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A Value-Focused Thinking Approach to Assessing Container on Barge Readiness within Maritime Transportation Systems

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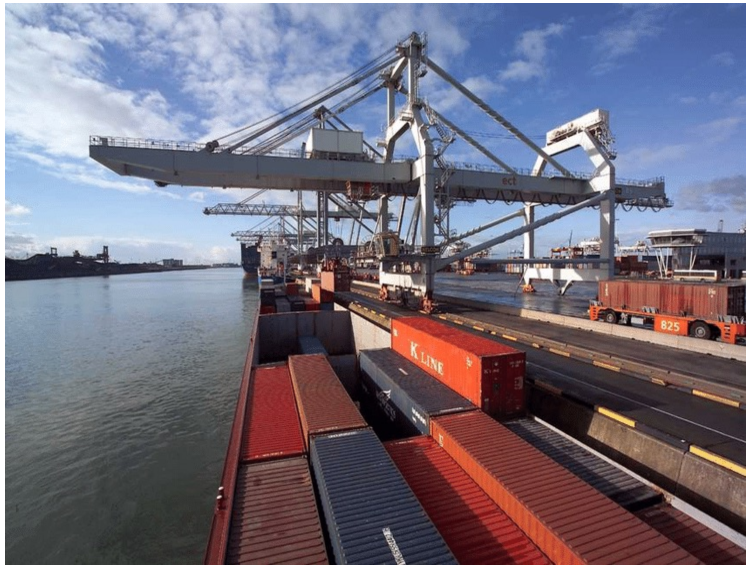
Outline

- System Background
- Research Objectives & Methodological Approach
- Summarized Results
- System Impacts



System Background

Maritime Transportation System

- Provides safe, reliable, efficient, effective and environmentally sustainable waterborne transportation system of systems
- Generally faced with ongoing budget constraints and a mission that has international economic and societal impacts
- Significant navigation asset portfolio including ports, intermodal landside connectors, navigation structures, bridges, lock sites, and inland river channels
- 90% of trade travels via maritime conveyance; global supply chain heavily relies upon the maritime transportation system

System Importance and Vulnerability

- Security, resiliency, and efficiency of the system is crucial, and multiple recent events exhibit susceptibility of the system to physical and cyber disruptions
  - Blockage of the Suez Canal by a massive container ship caused global shipping delays at the cost of $9 billion a day and increasing the price of crude oil
  - Ransomware attack on the Massachusetts-based Steamship Authority disrupted online ticket purchasing for ferry service
  - Hurricane Ida caused damage and shutdown of key oil refineries, platforms, and other maritime facilities within the supply chain, resulting in the loss of over a million barrels of oil/day for 10 days
  - Closure of the Mississippi River due to a bridge crack delayed 60 vessels and over 1000 barges transporting agricultural goods and fuel
  - Cyber-attack on the Port of Houston demonstrated the vital nature of investing in cyber security to develop, practice, and execute a response plan to mitigate cyber threats

Inland Waterway Navigation Systems

- In United States
  - 12,000 miles navigable inland waterways
  - 13,000 miles intracoastal channels
  - Serve 41 out of 50 states
  - Contributed $15.9 billion Gross Domestic Product and 67,000 jobs in 2019
  - Carried 1,001 million tons of cargo which worth $689 billion dollars in 2020

Operational Challenges

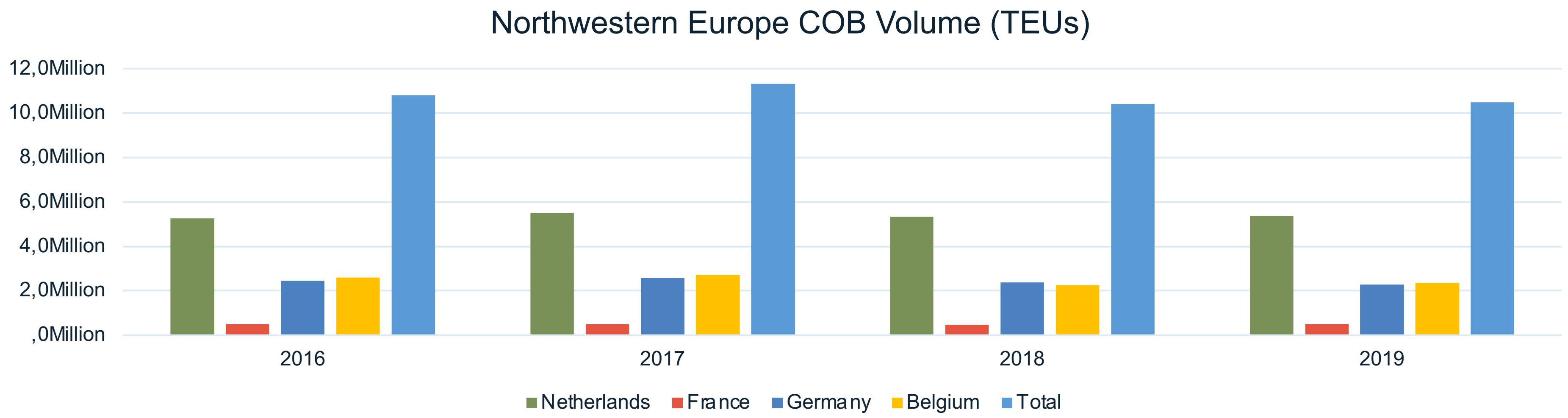
- **Decentralized Governance**: System of individual navigation projects is not governed by a formal maritime transportation strategy or a single, international (or even national-level in the U.S.) stakeholder group
- **Limited Awareness**: Inland transport is often overlooked in favor of more obvious modes like road and rail, hindering its broader adoption and investment
- **Lack of Digitization**: The industry has been slow to adopt modern technologies, negatively impacting efficiency and integration with other logistics systems
- **Fragmentation Industry**: The barge industry has fragmented processes and operations, leading to inefficiencies and inconsistencies in service delivery
- **Lack of Standardized Processes**: The absence of standardized processes across the industry creates operational challenges, hindering seamless integration and coordination
- **Aging Infrastructure**: Faced with the challenge of operating and maintaining aging infrastructure systems under constrained budgets

