RISK AND RESILIENCE OF BRIDGES: TOWARD DEVELOPMENT OF HAZARD-BASED ASSESSMENT FRAMEWORK, RESEARCH NEEDS, AND BENEFITS OF ACCELERATED CONSTRUCTION

Quarterly Progress Report
For the period ending May 31, 2021

Submitted (Jointly) by:
Graduate Student- Paul Cancino[1]
PI: Dr. Islam M. Mantawy, Florida International University[2]
PI: Dr. Mohamed Moustafa, University of Nevada, Reno[3]
PI: Dr. Musharraf Zaman, University of Oklahoma
Co-PI- Dr. Edward Cokely, University of Oklahoma

[1]School of Civil Engineering and Environmental Science, University of Oklahoma,
[2]Department of Civil and Environmental Engineering, Florida International University
[3]Department of Civil and Environmental Engineering, University of Nevada, Reno

ACCELERATED BRIDGE CONSTRUCTION
UNIVERSITY TRANSPORTATION CENTER

Submitted to:
ABC-UTC
Florida International University
Miami, FL

1. Background and Introduction

Transportation networks are modeled in the form of links and nodes. Links represent the highways, while the nodes representing bridges connecting the highways which act as hubs for several links. Closure of a single bridge within the transportation network can lead to substantial disruptions to the entire network and the communities it serves. For example, the local damage of the I-65 North overpass bridge in Alabama in January 2002 (due to truck accidental explosion) caused a traffic interruption for almost 50 days. Assessment of risk and resilience of existing bridges and new bridges, including ABC bridges, accelerated upgrade, and accelerated repair is important to devise appropriate pre-hazard preparedness plans and post-hazard mitigation response strategies and recovery time. This joint project seeks to document and synthesize the current state of practice related to assessment of risk and resilience of bridges and other structures and to conduct target surveys to identify the current practices within transportation agencies and cities. The collected information will be utilized to develop a holistic resilience and risk assessment framework for existing and new bridges, including ABC bridges, accelerated upgrade (enhanced robustness), and accelerated repair (enhanced rapidity), under multi-hazards to emphasize on accelerated construction benefits. Finally, the project will develop a specific resilience framework for seismic hazard. The success of this project will promote ABC nationwide to stakeholders as one of the most suited construction methods for resilient bridges and transportation infrastructures.

2. Problem Statement

Assessment of resilience of roadway bridges due to natural and man-made hazards is an important element of economic and societal vulnerability and safety because the closure of a single bridge within a transportation network can cause major disruptions to the entire network and the communities it serves. Also, the assessment of risk and resilience of individual bridge components as well as bridge systems is important to devise pre-hazard preparedness plans and post-hazard mitigation response strategies and recovery time. Recent developments in informed decision-making including risk and decision analysis, risk analytics, risk science and decision support standards are excellent tools for quantifying benefits of accelerated bridge construction. In addition to including risk and resilience with respect to structural performance under natural and man-made hazards, such tools allow for integration of stakeholders' perception and policy toward accelerated construction, maintenance, and rehabilitation, thereby promoting ABC to stakeholders. Currently, assessment of risk and resilience of roadway bridges is either performed qualitatively by expert judgments or quantitatively by statistical analyses and other tools depending upon the available data. The purpose of this multi-institutional and multidisciplinary project is to develop a framework for hazard-based assessment, research needs, and benefits of accelerated construction. One of the unique aspects of the proposed framework is integration of stakeholders' perception and policy toward accelerated construction using the recent developments in social and risk sciences. The proposed framework will address risk and resilience of both existing and new bridges, with a priority on ABC bridge systems, to highlight the benefit of accelerated construction. Both natural and man-made hazards will be considered.

