MANUALS AND REPORTS ON
ENGINEERING PRACTICE 146

Objective Resilience
Policies and Strategies

ASCE

Edited by
Mohammed M. Ettouney, Ph.D., P.E.

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Objective Resilience

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Objective Resilience

Policies and Strategies

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Edited by
Mohammed M. Ettouney, Ph.D., P.E.

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MANUALS AND REPORTS ON ENGINEERING PRACTICE

(As developed by the ASCE Technical Procedures Committee, July 1930, and revised March 1935, February 1962, and April 1982)

A manual or report in this series consists of an orderly presentation of facts on a particular subject, supplemented by an analysis of limitations and applications of these facts. It contains information useful to the average engineer in his or her everyday work, rather than findings that may be useful only occasionally or rarely. It is not in any sense a "standard," however, nor is it so elementary or so conclusive as to provide a "rule of thumb" for nonengineers.

Furthermore, material in this series, in distinction from a paper (which expresses only one person's observations or opinions), is the work of a committee or group selected to assemble and express information on a specific topic. As often as practicable, the committee is under the direction of one or more of the Technical Divisions and Councils, and the product evolved has been subjected to review by the Executive Committee of the Division or Council. As a step in the process of this review, proposed manuscripts are often brought before the members of the Technical Divisions and Councils for comment, which may serve as the basis for improvement. When published, each manual shows the names of the committees by which it was compiled and indicates clearly the several processes through which it has passed in review, so that its merit may be definitely understood.

In February 1962 (and revised in April 1982), the Board of Direction voted to establish a series titled "Manuals and Reports on Engineering Practice" to include the manuals published and authorized to date, future Manuals of Professional Practice, and Reports on Engineering Practice. All such manual or report material of the Society would have been refereed in a manner approved by the Board Committee on Publications and would be bound, with applicable discussion, in books similar to past manuals. Numbering would be consecutive and would be a continuation of present manual numbers. In some cases of joint committee reports, bypassing of journal publications may be authorized.

A list of available Manuals of Practice can be found at http://www.asce.org/bookstore.

DEDICATION

This objective resilience manual of practice is dedicated to the essential workers who are exposed daily to the dangers of the COVID-19 pandemic. Included among the many groups of workers are the following: healthcare personnel, first responders, public safety officers, correction facility workers, food and agriculture, grocery store workers, teachers, US postal service workers, public transit workers, and many more people who work tirelessly to maintain a sense of normalcy in these unprecedented times.

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BLUE RIBBON PANEL
(In Alphabetical Order)

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PREFACE

Engineering is a balance between analysis and design. Objectivity forms, mostly, the basis of mathematics and science, which form, mostly, the basis of analysis. Subjectivity forms, mostly, the basis of art, intuition, and imagination, which form, mostly, the basis of design (see Figure 1). Achieving a proper balance between subjectivity and objectivity during

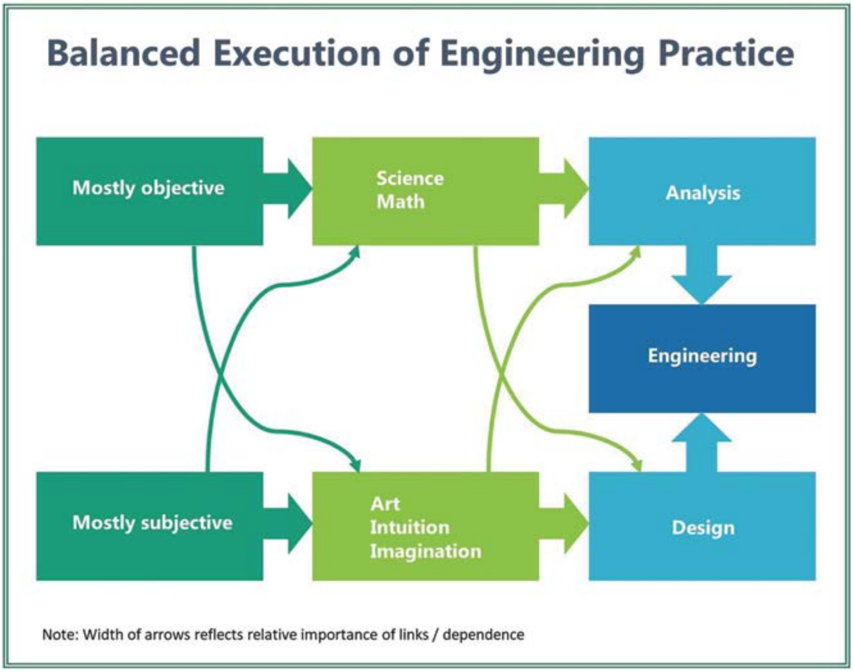

Figure 1. Balanced Execution of Engineering Practice.

the engineering process will ensure an optimal product. This is true especially for complex products that have multitudes of different types of components. Admittedly, community and asset resilience is a complex issue, and as such dealing with it from the engineering viewpoint will require a proper balance between objective and subjective processing.

