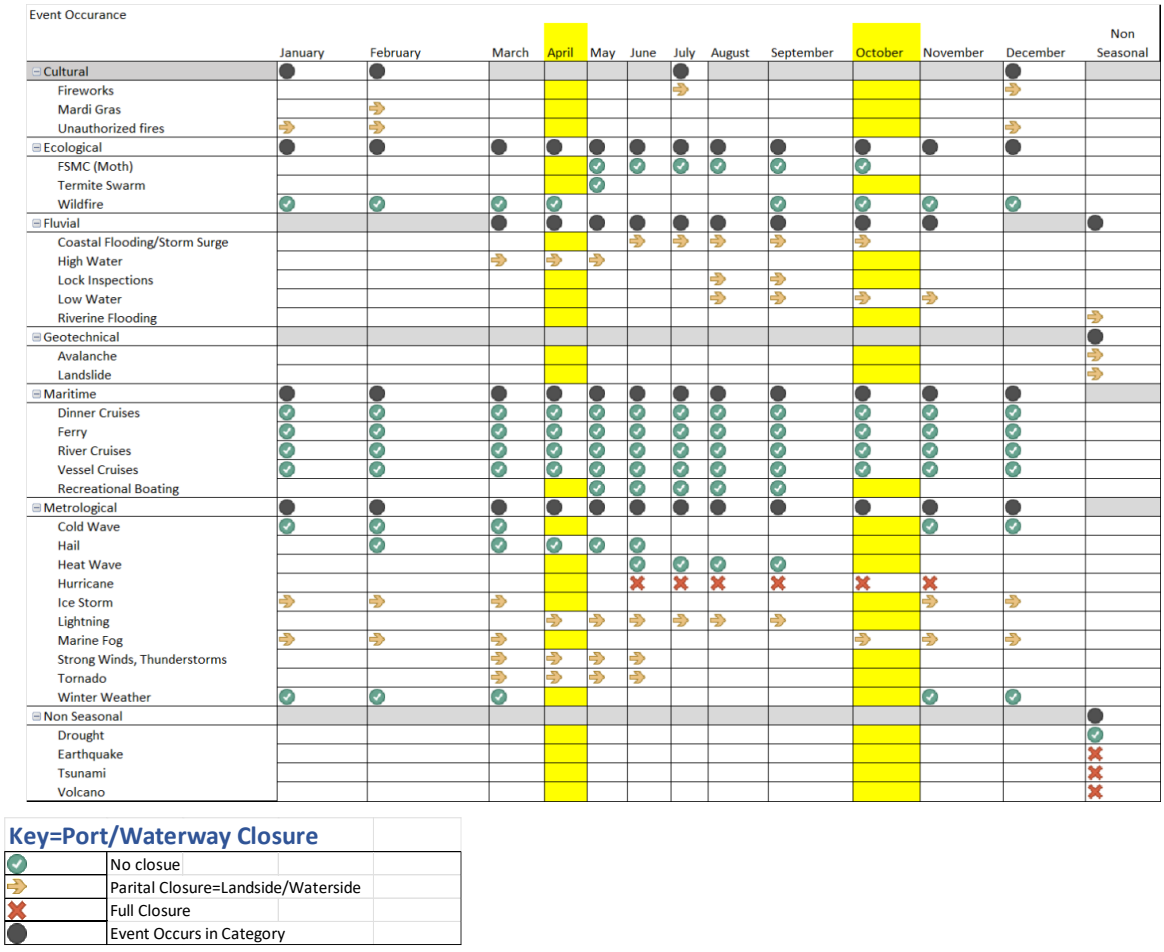

Figure 7. Orleans Parish, Louisiana Initial SEM.

If one made a cursory comparison between April and October (the highlighted areas), one would see a much different seasonally influenced river. April is typically a high-water season with seasonal thunderstorms, but in October, while there is Hurricane season and potential marine fog, there are fewer seasonal thunderstorms. The cargo is different, as the grain season starts as grain moves down the river by barge. The U.S. Army Corps does most of its "in-water" inspections and repairs during low-water periods. These tables were shown to the respective regional stakeholders for validation.

Warren County, Mississippi, has fewer natural disaster risks due to its inland location (Figure 8). As with Orleans Parish, it does experience similar metrological events, such as thunderstorms and winds, but there are no coastal-related risks. However, as Warren County sits along the Mississippi River, its maritime community does respond to the exact change in seasonal water levels, and its docks and terminals are constructed to manage the changes in water levels. Moreover, like Orleans Parish, some changes occur when one compares April to October, primarily due to water levels and other potential national disasters.