3. Objectives and Research Approach

The main objectives of this project are:

- Documenting the current state of practice related to assessment of risk and resilience of bridges nationally and internationally.
- Synthesizing the state of practice related to assessment of risk and resilience of other structures against man-made and natural hazards with the goal of identifying frameworks and assessment tools can be readily adopted for bridges.
- Conducting target online survey for state DOTs and cities to evaluate the practice of existing bridge performance tools.
- Developing a holistic resilience and risk assessment framework for existing and new bridges, including ABC bridges (accelerated upgrade, and accelerated repair), under multi-hazards to emphasis on accelerated construction benefits.
- Developing a specific resilience framework for seismic hazard as an example of natural hazards.

Regarding the approach, the adopted methodology is known as the 4R-Methodology and it will be further expanded to 5R-Methodology, considering a new dimension, Regional Societal impact, which will help quantify economical and social impacts. The 5R-methodology includes the following:

- **Robustness:** The ability to withstand a hazard with little or no loss of functionality.
- **Rapidity:** Recovery time needed for the system functionality to be recovered.
- **Redundancy:** Components that keep the systems functionality even after the loss of part of the system.
- **Resourcefulness:** Ability to mobilize resources after the hazard.
- **Regional societal impact:** Economic and social impact including safety and mobility.

4. Description of Research Project Tasks

The following is a description of tasks carried out to date.

Task 1 – Conducting a literature review on risk and resilience of roadway bridges under natural and man-made hazards.

In this task, documentation of the existing guidelines and protocols used by state and federal DOTs and cities for the assessment of risk and resilience of roadway bridges due to natural and man-made hazards. The literature focused on the guidelines and protocols available nationally and internationally is being collected, reviewed, synthesized, and documented. It is expected that the existing methodologies for the assessment of risk and resilience of buildings and other structures

will aid in the development of the framework for risk and resilience of bridges due to natural and man-made hazards

For the assessment of risk and resilience of roadway bridge:

- Documentation of the existing guidelines and protocols used by state and federal DOTs and cities due to natural and man-made hazards.
- Guidelines and protocols available nationally and internationally will be collected, reviewed, synthesized, and documented.

<u>Description of work performed up to this period: 25%</u>

During the first quarter, 45 sources of relevant literature have been reviewed and categorized for further study. This first categorization will help identifying the areas that need additional sources. Figure 1 shows the distribution of the documents for each category reviewed during the first quarter.

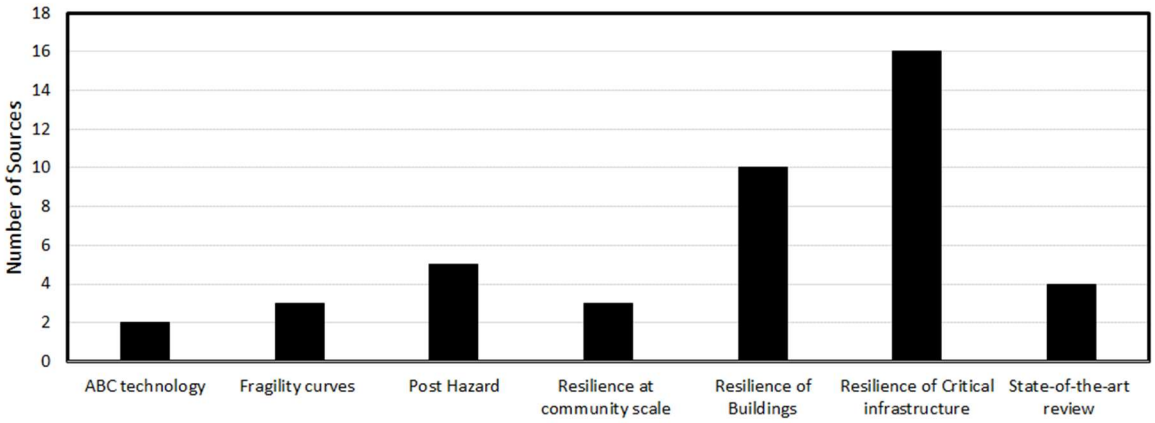


Figure 1: Number of sources in each Category

The list of sources and their different categories can be seen in detail in Appendix 1. The information includes the full reference, authors, country of origin, category and subcategories.

The categories and subcategories are listed in Figure 2.

