

# FIU

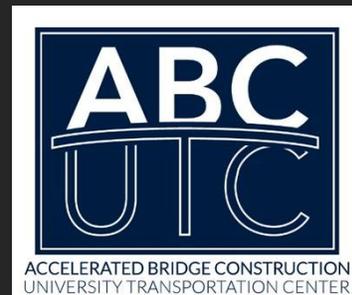


## ABC-UTC Research Seminar

### Critical Impacting Factors and Trends on Bridge Design, Construction, and Operation for Future Planning

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# Introduction

- Infrastructure systems in the U.S. are deteriorating
- “*continuing to use the same processes, practices, technologies, and materials that were developed in the 20th century will likely yield the same results*” (NRC 2015)
- We need “a **paradigm shift**” in how the nation “*thinks about, builds, operates, and invests in infrastructure systems*” (NRC 2015)



A paradigm that “brings **more information** and **more stakeholders** to the table”, makes use of **innovative methods** and **technologies**, and adapts to the future **environmental, social, economic, and technological trends**.

# Introduction

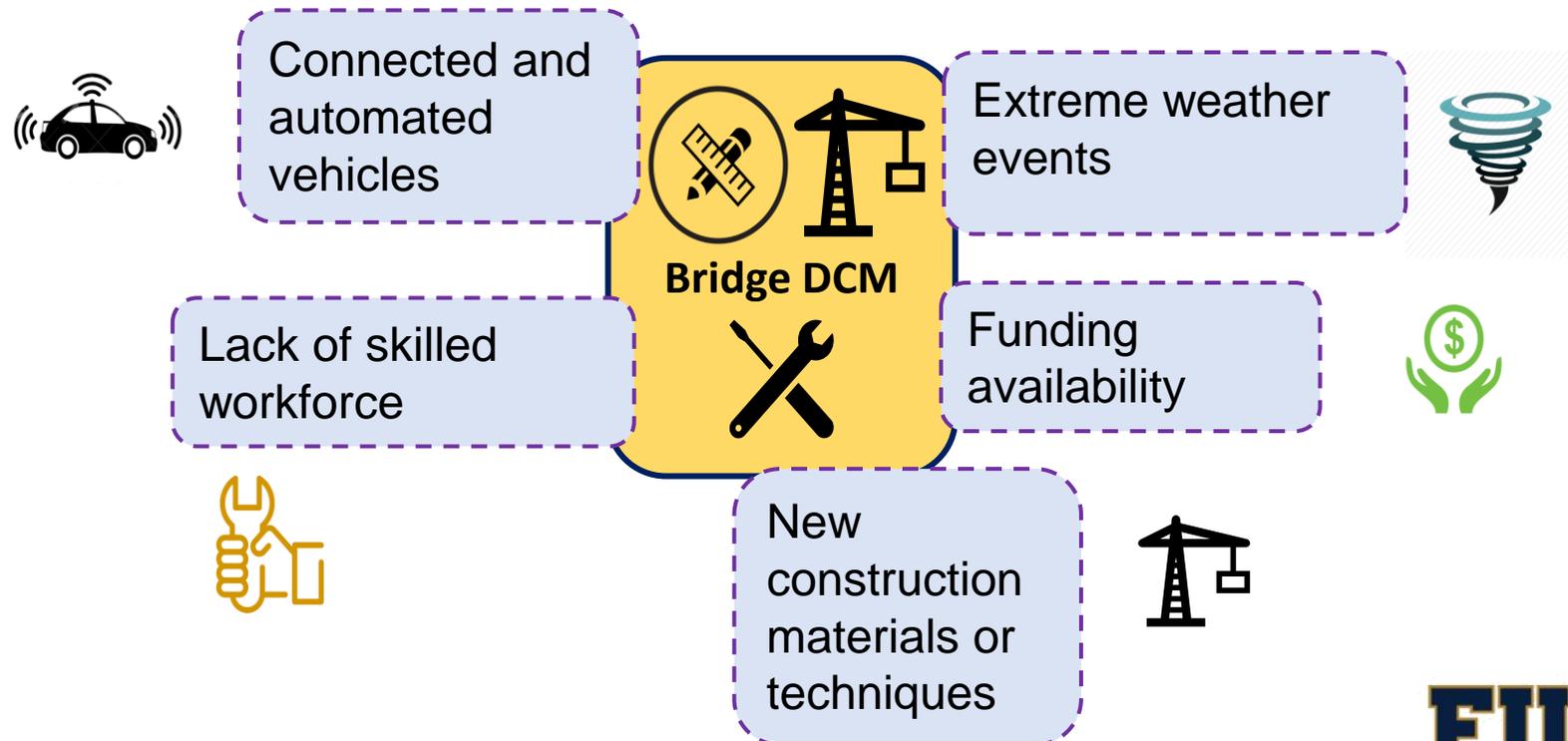
- Various impacting factors have driven the changes in the infrastructure sector at an unprecedented speed.
  - Advances in technology
  - Climate change
  - Economic shifts
  - Social indices
- Critical for transportation agencies to be more proactive to changes and adapt to new trends