[11] As one of the authors lives in the greater New Orleans Area, there is a bias towards more information on the lower Mississippi River then in other regions.

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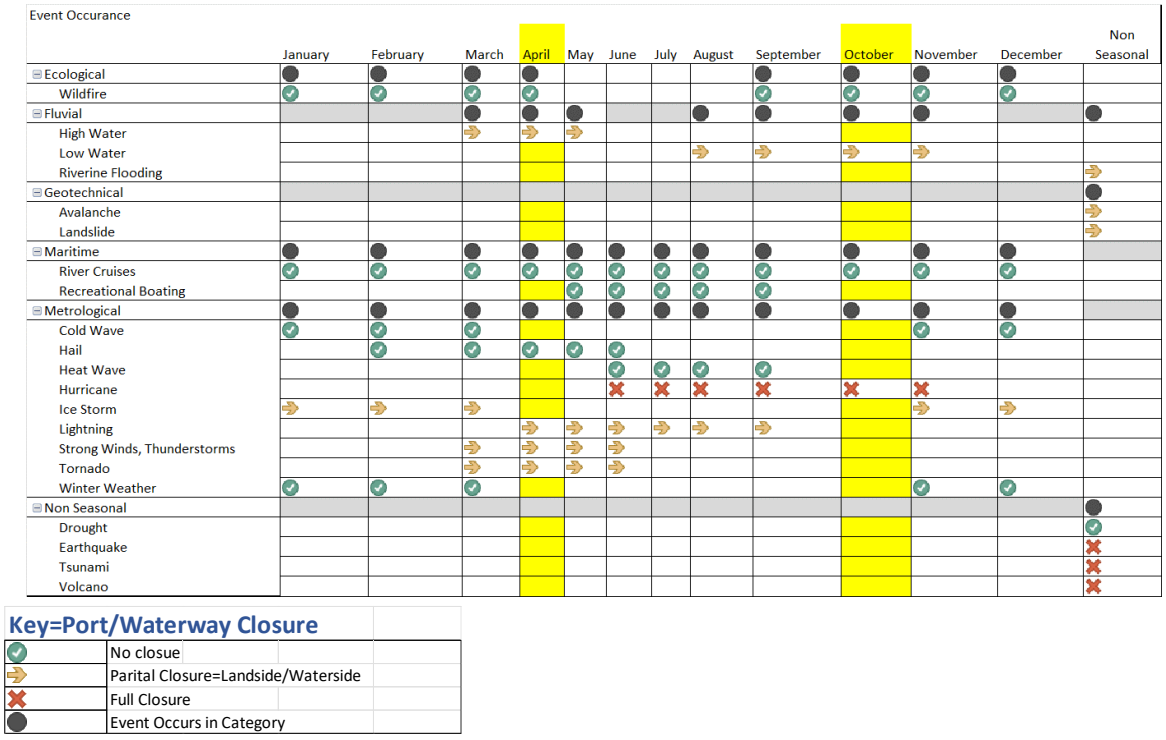

Figure 8. Warren County, Initial SEM.

Stakeholder Review

SEM outputs were shared with regional stakeholders, who, once briefed on the SEM structure, recognized its ability to organize some awareness of seasonal events.[12] They also recognized its usefulness in framing risks. These risks are often not considered at a national level but are important locally and as a training tool for inexperienced staff moving into the area. There were concerns over maintaining such a table, as well as how to share the information with other stakeholders. The general viewpoint by federal officials was practical, especially as related to training unfamiliar staff, while the non-federal officials saw the SEM as helpful in engaging non-local ship agents and beneficial cargo owners. Both groups appreciated having a framework for looking at regional events beyond their traditional planning calendars that incorporated other elements considered "external" to their specific operations. It was also stressed that their feedback was not "an official" support of this SEM by themselves or their organizations.

In conclusion, one should review this framework as a planning tool incorporating nationalized information on seasonal events and supplemented by localized knowledge. The potential for cascading and unrelated events exists, in addition to quantifying small events, which may be treated as simply the cost of doing business. For example, heavy fog may result in a vessel remaining at the dock, resulting in additional fees for dockage. There is no significant loss if no one moves, but moving in heavy fog conditions can lead to damage/loss to vessels, docks, or staff. Other elements, while small, are only observable when there is a failure. In all cases, each can disrupt operations. However, the relationships of the four realms can vary due to the nature of the event itself and the ability of various groups to understand the "normalization" of an event into a predictable structure. While not focusing on primary data collection and a specific, quantifiable element, the focus on identifying what elements could be included in a risk assessment is worthwhile.