Row Labels
ABC technology
ABC Toolkit for design recommendations
Implementations of methods to be used ABC Manual
Fragility curves
Estimation for Retrofit Bridges
Estimation of fragility curves for Bridges
Integration of Fragility Curves and Restoration Functions for Bridges
Post Hazard
Flow capacity of bridges
Functionality
Loss estimation: FEMA and Huzus-HM Applied to bridges
Loss estimation: FEMA P-58 applied to region
Seismic Evaluation of bridge portfolio using machine learning
Resilience at community scale
Multihazard PEOPLES Resilience
Seismic Resilience of Communities
Resilience of Buildings
Expected Seismic Performance of Code
Guidelines for Seismic Design of Buildings
Methodology
Methodology for Assessing Environmental Impacts
Methodology supporting materials
Implementation Guide
Organizational Resilience, Building Resilience, and Ambient Resilience
Recommendation for seismic evaluation
resilience-based earthquake design for new buildings
Tools for Seismic Design and Assessment
Resilience of Critical infrastructure
Concepts and measurement of resilience
Congestion Prediction Application of big Data
Definition, Metrics, and Valuation for Decision Making
Guidelines for Seismic Performance Assessment of Bridges
Man made Hazard: application to blast risk assessment
Measurement Frameworks and Metrics
Method for evaluation Comparing resilience
Probabilistic Resilience Infrastructure
fragility analysis and traffic flow distribution under extreme events
Resilience management ISO 31000 Risk Management
Resilience Metrics and case study
Resilience of lifelines: Seismic Hazard
Seismic Resilience +aging transportation network
Societal Resilience
Theorical Classification of vulnerability
Transportation Networks Subjected to Hazard-Induced Bridge Damages
State of the art review
Critical infrastructure and recommendations
Interdisciplinary Resilience International
Multiple-Hazard Fragility and Restoration Model
Seismic Hazard
Grand Total

Figure 2: categories and subcategories of the articles collected as part of literature search

Task 2 – Conducting a target survey for state DOTs and cities using online survey service to evaluate the current practice and efficacy of existing bridge performance assessment tools.

In this task, a targeted survey of state DOTs and cities will be conducted to evaluate the current practice and efficacy of existing bridge performance assessment tools. The survey questionnaire will also capture agency preparedness and protocols for handling risk and resilience of bridges. The survey questionnaire will be developed with assistance from the ABC-UTC Advisory Committee, which includes representatives from state DOTs, AASHTO, FHWA and industry. In addition to providing useful information on risk and resilience framework, the survey is expected to identify topics and priorities for future research. The survey will be conducted through online service and will take about 15 minutes to complete. This is expected to increase participation and avoid overwhelming stakeholders with requests (OU to lead this effort with assistance from the FIU and UNR teams). In addition, in collaboration with the University of Oklahoma National Institute for Risk and Resilience (NIRR) and Decision Analytics Lab (DAL), a survey of stakeholders will be conducted to gain an insight of their awareness, perception, and benefits of ABC. The research team will work with the ABC-UTC leadership to identify stakeholders. The NIRR and DAL are experienced in social surveys and are equipped with the analysis tools. The survey results are expected to have broad benefits for ABC-UTC, including and beyond the scope of this project. Also, impact (safety, mobility, life cycle cost, etc.) of an existing ABC project will be determined using tools available at DAL (OU to lead this effort with FIU and UNR playing a supporting role). In some cases, strategically-designed interviews with specific professionals will be conducted for those overwhelmed with surveys to obtain more information related to the current practice and efficacy of existing bridge performance assessment tools.

<u>Description of work performed up to this period: 16%</u>

Characteristics of the Survey of existing tools and current practices:

- Executed with Assistance of ABC-UTC Advisory Committee (includes representatives from state DOTs, AASHTO, FHWA and industry).
- Providing useful information on risk and resilience framework.
- Capture protocol handling risk and resilience of bridges.
- Identify topics and priorities for future research.
- 15 min online.