Container on Barge

- Container on Barge (COB) transports stacked layers of shipping containers via barge (left image)
- Different from traditional bulk cargo barge transport (right image)
- Benefits of COB
  - Enhance container bundles in intermodal transportation
  - Lower total shipment costs by generating economies of scale
  - Accelerate regional intermodal container transportation development
  - Alleviate port/terminal congestion by reducing the utilization of trucks
  - Reduce CO_2 emissions

Growth of Container on Barge

- Northwestern Europe (Netherlands, France, Germany, and Belgium) and China are leading COB development
- From 2016 to 2019, more than 20 million TEUs were annually transported by COB in Northwestern Europe
- In 1990, 106,000 TEUs shipped by COB in China - this has increased to 19.6 million TEUs in 2018



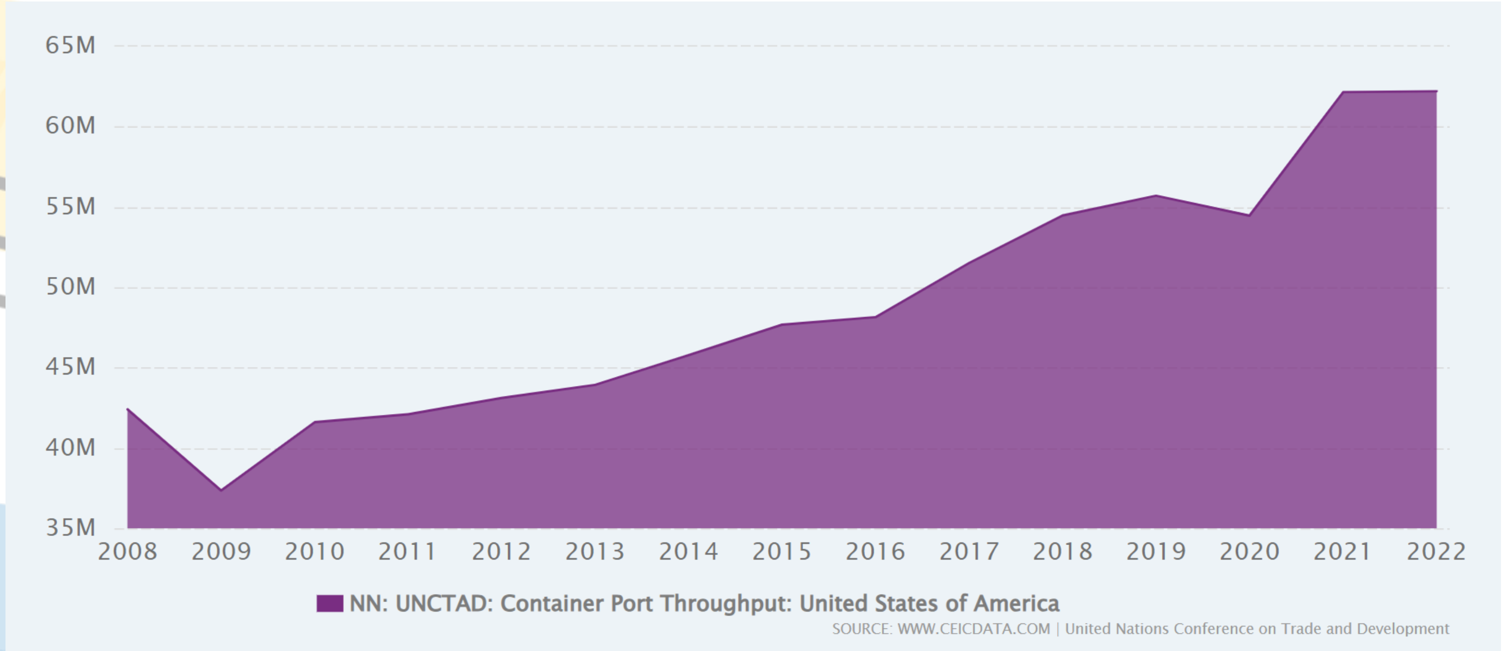
Container on Barge Success Factors