# Introduction

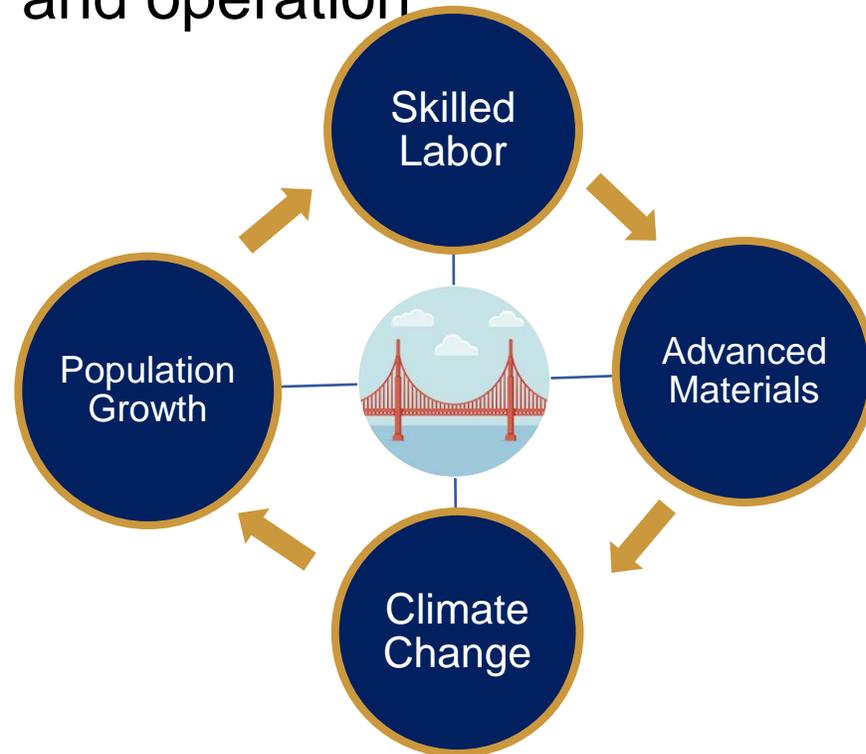
- **Critical impacting factors**

- Factors that may be considered lacking refinement, relatively unknown, but have the potential to affect bridge design, construction, and operation in the short- or long-term.



# Knowledge Gaps

- Lack of understanding on how these changes will affect bridges in short and long period of time
  - Difficulty in predicting the trends of these factors
  - Challenge in understanding the interplay between factors and bridge design, construction, and operation