[12] Discussions with Trade Associations, Pilots, Weather Service forecasters, Ports, and Federal Agencies were conducted throughout 2023 and early 2024.

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5. Discussion

There is a need to consider risks and uncertainties, but knowing what to evaluate is as essential as the actual monitoring itself. The adage "forewarned is forearmed" is relevant when mitigating risks, as a small amount of knowledge can be helpful. One of the challenges is that there appears to be no structured approach to classify known, predictable events at a localized level to assess risks and how to manage that response. There remains a need to collect and share information to provide a framework for disaster management to meet the UN Sustainability Development Goals. However, as most goals are reported on an annual data, and normally report deaths, they may not be appropriate for looking at other events, which have other data collection challenges.

Also, not all data elements will come from publicly available information on risk events. For example, how does one quantify events like Mardi Gras or Christmas fires along the waterfront? The focus is collecting information on known things that may occur, including non-statistical information. The use of the SEM model lies in its simplicity, where robust climatological data can be integrated with other, less qualitative data to form a basic structure to consider seasonally determined risks at a localized level. If SEM estimates are developed across broad regions, in this case, the Central Gulf, the same could be expanded to more significant regions, such as at a national level. However, that may also require a reexamination of the metrological data used in this report to align risks at a local level better. As such, the SEM could provide a basis for more scenario-based risk frameworks, which can alleviate component-based risk estimations that are typically estimated.[66] Also, some of these ecological events could be gleaned from other documents related to environmental impact assessments or statutory documentation required to secure specific permits. Regarding Climate Change, the nature of seasons may change as stationary assumptions about weather patterns may be in flux, so baselining against operational changes may be an additional study area. In this regard, the SEM model may help link broader discussions about climate adoption and resiliency.

But the SEM may be extended to other industries, as there may exist a need for such a framework beyond waterways. Several studies on airport conditions suggest such a framework may be beneficial when looking at regional airport networks, as each discussed weather conditions but never attempted to classify them into a single matrix that accounted for the totality of delays mentioned by Kulesa.(Algarin Ballesteros & Hitchens, 2018; Ismail Gultepe, 2023; Lopez, 2016) Weather conditions or other industry studies influence highway and rail transportation, so the framework can be applied to any entity with a domain awareness role if the focus is on known risks but not specific probabilistic risk assessments.

SEM provides a foundational piece to link these groups to discuss these unique structures, but at best, it will remain a small part of any specific dialogue., as the rest of the SENDAI report highlights. As simple as this sounds, the information is not easily accessible or summarized in a manner that can be used to develop such a matrix. The goal of the SEM is ultimately one of communication, especially in the communication necessary to discuss the nature of risk events across diverse stakeholders. However, seasonal focus could be integrated with other risk formulas, such as equations that add predictability as another quantifiable variable.

Using SEM to organize predictable risks may be criticized as too simplistic or not contributing to primary research. However, the matrix's focus is not on creating new knowledge but on determining how to integrate existing knowledge to assist in managing risk awareness, in this case, for the maritime system in the Central Gulf. With the potential for simultaneous events to occur, which may influence a response posture, or from non-specialists overstating a risk event without local knowledge, the SEM may fill that knowledge gap and assist in addressing the SDG 17 Goal of improving collabration

6. Conclusion

Concerns over climate change has led to the adoption of 17 Sustainability Goals by the United Nation. Within that structure are concerns over how natural disasters will shape the world, given concerns over emissions, sea-level risk, and exposure to weather events. During the same period, there has been a n increased focus on understanding disaster-related risk, especially regarding the

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maritime sector. Understanding the nature of risks, which range from catastrophic events to manageable "annoyances", may not necessarily consider the predictability of the possible timing of an event.

Navigation is one of many industries with predictable, seasonal elements, ranging from storms, changing water levels, regulatory restrictions, and diverse cargo seasons. While these seasonal events are known, there is a lack of a basic framework to examine them despite the amount of available data and localized knowledge. This paper attempted to fill that gap by developing the Seasonal Event Matrix to integrate the awareness of locally predictable events with other natural disasters and to link navigation risk to the United Nations's Sustainability Development Goals. The SEM Framework is not designed to capture all events or provide localized probabilities regarding risk assessment, especially as not all events can be quantified, but they can be categorized.