- Successful development of COB transportation on an inland waterway transportation system relies on:
  - Port infrastructure
  - Intermodal network
  - Container shipping market growth
  - Supportive government policies
    - Since 2010, European policies have increased the percentage of total container transported by inland waterway which further motivated the development of container barge transportation. Netherlands will have 50% of total containers transported by COB before 2030.
    - Chinese government issued *The National Plan for the Yangtze River Economic Belt Development* in 2016
- While in the US…there are inland waterways that exhibit these success factors

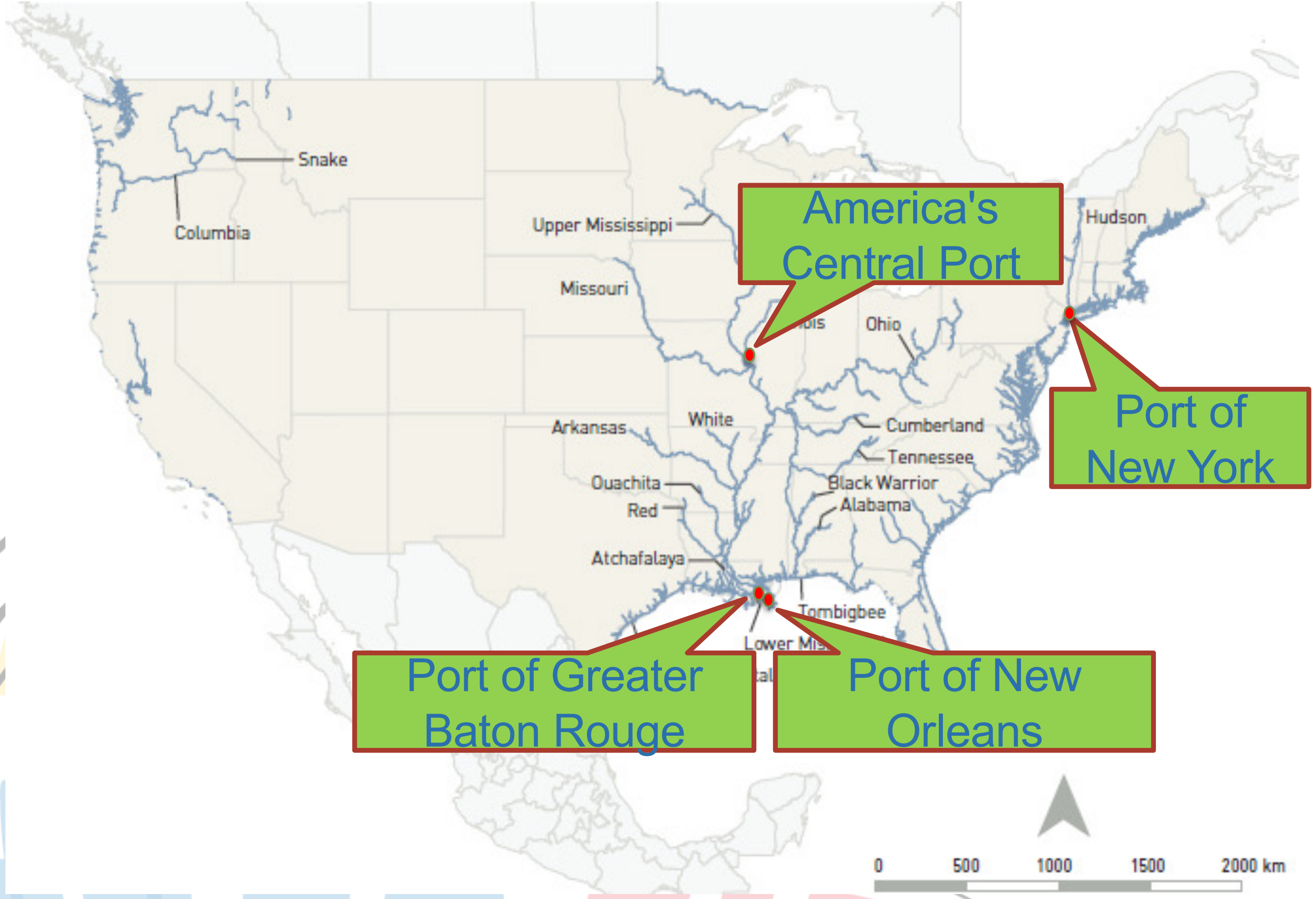
Bu, F., & Nachtmann, H. (2021). Literature review and comparative analysis of inland waterways transport: “Container on Barge”. Maritime Economics & Logistics, 1-34.