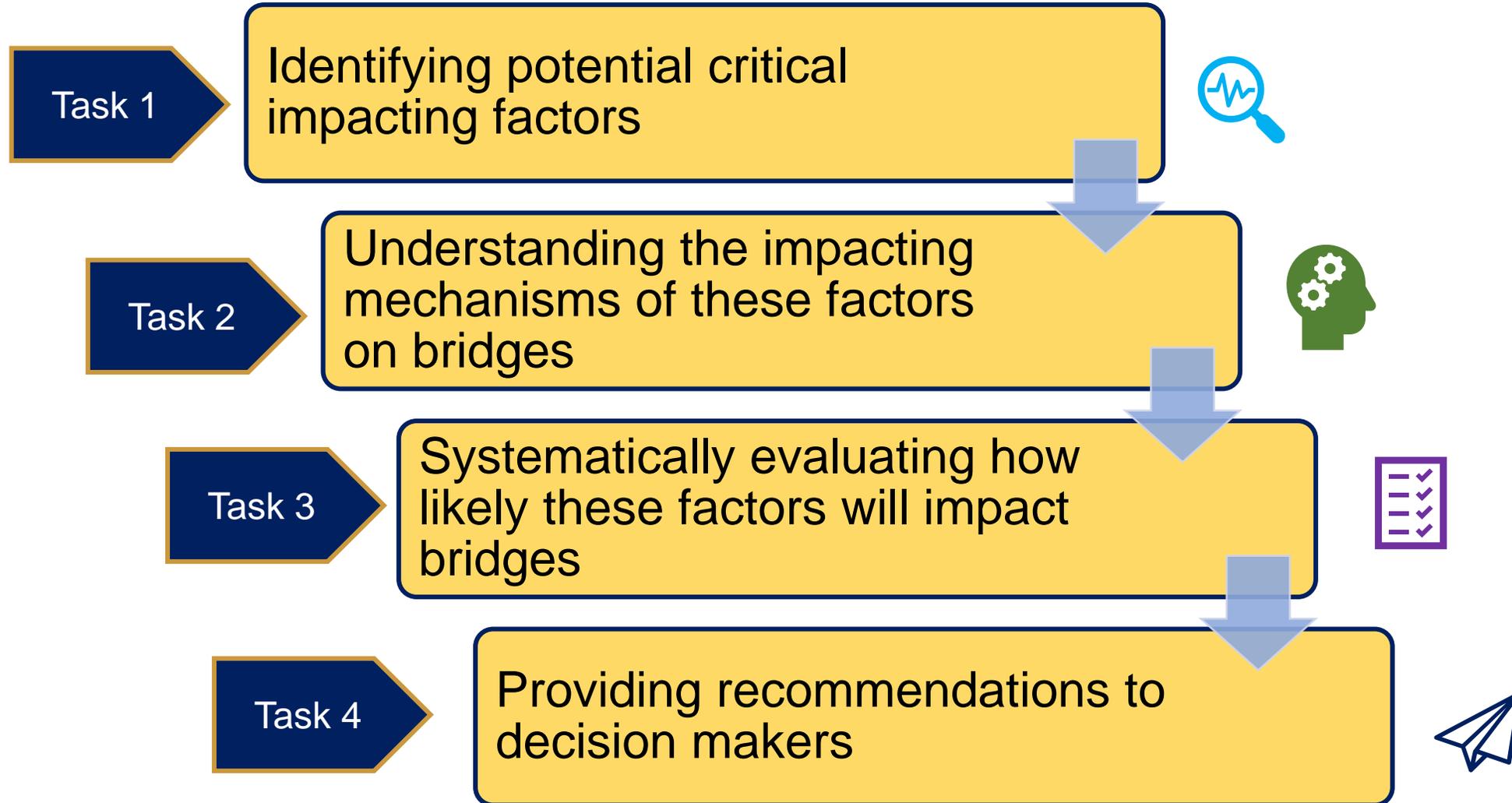


# Research Objectives

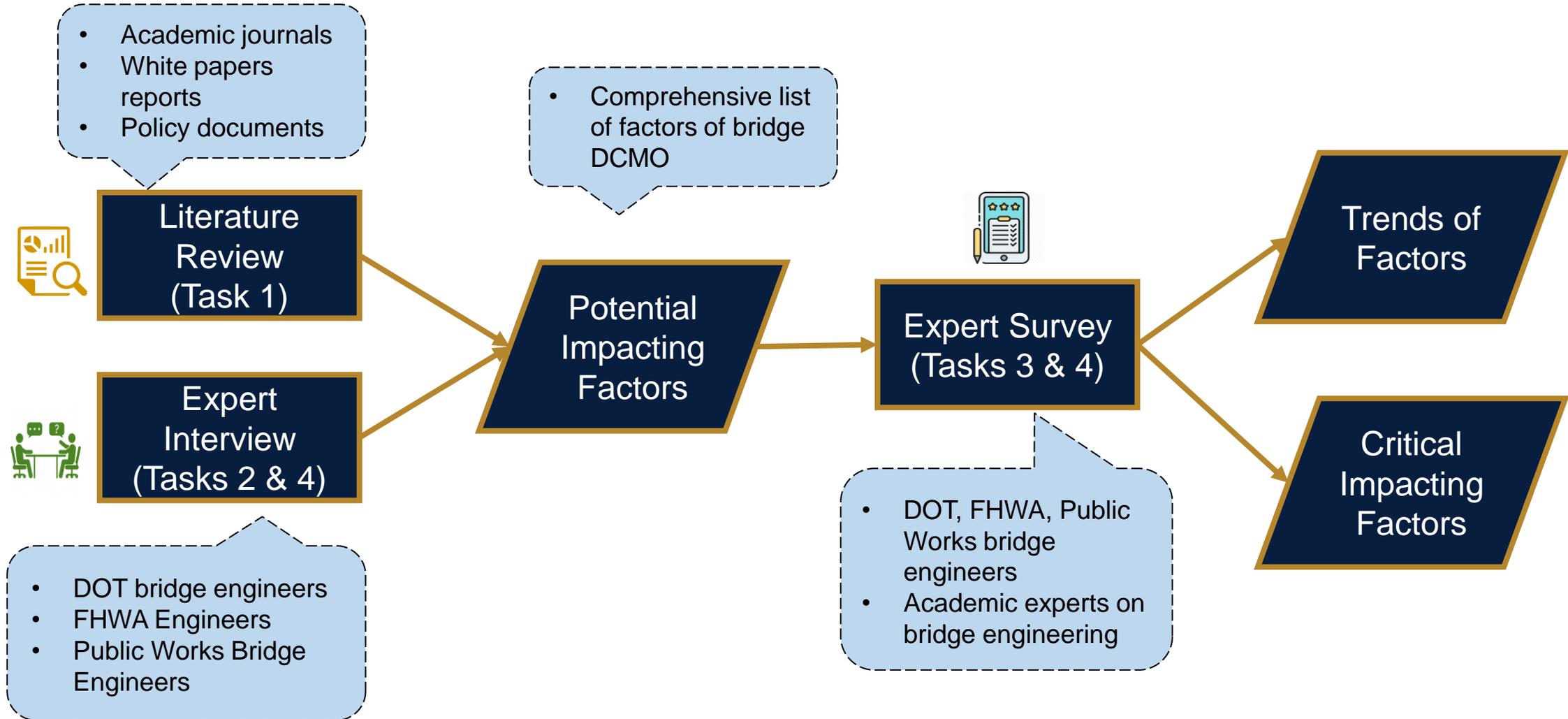
- Identifying critical impacting factors of bridges
- Examine the impact of these factors on bridge design, construction, and operation



# Research Tasks



# Research Overview



# Task 1 – Identifying potential critical impacting factors

- Conducted a comprehensive literature review by reviewing research articles and reports in several domains
  - Technology trends and bridges
  - Climate change and bridges
  - Social impacts and bridges
  - Economic trends and bridges



# Task 1 – Identifying potential critical impacting factors

- Semi-structured interview
  - Solicited expert opinions on potential factors that affect bridge design, construction, and operation
  - 21 bridge experts were interviewed through 19 interviews
  - Experts were from State DOTs and Government-owned transportation agencies (e.g., FHWA)
  - Recorded interviews were transcribed through Sonix and analyzed through NVivo 12



# Task 1 – Identifying potential critical impacting factors

## Impacting Factors

### Technological Factors

New transportation facilities or methods (F1)

Interference between human and traffic (F2)

Adoption of new construction materials or structures (F3)

Adoption of new construction techniques (F4)

Advancement in structural health monitoring techniques (F5)

Change in ways of management and communication (F6)

### Environmental Factors

Climate Change (F7)

Change in Temperature (F7.1)

Change in relative humidity (F7.2)

Change in precipitation (F7.3)

Sea level rise (F8)

Change in intensity and frequency of extreme events (F9)

Change in air quality (F10)

Change in soil quality (F11)

Change in water quality (F12)

### Social Factors

Change in demographic features (F13)

Change in socioeconomic status (F14)

Change in aesthetic preferences (F15)

Change in land use patterns (F16)

Change in legislation and policies (F17)

Change in safety requirements (F18)

Change in labor market (F19)

Change in perceptions on careers (F20)

Education on new technical knowledge (F21)

### Economic Factors

Economic growth (F22)

Change in fuel price (F23)

E-commerce growth (F24)

Change in road pricing (F25)

Globalization and trade war (F26)

Availability of funding (F27)

Public-private partnership trend (F28)

Change in construction cost (F29)

Change in taxation (F30)

- Only from literatures
- Only from interviews
- From both

# Task 2 – Understanding impacting mechanisms

- Identification and analysis of critical impacting factors

## Adoption of new construction materials or structures

(UHPC, HPS, thermoplastic materials)



95%



## New transportation facilities or methods

(CAV, Shared mobility, Hyperloop)



90%



## Climate change

(Change in temperature, precipitation, and humidity)



81%



## Sea level rise



76%



## Change in labor market

(Labor shortage)



90%



## Change in safety requirements



48%



## Public-private partnership trend



86%



## Change in fuel prices



65%



# Task 2 – Understanding impacting mechanisms

## Adoption of new construction materials or structures

- High performance steel
- Ultra-high-performance concrete (UHPC)
- Fiber-reinforced polymer
- Elastomeric bridge bearing

95% of experts emphasized the rising trend of using new construction materials

*e.g., A bridge engineer from Arizona DOT  
“I think as our materials get better... we can build longer spans that allow us to eliminate foundations in the water.”  
“We're already seeing the benefits of using new types of materials”*



# Task 2 – Understanding impacting mechanisms

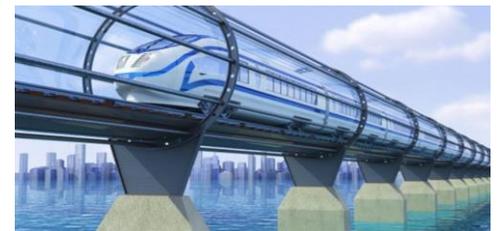
## New transportation facilities or methods

- Connected and autonomous vehicles
- Shared mobility
- Urban transport pod
- Hyperloop
- Maglev train

90% of experts agreed adoption of new transportation facilities could lead to revision of design codes of bridges

*e.g., A bridge engineer from South Carolina DOT*

*“...Autonomous vehicles and connected vehicles, fleets of trucks, vehicles which are driverless and tagged together, that's going to change how the bridge is designed for vehicles”*