Characteristics of the Survey of Stakeholders:

Collaboration with the University of Oklahoma National Institute for Risk and Resilience (NIRR) and Decision Analytics Lab (DAL), team will work with the ABC-UTC leadership to identify stakeholders.

- Gain an insight of their awareness, perception, and benefits of ABC.
- Identify stakeholders.

So far, regarding the surveys, review of literature and definitions of objective and scope have been conducted. Based on the meetings held with the OU team, theresearch team has identified that conducting some interviews with specific professionals will help to identify practices conducted in their everyday operation, which will enrich the quality of the survey. Bi-weekly meetings have been set up with the OU team, to ensure the aforementioned objectives are met.

Task 3- Development of holistic resilience and risk assessment framework of existing and new bridges under multi-hazards to emphasis on accelerated construction benefits.

In this task, the results from the abovementioned efforts will be utilized to develop a holistic resilience and risk assessment framework for existing and new bridges and the benefits of accelerated repair methods (shorter rapidity) and accelerated upgrade methods (higher robustness). The framework will be developed in a generic form for different natural and manmade hazards. The resilience will be quantified using a modified 5R-methodology described hereinbefore. These quantities will be used to develop resilience loss indicators (I_R)

Description of work performed up to this period: No progress to report at this period

Task 4- Development of a specific resilience framework.

In this task, specific resilience framework will be developed for assessing the seismic resilience of existing bridges and ABC bridge candidates such as those with self-centering capabilities. The framework will include the benefit of accelerated upgrade before the event and accelerated repair after the event on the resilience of existing bridges

Description of work performed up to this period: No progress to report for this period

Task 5- Final Report.

In this Task, full assessment of the findings from Task 1 through Task 4 will be conducted and a report will be published for risk and Resilience assessment of existing and new ABC bridge systems. The benefit from accelerated upgrade prior to an event and accelerated repair after an event will be emphasized to promote ABC to shareholders.

Description of work performed up to this period: No progress to report at this period

5. Expected Results and Specific Deliverables

- Documented state of practice related to assessment of risk and resilience of bridges nationally and internationally.
- Documented state of practice related to assessment of risk and resilience of other structures against man-made and natural hazards.
- Survey of state DOTs and cities: **Survey of existing tools and current practices**

- Survey of state DOTs and cities: **Survey of Stakeholders**
- Developing a holistic resilience and risk assessment framework for existing and new bridges, including ABC bridges with an emphasis on accelerated construction benefits.
- Developing a specific resilience framework for seismic hazard as an example of natural hazards.
- Final Report

6. Schedule

Progress of tasks in this project is shown in the table below. The calculation for the total amount of work done has been made according to the time spent and the total time for each task. The literature review was considered to be ongoing throughout the life of the project.

Item	% Completed
Percentage of Completion of this project to Date	17.5%

Research Tasks	2021												2022					
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Task 1 – Conducting a literature review on risk and resilience of roadway bridges under natural and man-made hazards.	25%					75%												
Task 2 – Conducting a target survey for state DOTs and cities using online survey service to evaluate the current practice and existing bridge performance assessment tools.				16%		84%												
Survey 1 - Survey of existing tools and current practices				16%														
Subtask 1 - Review of Literature																		
Subtask 3 - Definition of objectives and scope																		
Subtask 4 - Elaboration of Survey																		
Subtask 5 - Execution of survey																		
Subtask 6 - Analysis of information obtained																		
Survey 1 - Survey of Stakeholders				16%														
Subtask 1 - Review of Literature																		
Subtask 3 - Definition of objectives and scope																		
Subtask 4 - Elaboration of Survey																		
Subtask 5 - Execution of survey																		
Subtask 6 - Analysis of information obtained																		
Task 3- Development of holistic resilience and risk assessment framework of existing and new bridges				100%														
Task 4- Development of a specific resilience framework.										100%								
Task 5- Final Report.																100%		