Potential for COB Development in U.S.

- More than 40 million TEUs of annual container traffic since 2011 and an increasing trend
- Major seaports face dramatic congestion due to truck container shipping
- $9.5 million granted to start U.S. COB development projects in 2020



Potential for COB Development in U.S. (cont.)



Status

- Four COB ports are in development
- Less than 100,000 TEU per year
- More ports are attempting

Potential

- More than 150 inland waterway ports
- More than 34,000 barges
- More than 50 million TEU traded annually at U.S. seaports since 2017

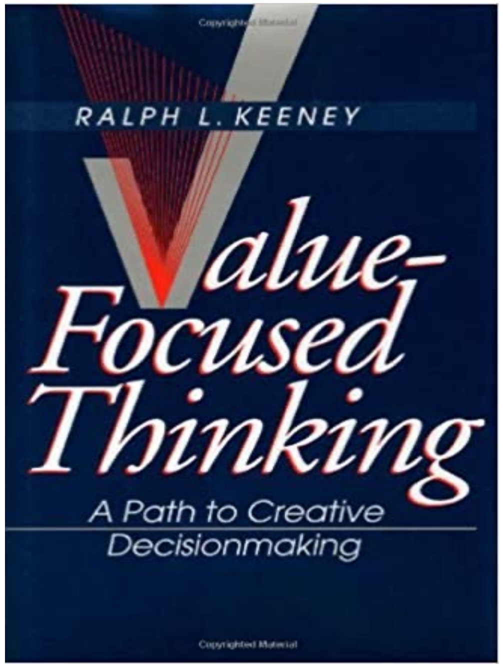
Research Objectives & Methodological Approach

Research Objectives

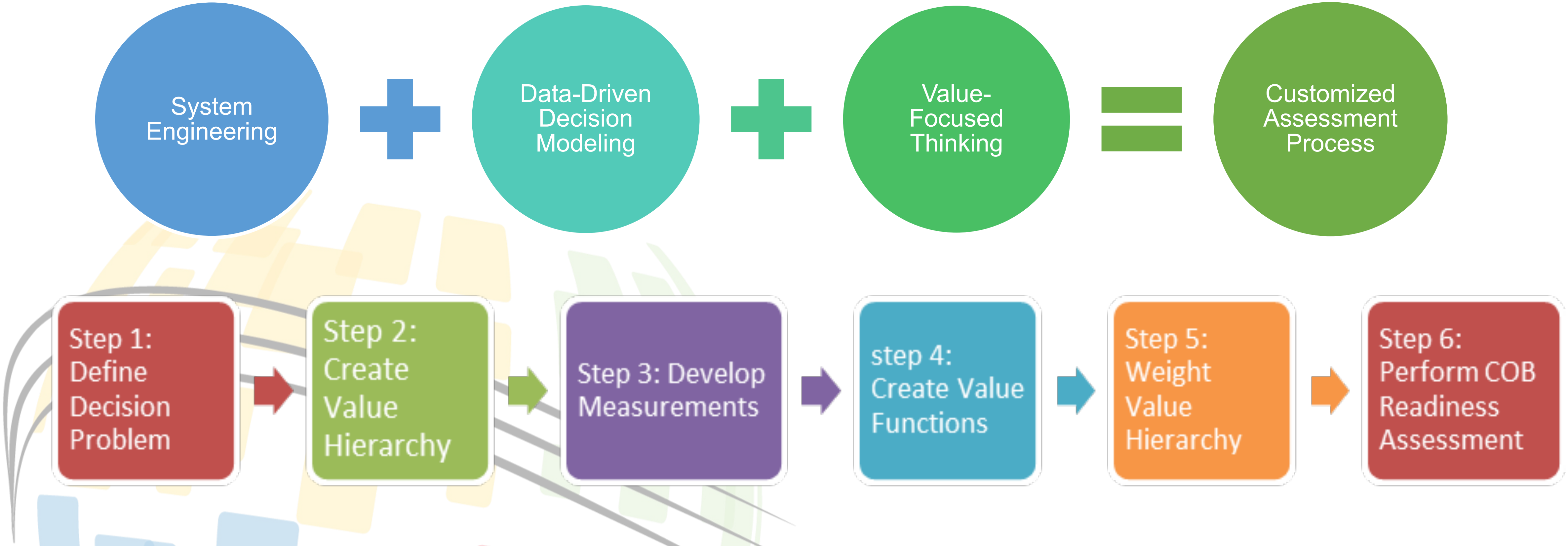
- Provide a comprehensive and integrated decision support tool that enables U.S. inland waterway port decision makers to identify values of COB development from multi aspects
- Practically assess COB success factors with available quantitative and qualitative data
- Generate better COB development plans by considering limitations, opportunities, and conditions