# Task 2 – Understanding impacting mechanisms

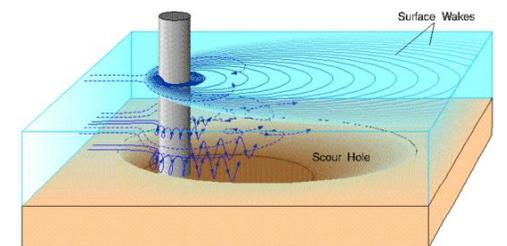
## Climate change

- Higher temperatures
- Increased precipitation
- Change in relative humidity

81% of experts agreed on the effects of climate change on bridge design, construction, and operation

*e.g., A bridge engineer from Colorado DOT*

*“...Obviously, because climate change can affect the frequency and magnitude of the flooding. So that's going to have a major impact on the future of bridges”*



# Task 2 – Understanding impacting mechanisms

## Change in labor market

90% of experts mentioned labor shortage and lack of skilled workforce

*e.g., An engineer from Wisconsin DOT*

*“Skilled labor is what's becoming harder to find....It's uncertain what's going to happen when there's really not a huge group of people to take on those skilled labor tasks.”*

*e.g., A bridge contractor*

*“We need to reach out to high school kids to spread the information and provide training....we need to build the positive image of construction industry and bring more labor”*



# Task 2 – Understanding impacting mechanisms

## Public-private partnership (P3)

86% of experts mentioned the importance of P3 for bridge projects

- P3 is cooperative arrangement formed between two or more public and private-sector partners
- Growing popularity of P3 in bridge projects

*e.g., An engineer from Washington DOT*

*“....less discussed benefit P3, is that it can potentially increase project quality and reduce maintenance needs by engaging the private partners in both construction and future operation and maintenance....”*



# Task 3 – Systematic evaluation

- All 32 impacting factors were included in a survey
- Survey has three main sections:
  - (1) Impact assessment of factors
  - (2) Trend analysis of the factors
  - (3) Background information of respondents
- Conducted through Qualtrics
- From Apr 2020 to Oct 2020

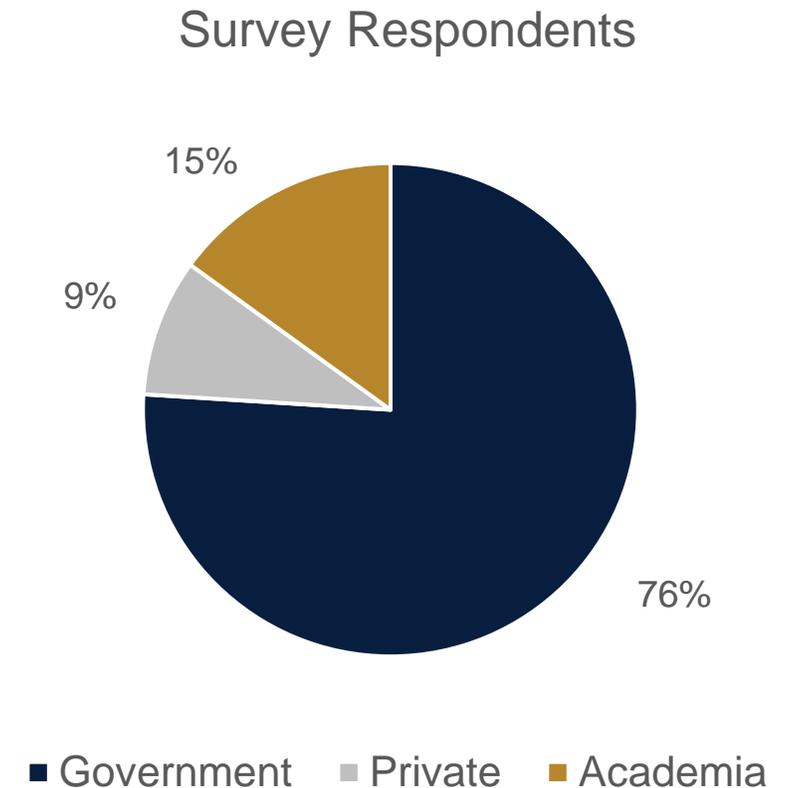
	Extremely Likely	Very Likely	Likely	Not Likely	No Impact
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<b>Change in relative humidity</b> (e.g., climate change casues increase in humidity level)	<input type="radio"/>				

	Trend continues	Trend stops	Trend reverses	Unpredictable trend
<b>Change in temperature</b> (e.g., increase in average annual temperature, more frequent extreme temperatures)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
<b>Change in relative humidity</b> (e.g., climate change casues increase in humidity level)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

qualtrics<sup>XM</sup>

# Task 3 –Systematic evaluation

- Targeted bridge experts:
  - Government agencies (state DOTs, AASHTO, FHWA): 76%
  - Private sectors (bridge industry, companies, firm, consultants): 9%
  - Academia (university faculty, researchers): 15%
- Emails sent to experts: 763
- Number of responses: 132
- Number of completed survey: 108
- Response rate: 17%