Work performed

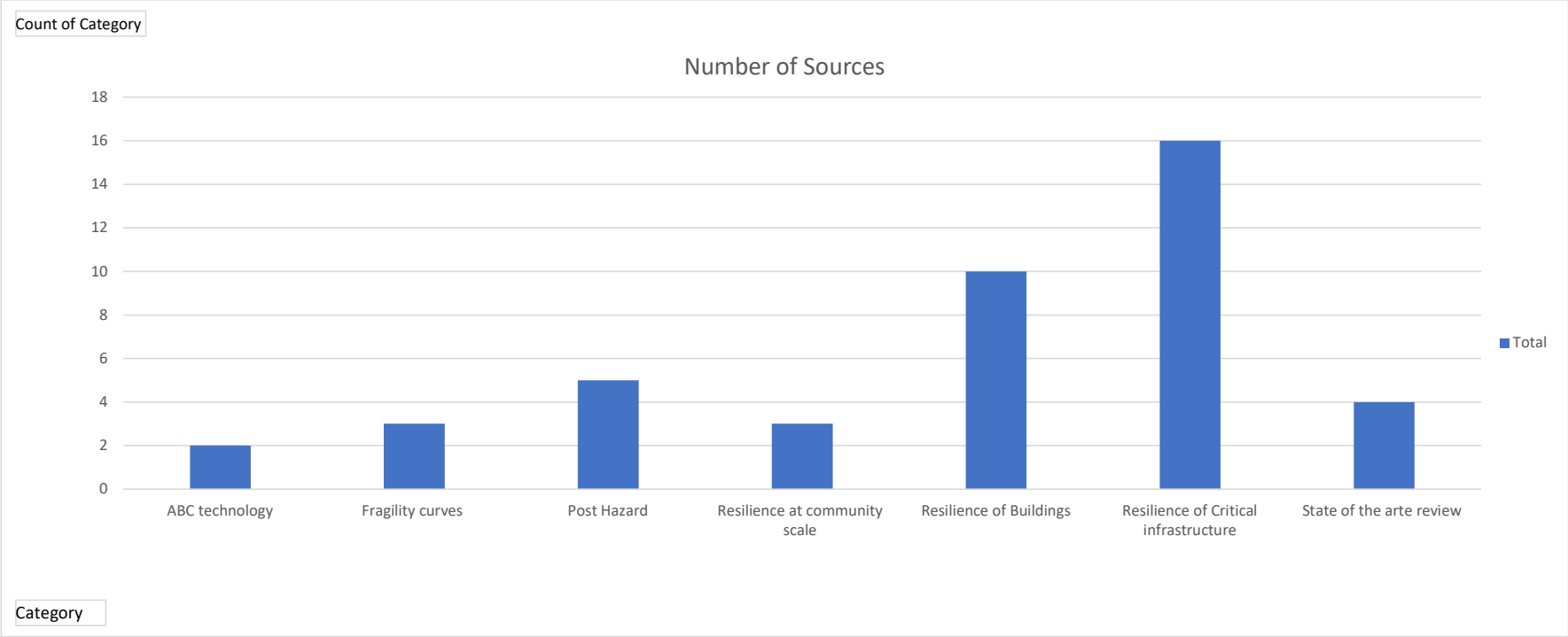
Work to be performed

7. References

1- See all sources in Appendix 1.

Appendix 1

Row Labels	Count of Category
ABC technology	2
Fragility curves	3
Post Hazard	5
Resilience at community scale	3
Resilience of Buildings	10
Resilience of Critical infrastructure	16
State of the arte review	4
Grand Total	**43**