Value-Focused Thinking (VFT)

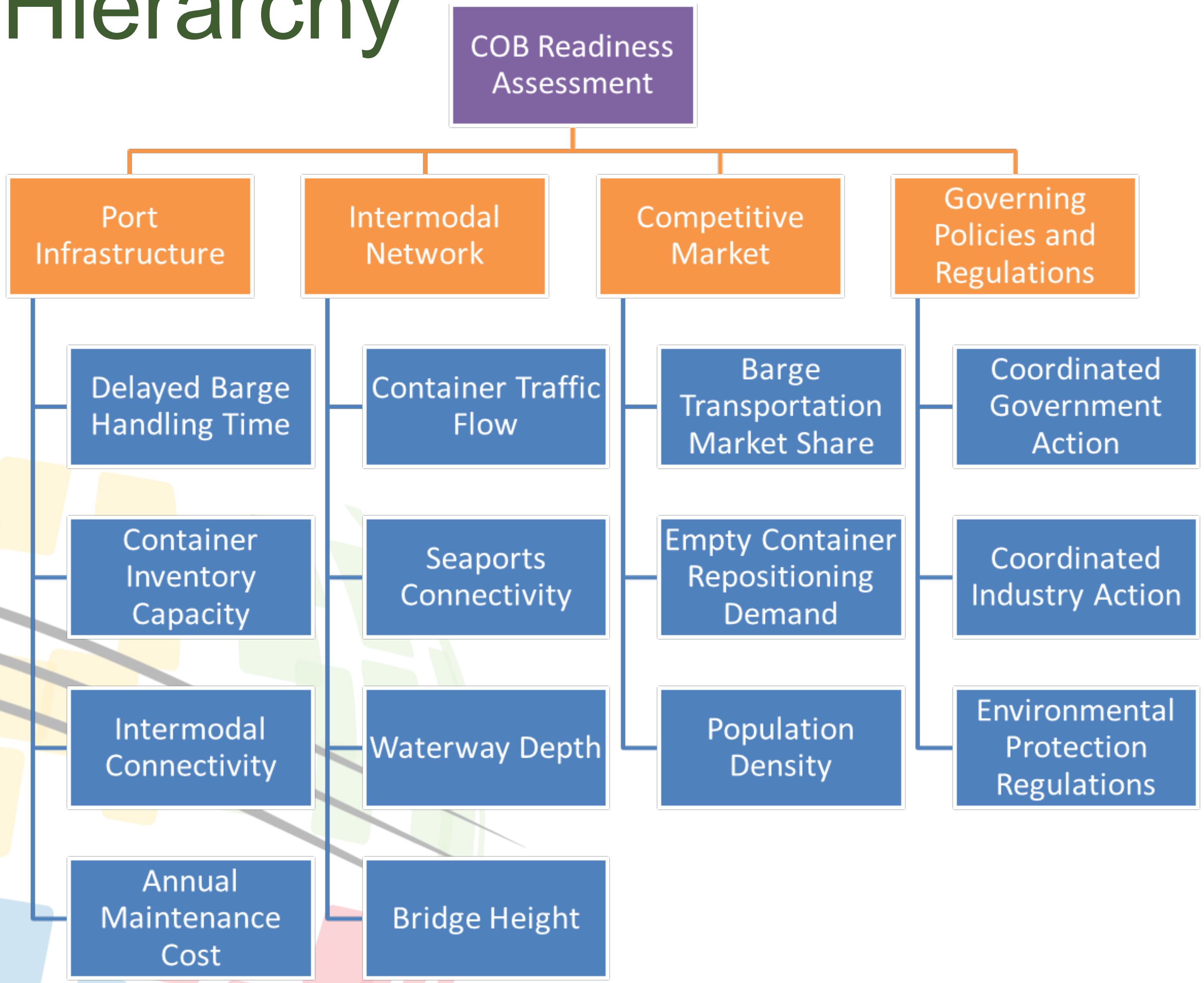
- Decision-making methodology which identifying and articulating fundamental values of system engineers (stakeholders) to discover better decision opportunities and creating better alternatives (Keeney, 1996)
- Important to identify values and possible needs to build a comprehensive understanding to fully assess COB readiness of a port/terminal location
- VFT provides a framework to do this and was selected as the framework for our methodological approach
- Prior scholars have employed VFT in the study area of inland waterway transportation (Merrick et al., 2004; Tong et al., 2015; Wilby et al., 2019; Boudhoum et al., 2021)