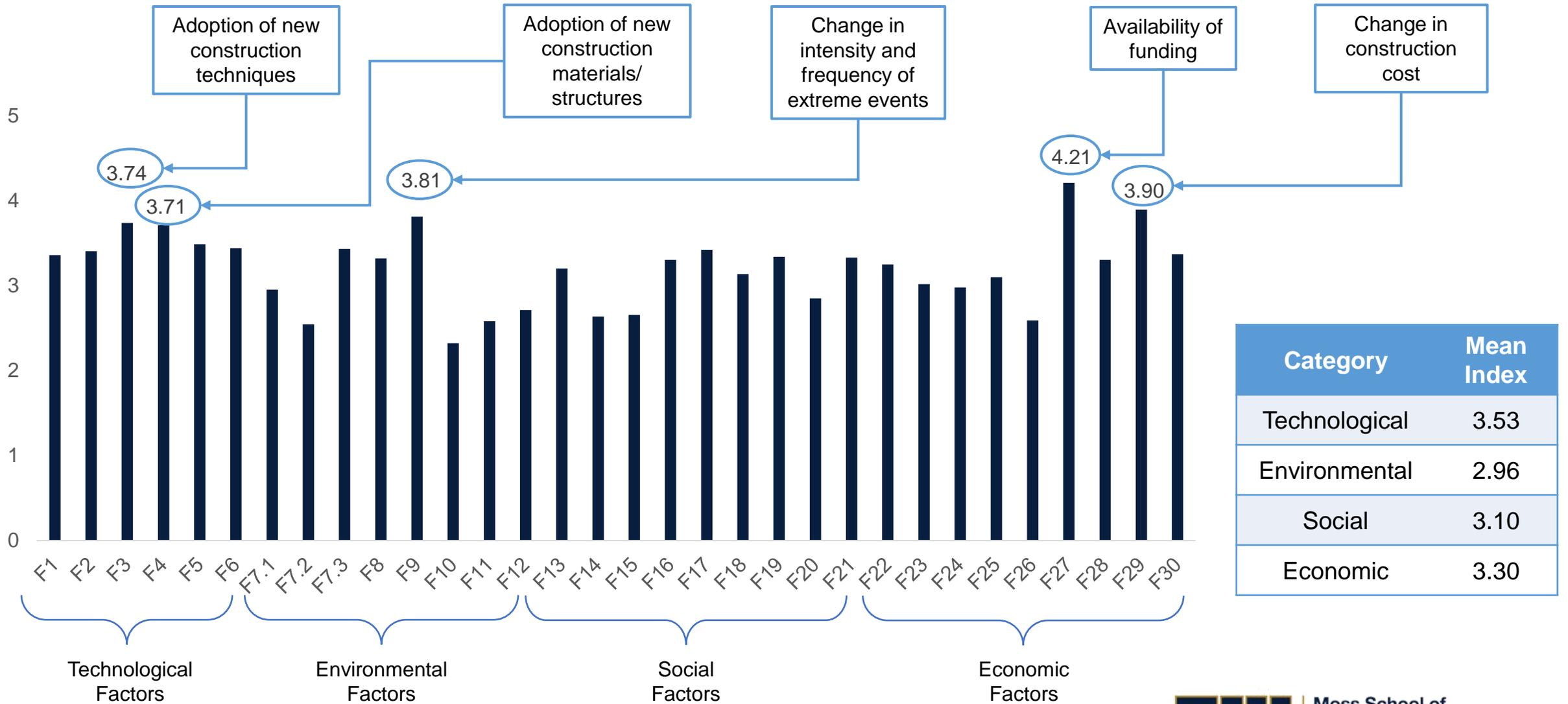


# Task 3 – Results Analysis

- How likely will each of the factors **impact** bridges in the future?
- What are the **future trends** of the impacting factors based on the experts' opinions?
- What are the factors that are **most impactful** and **most likely** to happen?
- Do different groups of experts have **different opinions** on the importance of critical impacting factors (e.g., based on their job position, years of experience, region, etc.)?