Number	Full Reference	Authors	Country of Origin	Category	Sub-category
1	Seismic Resilience of Transportation Networks with Deteriorating Components	Alice Alipour, Ph.D., P.E., M.ASCE1; and Behrouz Shafei,	US	Resilience of Critical infrastructure	Seismis Resilience +aging trnasportation network
2	The REDI™ rating system: a framework to implement resilience-based earthquake design for new buildings	Almufti1 and M. Willford2	Us	Resilience of Buildings	resilience-based earthquake design for new buildings
3	Systems Resilience for Multihazard Environments: Definition, Metrics, and Valuation for Decision Making	Bilal M. Ayyub	US	Resilience of Critical infrastructure	Definition, Metrics, and Valuation for Decision Making
4	A stochastic computational framework for the joint transportation network fragility analysis and traffic flow distribution under extreme events	Paolo Bocchini ∗, Dan M. Frangopol ∗	Us	Resilience of Critical infrastructure	ragility analysis and traffic flow distribution under extreme events
6	Estimation of Earthquake Loss due to Bridge Damage in the St. Louis Metropolitan Area. II: Indirect Losses	David L. Enke1; Chakkaphan Tirasirichai2; and Ronaldo Luna3	US	Post Hazard	Loss estimation: FEMA and Hazus-HM Applied to bridges
7	Multiple-Hazard Fragility and Restoration Models of Highway Bridges for Regional Risk and Resilience Assessment in the United States	Ioannis Gidaris; Jamie E. Padgett; Andre R. Barbosa; Suren	US	State of the arte review	Seismeic Hazard
8	Emergency Reconstruction of Critical Transportation Infrastructure	Wilbur A. Hitchcock, Sandra Nunez, and Stephanie Watson	US	State of the arte review	Multiple-Hazard Fragility and Restoration Model
9	Lifelines in earthquakes a case study based on wellington	D. C. Hopkins, J. L. Lumsden , J. A. Norton	New Zeland	Resilience of Critical infrastructure	Resilience of lifelines: Seismeic Hazard
10	Post-hazard flow capacity of bridge transportation network considering structural deterioration of bridges	Y.-J. Lee , J. Song , P. Gardoni & H.-W. Lim	Us	Post Hazard	Flow capacity of bridges
11	Post-earthquake functionality of highway overpass bridges	K. R. Mackie and B. Stojadinović	US	Post Hazard	Functionality
12	Rapid seismic damage evaluation of bridge portfolios using machine learning techniques	Sujith Mangalathua, Seong-Hoon Hwangb, Eunsoo Choic, Jong-Su	Us & Republic of Korea	Post Hazard	Seismic Evaluation of bridge portfolio using machine learning
15	Multi-Scale Classification of Ontario Highway Infrastructure: A Network Theoretic Approach to Guide Bridge Rehabilitation Strategy	Fayez Sheikh Alzoor B. Eng., E.I.T.	Ca	Resilience of Critical infrastructure	Theorical Clasification of vulnerability
16	Resilience of Regional Transportation Networks Subjected to Hazard-Induced Bridge Damages	Richard Twumasi-Boakye, A.M.ASCE; and John O.	Us	Resilience of Critical infrastructure	Transportation Networks Subjected to Hazard-Induced Bridge Damages
17	Predicting Congestion States from Basic Safety Messages by Using Big-Data Graph Analytics	Meenakshy Vasudevan, Daniel Negron, Matthew Feltz, Jennifer	Us	Resilience of Critical infrastructure	Congestion Prediction Application of big Data
18	Functionality-fragility surfaces	Aman Karamlou and Paolo Bocchini	Us	Fragility curves	Integration of Fragility Curves and Restoration Functions for Bridges
19	Resilience-based design of urban centers: application to blast risk assessment	Shady Salem, Manuel Campidelli, Wael W. El-	Ca	Resilience of Critical infrastructure	Man made Hazard: application to blast risk assessment
20	Resilience Metrics	Valentin Zieglmeier Advisor: Dr. Heiko Niedermayer	International	Resilience of Critical infrastructure	Resilience Metrics and case study
21	Measurement Frameworks and Metrics for Resilient Networks and Services: Technical report	ENISA	Europe	Resilience of Critical infrastructure	Measurement Frameworks and Metrics
22	Probabilistic Resilience-Guided infrastructure risk Management	Shady Salem, A.M.ASCE1; Ahmad Siam, A.M.ASCE2;	US	Resilience of Critical infrastructure	Probabilistic Resilience Infrastructure
23	Redi™ Rating System: Resilience-based Earthquake Design Initiative for the Next Generation of Buildings	REDi	International	Resilience of Buildings	Organizational Resilience, Building Resilience, and Ambient Resilience
24	Volume 1 – Methodology Second Edition. Seismic Performance Assessment of Buildings	FEMA P-58-1 / December 2018	US	Resilience of Buildings	Methodology