VFT-Based COB Readiness Assessment

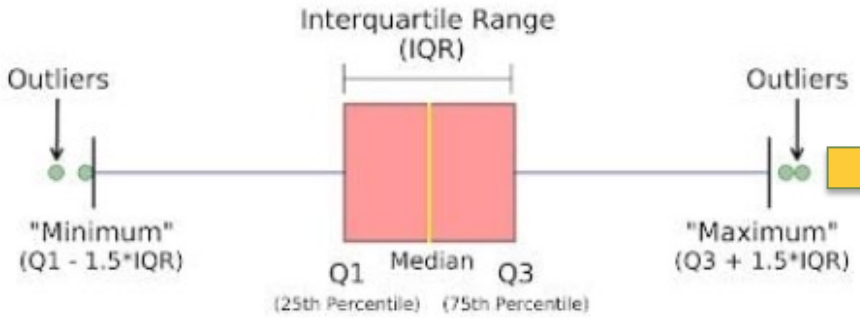


1) Value Hierarchy



2) Develop Measures and Scales: Quantitative Examples

Requires data collection and analysis



Attribute	Measurement Scales	Score
Barge Transportation Market Share	11.6% and above	4
	4.5% to 11.5%	3
	0.5% to 4.4%	2
	0.4% and below	1
Bridge Height	Above 27 feet high	3
	Above 18 feet but below 27 feet high	2
	Below 18 feet high	1

2) Develop Measures and Scales: Qualitative Example

Generating list of essential conditions of coordinated government action and counted the conditions each port meets

- Policy to boost rail-barge intermodal container shipment
- Policy or regulations to increase modal shift from truck or train to barge
- Investment or funding for COB development from the government
- …

Attribute	Measurement Scales	Score
Coordinated Government Action	9 components present	5
	6-8 components present	4
	3-5 components present	3
	1-2 components present	2
	no component present	1

3) Create Value Functions

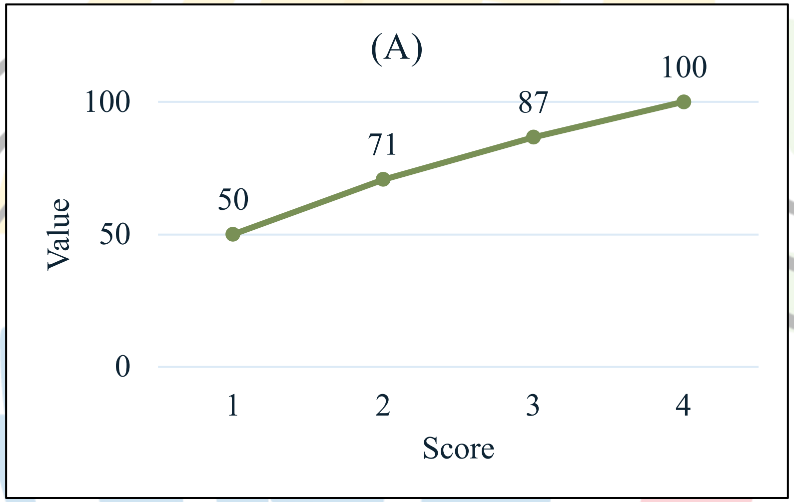
$$v_i = c_i(s_i),\ i = 1, \ldots, n$$

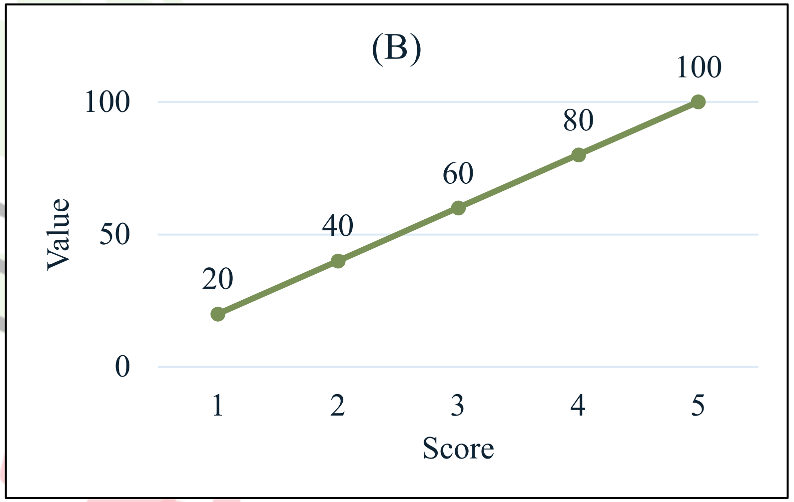
value of attribute *i* (v_i)