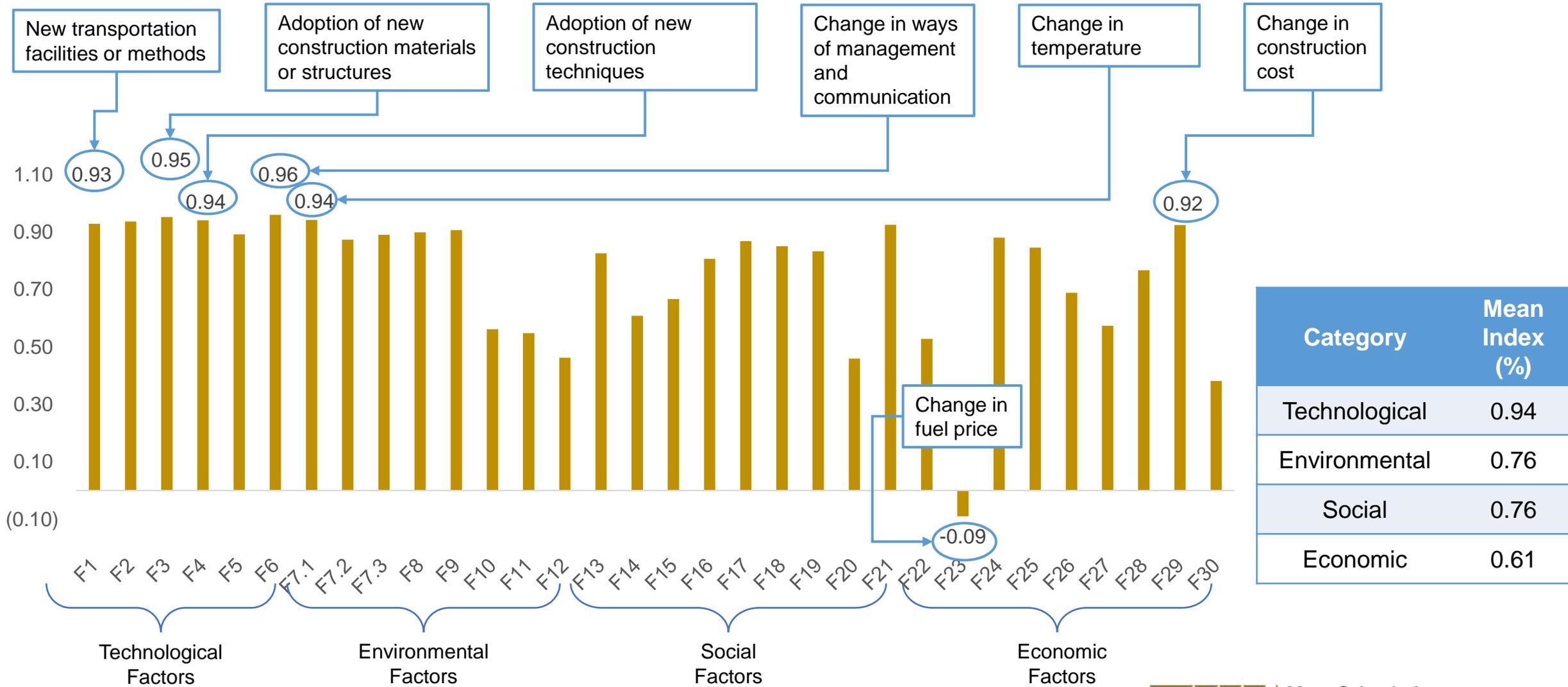


# Task 3 – Systematic evaluation: Impact Rating



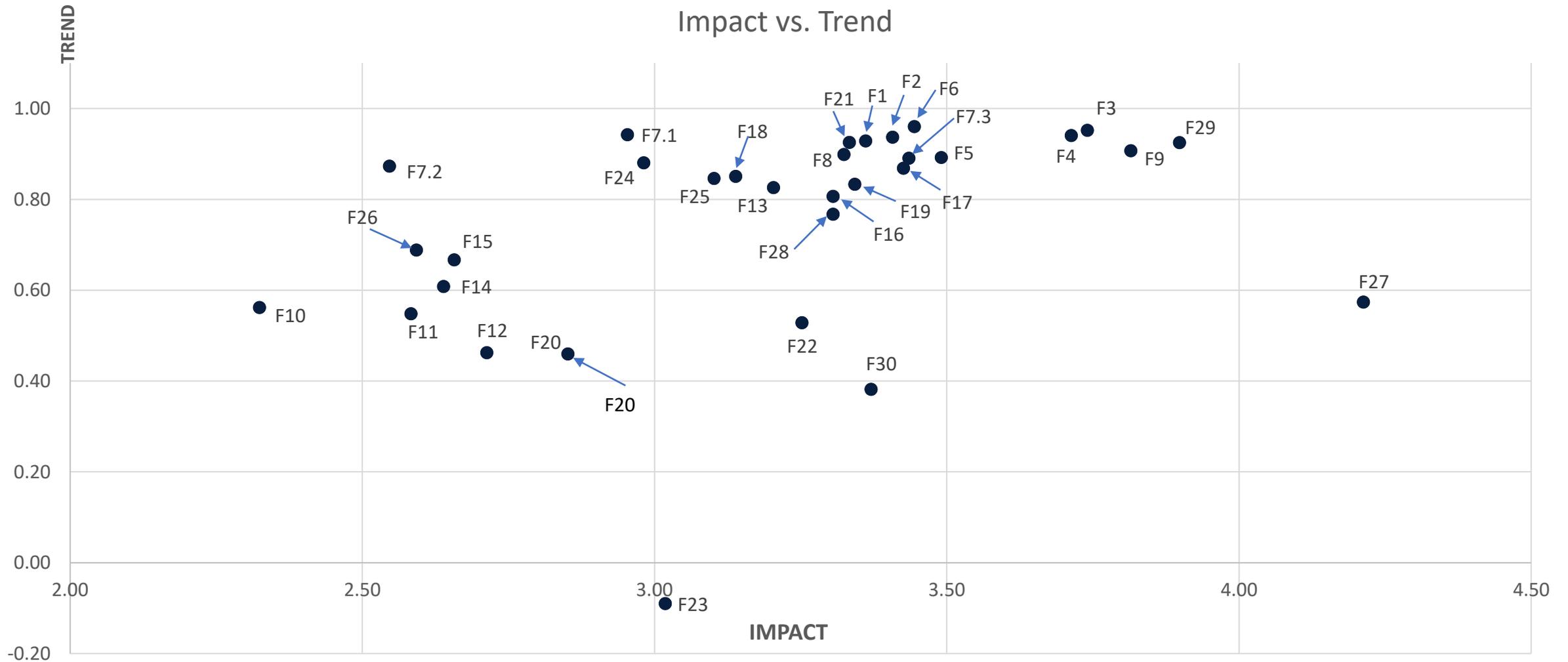
Mean Indexing of Impact Ratings for All Factors

# Task 3 – Systematic evaluation: Trend Rating



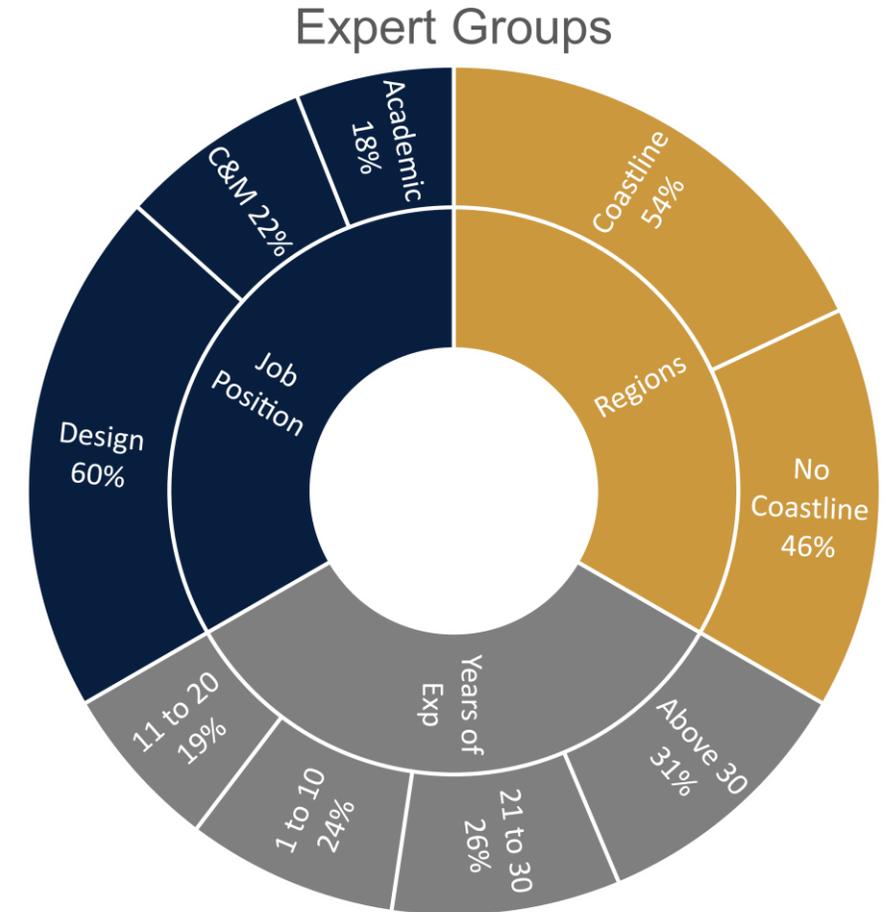
Mean Indexing of Trend Rating of All Factors