25	Volume 2 – Implementation Guide. Seismic Performance Assessment of Buildings	FEMA P-58-2 / December 2018	US	Resilience of Buildings	mplementation Guide
26	Volume1 Methodology supporting materials. Seismic Performance Assessment of Buildings	FEMA P-58-1-SE	US	Resilience of Buildings	Methodology supporting materials
27	Volume 4 – Methodology for Assessing Environmental Impacts. Seismic Performance Assessment of Buildings	FEMA P-58-4 / December 2018	US	Resilience of Buildings	Methodology for Assessing Environmental Impacts
28	Volume 5 – Expected Seismic Performance of Code-Conforming Buildings. Seismic Performance Assessment of Buildings	FEMA P-58-5 / December 2018	Us	Resilience of Buildings	Expected Seismic Performance of Code
29	Guidelines for Performance-Based Seismic Design of Buildings	FEMA P-58-6 / December 2018	Us	Resilience of Buildings	Guidelines for Seismic Design of Buildings
30	A Guide to State-of-the-Art Tools for Seismic Design and Assessment. Building the Performance, You Need	FEMA P-58-7 / December 2018	Us	Resilience of Buildings	Tools for Seismic Design and Assessment
31	Proposed AASHTO Guidelines for Performance-Based Seismic Bridge Design	Thomas P. Murphy, Modjeski and Masters, Inc., Stuart Bennion	US	Resilience of Critical infrastructure	Guidelines for Seismic Performance Assessment of Bridges
32	ABC Manual Experience in design, fabrication and erection of prefabricated bridge elements and systems manual	Final Manual	U.S	ABC technology	Implementations of methods to be used ABC Manual
33	Innovative Bridge Designs for Rapid Renewal ABC Toolkit	HNTB Corporation Genesis Structures, Inc. Structural	US	ABC technology	ABC Toolkit for design recommendations
35	Management of Resilience in Civil Infrastructure Systems: An Interdisciplinary Approach	Nader Naderpajouh, M.ASCE, Juyeong Choi, David J. Yu,	US	State of the arte review	Interdisciplinary Resilience International
36	Seismic Fragility Methodology for Highway Bridges	Nielson, Bryant G., Department of Civil Engineering, Clemson	US	Fragility curves	Estimation of fragility curves for Bridges
37	Retrofitted Bridge Fragility Analysis for Typical Classes of Multispan Bridges	Jamie E. Padgett, and Reginald DesRoches . MEERI	US	Fragility curves	Estimation for Retrofit Bridges
39	A Scalable Framework for Assessing Seismic Resilience of Communities	Omar A. Sediek, S.M.ASCE1; S. El-Tawil, Ph.D., P.E., F.ASCE2;	US	Resilience at community scale	Seismic Resilience of Communities
40	Resilience Criteria for Seismic Evaluation of Existing Buildings: A Proposal to Supplement ASCE 31 for Intermediate Performance Objectives	David Bonowitz, S.E.1	US	Resilience of Buildings	Recommendation for seismic evaluation
41	Application of the FEMA-P58 methodology for regional earthquake loss prediction	Xiang Zeng, Xinzheng Lu, T. Y. Yang, Zhen Xu4	China	Post Hazard	Loss estimation: FEMA P-58 applied to region
43	A framework for defining and measuring resilience at the community scale: the people's resilience framework	Chris S. Renschler, Amy E. Frazier, Lucy A. Arendt, Gian-	US	Resilience at community scale	Multihazard PEOPLES Resilience
44	A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities	Michel Bruneau, Stephanie E. Chang, Ronald T. Eguchi,	US	Resilience at community scale	Seismic Resilience of Communities
45	Comparative Visualization of Predicted Disaster Resilience	Christopher W. Zobel Virginia Polytechnic Institute and State	US	Resilience of Critical infrastructure	Method for evaluation Comparing resilience
46	Conceptualizing and Measuring Resilience	Kathleen Tierney and Michel Bruneau	US	Resilience of Critical infrastructure	Concepts and mesurement of resilience
47	From Risk Management to Resilience Management in Critical Infrastructure	Bjarte Rød1; David Lange, Ph.D.2; Marianthi Theocharidou,	US, mentions several International sources	Resilience of Critical infrastructure	Resilience management ISO 31000 Risk Management
48	Fragility of transport assets exposed to multiple hazards: State-of-the-art review toward infrastructural resilience	Sotirios A. Argyroudisa,b, Stergios A. Mitoulisa, Mike G.	EU	State of the arte review	Critical infraestructure and recommendations
49	ISRA: IMPROVER societal resilience analysis for critical infrastructure	H. Rosenqvist Danish Institute of Fire and Security Technology,	London	Resilience of Critical infrastructure	Societal Resilience