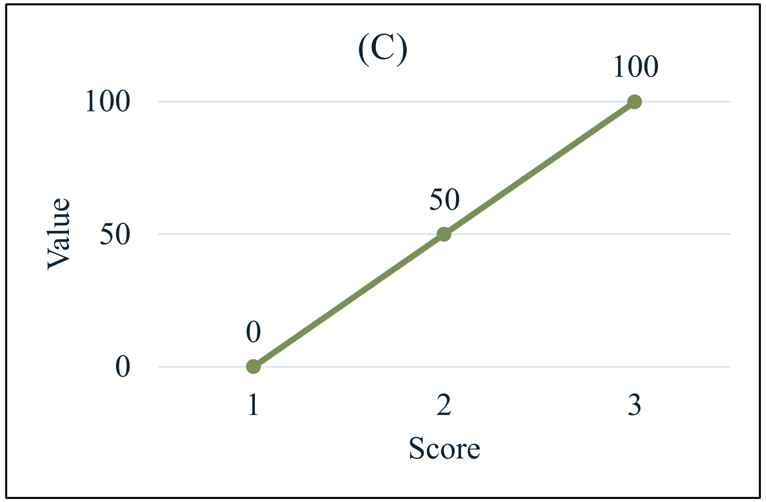
value function for attribute *i* (c_i)

score of attribute *i* (s_i)

Customize the right type for each attribute







4) Swing Weights and Normalized Weights

normalized weight of attribute i

$$w_i = \frac{f_i}{\sum_{i=1}^{n} f_i}$$

swing weight of attribute i

- Using experts' inputs to assign swing weight
- Swing weight can be flexible changed based on user's value preferences
- Normalized weight is calculated based on associated swing weight
- Normalized weights sum up to 1

5) Assigned Swing Weights Matrix

Swing Weight Matrix	Importance of the value measure to the decision makers and stakeholders (intuitive)									
		high			med			low		
Impact of the value measure changes on the decision (Impact of the value measure range variation)			fi	wi		fi	wi		fi	wi
	high	Seaports Connectivity	100	0.12	Annual Maintenance Cost	75	0.09	Waterway Depth	40	0.05
					Bridge Height	60	0.07			
	med	Barge Transportation Market Share	80	0.09	Container Inventory Capacity	60	0.07	Delayed Barge Handling Time	35	0.04
					Coordinated Industry Action	60	0.07			
					Empty Container Repositioning Demand	50	0.06			
					Population Density	50	0.06			
	low	Container Traffic Flow	75	0.09				Environmental Protection Regulations	30	0.03
		Intermodal Connectivity	75	0.09						
		Coordinated Government Action	75	0.09						

6) Perform COB Readiness Assessment

Obtain final score for a port

Assessment results for port *x*

$$v(x) = \sum_{i=1}^{n} v_i w_i$$

Numerical study on 9 global ports

Port No.	Port Name	Country	COB Status
1	Port of Shanghai	China	Developed
2	Port of Ningbo-Zhoushan	China	Developed
3	Lianyungang Port	China	Developed
4	Port of Rotterdam	Netherlands	Developed
5	Port of Antwerp	Belgium	Developed
6	Port of Greater Baton Rouge	U.S.	In Development
7	Port of New Orleans	U.S.	In Development
8	America's Central Port	U.S.	In Development
9	Port of New York	U.S.	In Development

Summarized Results

Illustrative Results for Port of Shanghai

Attribute	Score	Value	Normalized Weight	Weighted Value
Delayed Barge Handling Time	1	50	0.040	2
Container Inventory Capacity	5	100	0.069	7
Intermodal Connectivity	4	75	0.087	7
Annual Maintenance Cost	3	100	0.087	9
Container Traffic Flow	5	100	0.087	9
Seaports Connectivity	3	100	0.116	12
Waterway Depth	3	100	0.046	5
Bridge Height	3	100	0.069	7
Barge Transportation Market Share	4	100	0.092	9
Empty Container Repositioning Demand	4	75	0.058	4
Population Density	5	100	0.058	6
Coordinated Government Action	4	75	0.087	7
Coordinated Industry Action	5	100	0.069	7
Environmental Protection Regulations	5	100	0.035	3
			COB Readiness Score	**92**

COB Readiness Assessment Results

Predefined Readiness Levels

- Very Ready: 86 to 100
- Ready: 75 to 85
- Minimally Ready: 60 to 74
- Not Ready: 0 to 59