# Task 3 – Systematic evaluation: Impact vs Trend

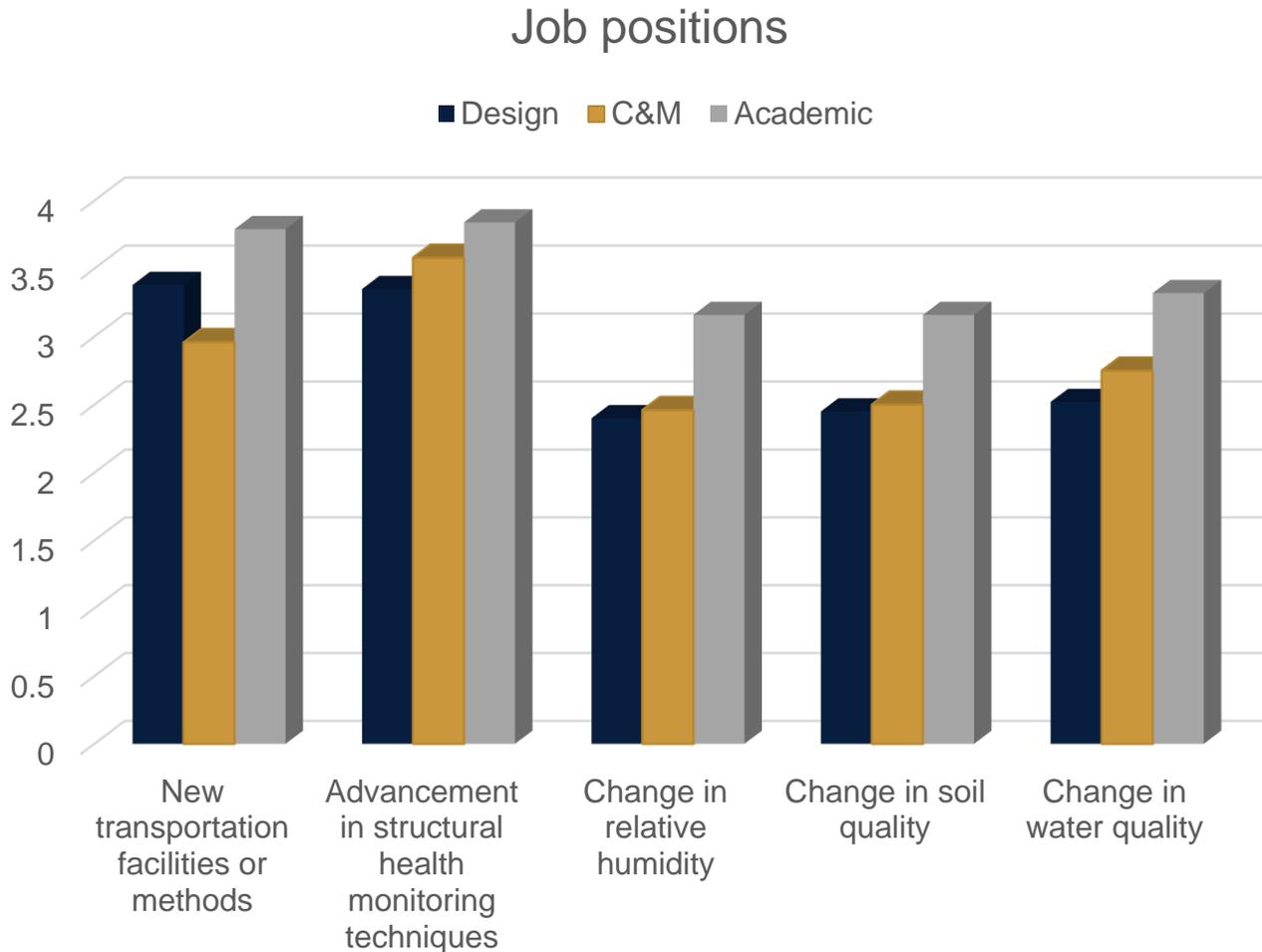


# Task 3 – Systematic evaluation: Comparisons

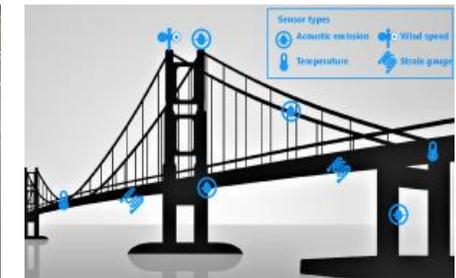
- Conducted to identify the factors that were rated significantly different by different groups of experts
- Mann-Whitney test:
  - Regions
- Kruskal-Wallis H test and Pairwise Comparisons:
  - Position
  - Years of Experience
- Pairwise comparisons conducted to identify which pairs of the groups have significantly different opinions



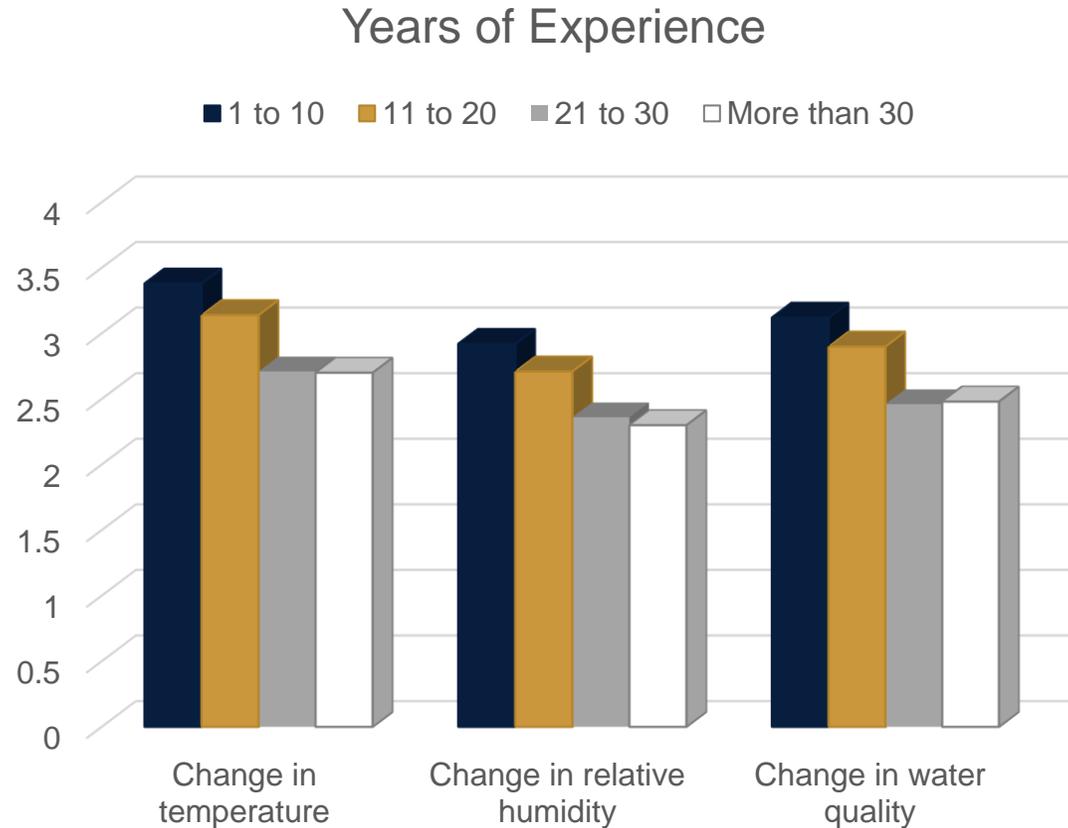
# Task 3 – Comparisons based on Job Positions