The paper sought to develop a framework to provide a basis for communicating predictable risks within a maritime system. The structure allows events to be collected, ranging from disasters to ongoing maintenance and regulatory activities to minor events, without any judgment concerning their duration or severity. The comparison between Warren County, Mississippi, and Orleans Parish, Louisiana, showed how local knowledge gaps exist, even in relatively similar regions, so relying on "normalized" risk assessments may not be adequate.

The Seasonal Event Matrix sought if a framework for groups to examine traditional disaster elements and localized events could be developed based on a mixed data method of integrating existing databases with localized knowledge. The work showed that such a framework is possible. Using the Central Gulf Region as an example, seasonality concerns do vary. While not every event is "a disaster", users could understand the local details when engaging in regional planning activities, especially when communicating known risks, including hurricanes, water levels, and cultural events.

Supplementary Materials: The following supporting information can be downloaded at the website of this paper posted on Preprints.org.

Appendix A

Table A1. List of Hazards listed in the National Risk Index., Source National Risk Index.

Hazard Type	Definition in National Registry
Avalanche	An Avalanche is a mass of snow in swift motion traveling down a mountainside
Coastal Flooding	Coastal Flooding is when water inundates or covers normally dry coastal land as a result of high or rising tides or storm surges.
Cold Wave	A Cold Wave is a rapid fall in temperature within 24 hours and extreme low temperatures for an extended period. The temperatures classified as a Cold Wave are dependent on the location and defined by the local NWS weather forecast office.
Drought	A Drought is a deficiency of precipitation over an extended period of time resulting in a water shortage.
Earthquake	An Earthquake is a shaking of the earth's surface by energy waves emitted by slowly moving tectonic plates overcoming friction with one another underneath the earth's surface.
Hail	Hail is a form of precipitation that occurs during thunderstorms when raindrops, in extremely cold areas of the atmosphere, freeze into balls of ice before falling towards the earth's surface.
Heat Wave	A Heat Wave is a period of abnormally and uncomfortably hot and unusually humid weather typically lasting two or more days with temperatures outside the historical averages for a given area. The temperatures classified as a Heat Wave are dependent on the location and defined by the local NWS weather forecast office.

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Hurricane	A Hurricane is a tropical cyclone or localized, low-pressure weather system that has organized thunderstorms but no front (a boundary separating two air masses of different densities) and maximum sustained winds of at least 74 miles per hour (mph). The Hurricane data also include tropical storms for which wind speeds range from 39 to 74 mph.
Ice Storm	An Ice Storm is a freezing rain situation (rain that freezes on surface contact) with significant ice accumulations of 0.25 inches or greater.
Landslide	A Landslide is the movement of a mass of rock, debris, or earth down a slope.
Lightning	Lightning is a visible electrical discharge or spark of electricity in the atmosphere between clouds, the air, and/or the ground often produced by a thunderstorm.
Riverine Flooding	Riverine Flooding is when streams and rivers exceed the capacity of their natural or constructed channels to accommodate water flow and water overflows the banks, spilling into adjacent low-lying, dry land.
Strong Wind	Strong Wind consists of damaging winds, often originating from thunderstorms, that are classified as exceeding 58 mph.
Tornado	A Tornado is a narrow, violently rotating column of air that extends from the base of a thunderstorm to the ground and is visible only if it forms a condensation funnel made up of water droplets, dust, and debris.
Tsunami	A Tsunami is a wave or series of waves generated by an earthquake, landslide, volcanic eruption, or even a large meteor hitting the ocean and causing a rise or mounding of water at the ocean surface. A Tsunami can travel across the open ocean at about 500 mph and slow down to about 30 mph as it approaches land, causing it to grow significantly in height.
Volcanic Activity	Volcanic Activity occurs via vents that act as a conduit between the Earth's surface and inner layers, and erupt gas, molten rock, and volcanic ash when gas pressure and buoyancy drive molten rock upward and through zones of weakness in the Earth's crust.
Wildfire	A Wildfire is an unplanned fire burning in natural or wildland areas, such as forest, shrub lands, grasslands, or prairies.
Winter Weather	Winter Weather consists of winter storm events in which the main types of precipitation are snow, sleet, or freezing rain.

Table A2. Summary of Episodes and Events for Alabama, Louisiana, and Mississippi, 2006-2022. Source NOAA Storms Database.