Row Labels
ABC technology
ABC Toolkit for design recommendations
Implementations of methods to be used ABC Manual
Fragility curves
Estimation for Retrofit Bridges
Estimation of fragility curves for Bridges
Integration of Fragility Curves and Restoration Functions for Bridges
Post Hazard
Flow capacity of bridges
Functionality
Loss estimation: FEMA and Huzus-HM Applied to bridges
Loss estimation: FEMA P-58 applied to region
Seismic Evaluation of bridge portfolio using machine learning
Resilience at community scale
Multihazard PEOPLES Resilience
Seismic Resilience of Communities
Resilience of Buildings
Expected Seismic Performance of Code
Guidelines for Seismic Design of Buildings
Methodology
Methodology for Assessing Environmental Impacts
Methodology supporting materials
Implementation Guide
Organizational Resilience, Building Resilience, and Ambient Resilience
Recommendation for seismic evaluation
resilience-based earthquake design for new buildings
Tools for Seismic Design and Assessment
Resilience of Critical infrastructure
Concepts and measurement of resilience
Congestion Prediction Application of big Data
Definition, Metrics, and Valuation for Decision Making
Guidelines for Seismic Performance Assessment of Bridges
Man made Hazard: application to blast risk assessment
Measurement Frameworks and Metrics
Method for evaluation Comparing resilience
Probabilistic Resilience Infrastructure
fragility analysis and traffic flow distribution under extreme events
Resilience management ISO 31000 Risk Management
Resilience Metrics and case study
Resilience of lifelines: Seismic Hazard
Seismic Resilience +aging transportation network
Societal Resilience
Theorical Classification of vulnerability
Transportation Networks Subjected to Hazard-Induced Bridge Damages
State of the art review
Critical infrastructure and recommendations
Interdisciplinary Resilience International
Multiple-Hazard Fragility and Restoration Model
Seismic Hazard
Grand Total

Research Tasks	2021												2022					
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Task 1 – Conducting a literature review on risk and resilience of roadway bridges under natural and man-made hazards.			25%									75%						
Task 2 – Conducting a target survey for state DOTs and cities using online survey service to evaluate the current practice and existing bridge performance assessment tools.				16%			84%											
Survey 1 - Survey of existing tools and current practices				16%														
Subtask 1 - Review of Literature																		
Subtask 3 - Definition of objectives and scope																		
Subtask 4 - Elaboration of Survey																		
Subtask 5 - Execution of survey																		
Subtask 6 - Analysis of information obtained																		
Survey 1 - Survey of Stakeholders				16%														
Subtask 1 - Review of Literature																		
Subtask 3 - Definition of objectives and scope																		
Subtask 4 - Elaboration of Survey																		
Subtask 5 - Execution of survey																		
Subtask 6 - Analysis of information obtained																		
Task 3- Development of holistic resilience and risk assessment framework of existing and new bridges									100%									
Task 4- Development of a specific resilience framework.											100%							
Task 5- Final Report.																	100%	

Work performed
Work to be performed