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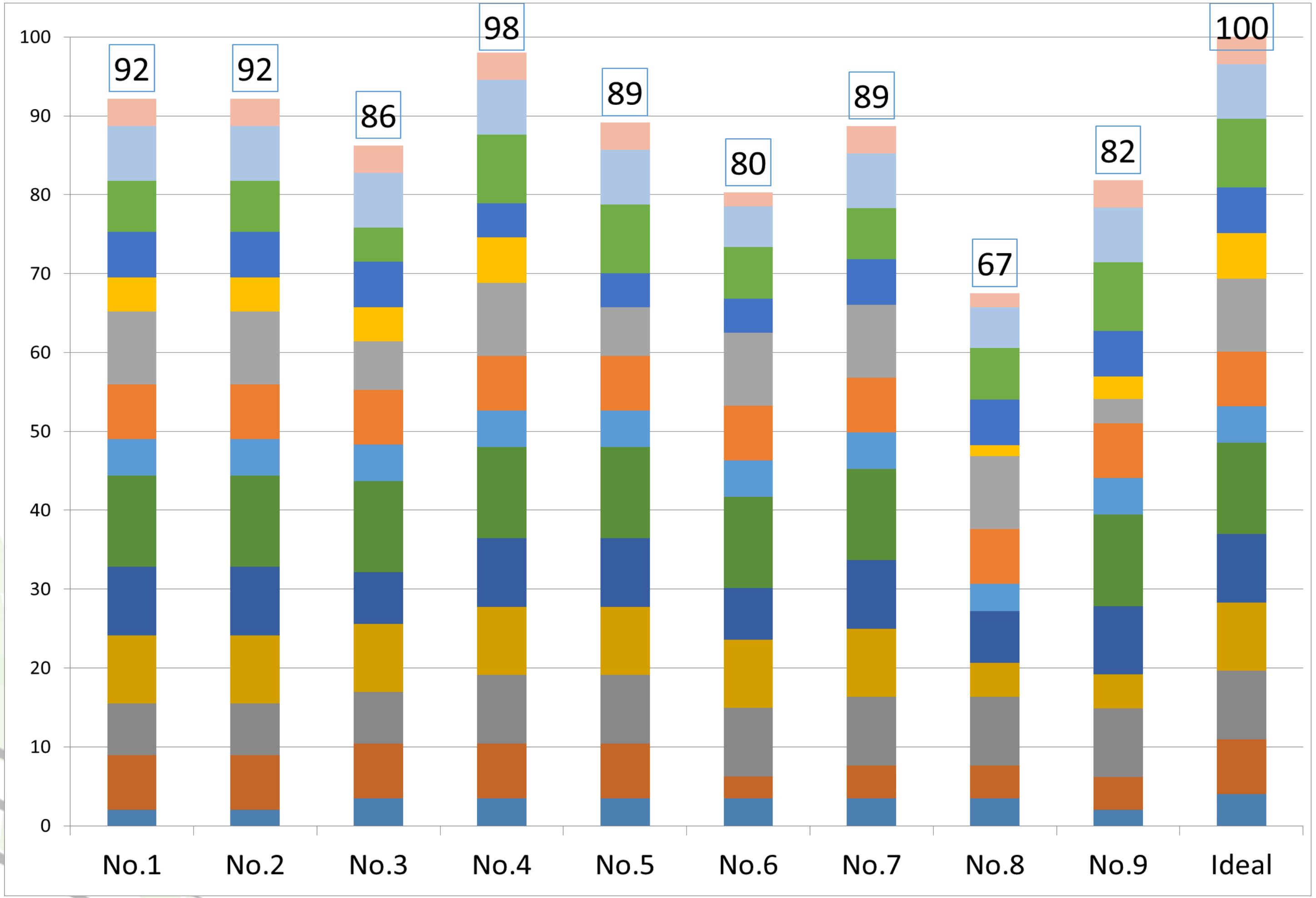
9	Port of New York	U.S.



System Impacts

Contributions

- Delivered a practical scorecard to assist transportation stakeholders in evaluating COB development readiness at maritime ports
- Break through the bottleneck of assessing the preconditions of COB development when the U.S. ports lack real-world industry data and COB success stories
- Assist ports to identify shortcomings and generate improvement plans to enhance COB success

Implications for System Engineers

- COB Readiness Assessment Scorecard supports system engineers and other decision makers in evaluating port readiness and developing COB transportation in U.S.
- By integrating the VFT philosophy into the scorecard design, essential attributes and hidden aspects of COB development success are identified and system engineers can leverage the insights from our scorecard to evaluate their port readiness for COB development
  - For instance, the Port of Greater Baton Rouge scored 2.8 out of 6.9 on Container Inventory Capacity, the lowest compared to other ports. This highlights a need for this port's system engineers to proactively expand the inventory area, upgrade the port's layout to enhance container stacking capacity, and/or avert potential future bottlenecks in COB development.
- System engineers can better utilize limited resources at ports to target improving conditions according to the priorities and increase overall COB readiness
- The methodical approach provides system engineers and other decision makers with a framework to search and identify engineering challenges in other system frameworks

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