	ALABAMA		LOUISIANA		MISSISSIPPI		Total	
Row Labels	**Count of Episode Id**	**Count of Event ID**	**Count of Episode Id**	**Count of Event ID**	**Count of Episode Id**	**Count of Event ID**	**Count of Episode Id**	**Count of Event ID**
Astronomical Low Tide			45	163	1	1	46	164
Coastal Flood	10	22	20	61	11	14	41	97
Cold/Wind Chill	12	138	8	99	6	77	26	314
Debris Flow	5	5			1	1	6	6
Dense Fog	4	4	5	5	2	2	11	11
Drought	232	2,096	87	682	87	870	406	3,648
Dust Devil	6	6	2	2			8	8
Excessive Heat	18	48	32	199	27	358	77	605
Extreme Cold/Wind Chill	4	24	3	6	2	23	9	53
Flash Flood	533	1,715	458	1,595	596	2,351	1,587	5,661

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Flood	111	380	121	205	63	158	295	743
Freezing Fog	5	19					5	19
Frost/Freeze	49	477			2	22	51	499
Funnel Cloud	78	121	79	105	52	63	209	289
Hail	905	3,183	725	2,090	856	3458	2486	8,731
Heat	80	526	74	748	52	781	206	2,055
Heavy Rain	105	185	59	118	48	80	212	383
Heavy Snow	34	213	16	113	23	338	73	664
High Surf	4	4					4	4
High Wind	30	78	12	35	11	66	53	179
Hurricane	2	7	6	69	3	11	11	87
Hurricane (Typhoon)			5	72	1	8	6	80
Ice Storm	10	65	14	82	19	162	43	309
Lightning	281	363	180	210	192	238	653	811
Rip Current	36	41	2	2			38	43
Seiche			2	5			2	5
Sleet	4	22	5	32	9	90	18	144
Storm Surge/Tide	12	38	22	174	14	39	48	251
Strong Wind	95	287	54	100	160	377	309	764
Thunderstorm Wind	1,703	9,709	1,301	4,499	1,440	8,419	4,444	22,627
Tornado	356	1,379	357	958	333	1,384	1,046	3,721
Tropical Depression	6	91	3	33	7	40	16	164
Tropical Storm	24	149	36	343	26	131	86	623
Wildfire	8	9	16	18	1	1	25	28
Winter Storm	19	198	20	165	28	290	67	653
Winter Weather	89	480	61	392	75	463	225	1,335
Grand Total	**4,870**	**22,082**	**3,830**	**13,380**	**4,148**	**20,316**	**12,848**	**55,778**

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Table A3. Seasonal Event Matrix Categories, Sorted by the 4 Realms and Sustainability Categories.

Seasonal Event Matrix - Event Categories

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There is no probability assigned to the event occurring within a single month.
Events listed here meet one of three conditions - the event peaks during this time of year or occurs during this time of year.

Non-Seasonal - Elements that should be noted as important, but have no seasonal element that can influnce its predictabilty

Realm

- Emergency Management Realm
- Domain Awareness
- Business Continitiy
- Supply Chain/Logistics

Event Occurance

	Cultural	Ecological	Fluvial	Geotechnical	Maritime	Metrological	Non Seasonal
Economic					●		
Dinner Cruises					▲		
Grain Exports					▲		
Inbound Containers					▲		
Military Cargo					▲		
River Cruises					▲		
Vessel Cruises					▲		
Commerical Fishing					▲		
Mobile Exports					▲		
Enviromental		●	●	●		●	●
Coastal Flooding/Storm Surge			⚑				
Cold Wave						⚑	
Drought							⚑
Earthquake							⚑
Hail						⚑	
Heat Wave						⚑	
High Water			▲				
Hurricane						⚑	
Ice Storm						⚑	
Landslide				⚑			
Lightning						⚑	
Lock Inspections			▲				
Low Water			▲				
Marine Fog						■	
Riverine Flooding			⚑				
Strong Winds, Thunderstorms						⚑	
Termite Swarm		▲					
Tornado						⚑	
Tsunami							⚑
Volcano							⚑
Wildfire		⚑					
Winter Weather						⚑	
Equity	●	●	●		●		
Christmas Bonfires	▲						
Ferry					▲		
Fireworks	■						
FSMC (Moth)		●					
Mardi Gras	■						
Salt Water Barrier Install					▲		
Unauthorized fires	▲						
Recreational Boating					■		
Lock and Dam Repairs			■				
Endangered Species		■					

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