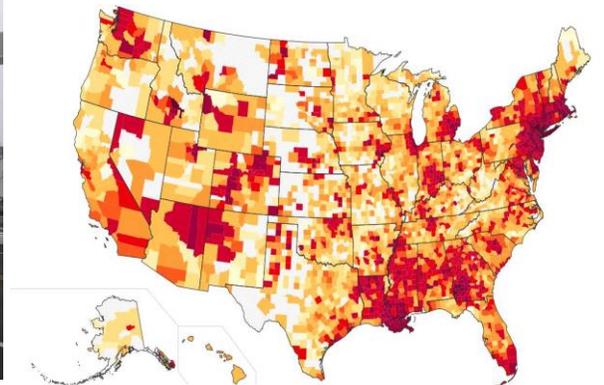
- Environmental Factors
- Technology Advancement
  - Researchers and design engineers are more concerned due to changing traffic dynamics and loads on bridges (Lu et al. 2019)
  - Increasing popularity of application among maintenance engineers
  - Increasing demand for research among academic experts



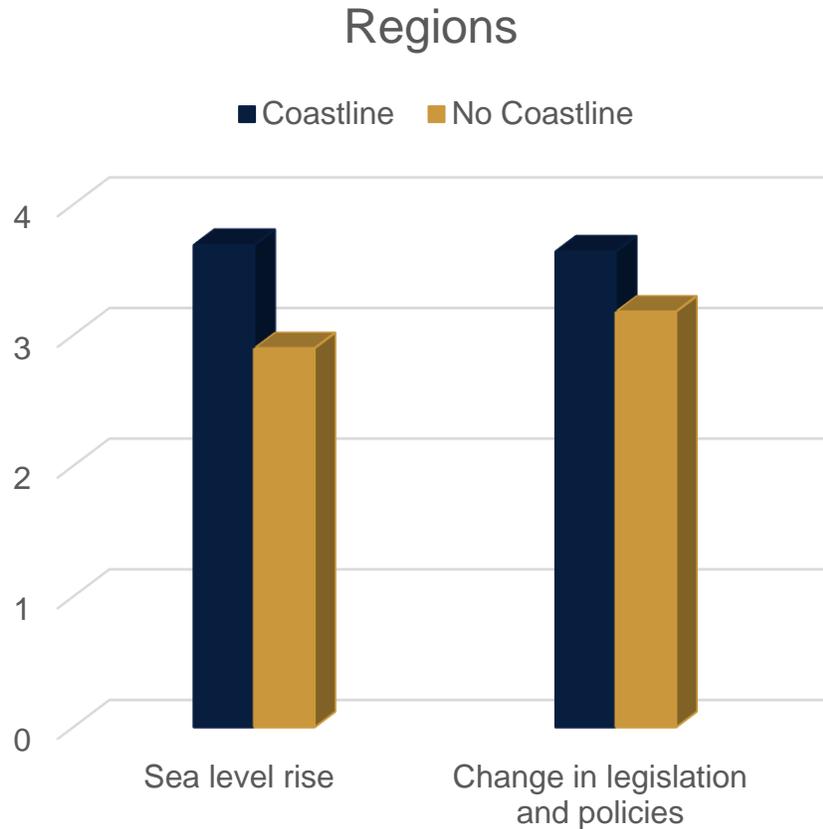
# Task 3 – Comparisons based on Years of Experience



- Climate change
  - Bridge professionals with less years of experience tend to rate the impact higher on bridge design, construction, and operation
  - Young professionals (engineers, researchers, experts) address climate effects in their work (NSPE, 2020)



# Task 3 – Comparisons based on Regions



- Sea level rise
  - Sea level is rising at an accelerating rate along the US East Coast and Gulf of Mexico
  - Coastal states have been more active to develop policies for dealing with climate change-related disasters and hazards (Babcock, 2013)



# Task 4 - Recommendations to decision makers

- **Technological Factors:**
  - Need support from policy makers and industry leaders to implement new technologies
  - Life cycle cost analysis is needed
  - Multisector collaboration is needed to facilitate technology development and implementation
- **Environmental Factors:**
  - Design standards may need to be constantly re-evaluated to adapt to environmental changes
  - Retrofitting and adaptation strategies need to be considered for existing structures

# Task 4 - Recommendations to decision makers

- **Social Factors:**
  - Need uplifting of skills and preserve the dignity of the workforce
  - Safety of workers and well-being of local communities should be prioritized
  - New construction techniques can address safety and productivity concerns
- **Economic Factors:**
  - Standardization of project financial programs (e.g., P3)
  - Reevaluation of typical project planning due to budget limits
  - Provide investment in critical bridge infrastructure to stimulate the economy

# Conclusions

- Advance understanding of critical impacting factors and their trends, as well as potential interactions between factors and bridge design, construction, and operation
- This is critical for transportation agencies and decision-makers:
  - Become more proactive to changes
  - Account for impacts of critical impacting factors in future decision making
  - Develop more adaptive and timely standards, regulations, and policies
  - Offer insights and drive a rethinking of how to better manage our bridges to prepare for inevitable changes

# Future Work

- New factors based on trends after 2020
  - COVID-19 pandemic
  - Infrastructure bill
  - Inflation
- Contribution by experts from various domains of research
- Each identified factor requires further investigation and analysis

# Acknowledgement

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Thank you !  
Questions?



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