The Objective Resilience Committee (ORC) of the Engineering Mechanics Institute (EMI) of ASCE was formed in 2015 to help achieve a balanced resilience treatment, especially from an objective viewpoint. Soon after its formation, the ORC initiated the development of an Objective Resilience Manual of Practice (OR-MOP) in 2016. The main objective of the OR-MOP is to provide a comprehensive basis of recommended practices that can help enhance community and asset resilience, while emphasizing the objective side of such practices. The developers of the OR-MOP quickly realized that because of the wide-ranging extent of community and asset resilience, the OR-MOP needed to split its focus into four basic categories: (1) Policies and Strategies, (2) Objective Processes, (3) Technology, and (4) Applications.

This book examines policies and strategies related to community and asset resilience. It aims at providing a comprehensive set of practices, after presenting and discussing the basis for these practices. It is recognized that this OR-MOP is limited, given the limiting factors of space and time, especially in view of the aforementioned wide range extent of resilience. However, the developers hope that the OR-MOP can be used as a guide in developing additional MOPs that would address additional aspects of resilience.

The development of the OR-MOP took almost five years. Many worked tirelessly on this project. This includes the authors of the contributing chapters, the external Blue Ribbon Panel, which independently reviewed the manuscript, and the ASCE Publications editors who provided valuable insights and feedback. Special thanks to Dr. Amar Chaker, the EMI director, for his efforts and help without which this OR-MOP could not have been possible.

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February 2021. West New York, New Jersey

INTRODUCTION

There are several popular definitions for resilience, including NIAC (2009), the NSC (2011), or the Office of the Press Secretary (2013). For example, NIAC (2009), defined infrastructure resilience as follows:

> Infrastructure resilience is the ability to reduce the magnitude and/or duration of disruptive events. The effectiveness of a resilient infrastructure or enterprise depends upon its ability to anticipate, absorb, adapt to, and/or rapidly recover from a potentially disruptive event.

As defined, resilience represents a major issue for society, given the magnitude of disaster costs of different kinds. Recognizing the needs of society to build and sustain resilient assets and communities, stakeholders (e.g., federal, state, and local officials, business owners, professionals, educators, and researchers) devoted considerable effort, time, and expense examining asset and community resilience. Given the wide range of factors that affects resilience, knowledge gaps of the subject are still significant. Similar to most important topics, treatment, handling, and communicating resilience-related matters started with a subjective basis. Objective developments lagged their subjective counterparts; however, these developments have been gaining momentum in the last few years. One primary reason for the elevated interest in resilience-related objective processes is that without adequate objectivity, it will remain difficult to provide optimal policies and strategies that aim at delivering practical asset and community resilience at reasonable costs.

Recognizing the needs for comprehensive and practical objective views of asset and community resilience, the Objective Resilience Committee (ORC) of the Engineering Mechanics Institute (MEI) of ASCE embarked on developing an Objective Resilience Manual of Practice (OR-MOP). The

MOPs of ASCE aim at providing discussions, overviews, developments, and/or best practices concerning different topics. To better attain the stated goals, the OR-MOP endeavors to explore and discuss some of the many issues regarding objective resilience. The OR-MOP also strives to provide best practices sections in all the resilience-related subjects it covers. The OR-MOP attempts to address the intersection of three different areas: resilience (*Re*), civil infrastructure (*CI*), and objective processes (*OP*), see Figure 1. In a set-theory formalism, we can express OR-MOP as

$$OR - MOP \equiv Re \cap CI \cap OP \tag{1}$$

Because of the different nature of the chapters of the OR-MOP, we expect that the extent of their treatment of *OP* would vary.

To cast as wide a net for resilience-related objective issues as possible, which is not an easy task in itself, the OR-MOP is subdivided into four books. Each book will examine objective resilience from different viewpoints. Figure 2 illustrates the general subjects of the four books.

This book, Policies and Strategies, is the first book in the OR-MOP collection. The main objective of the book is to explore different policies and

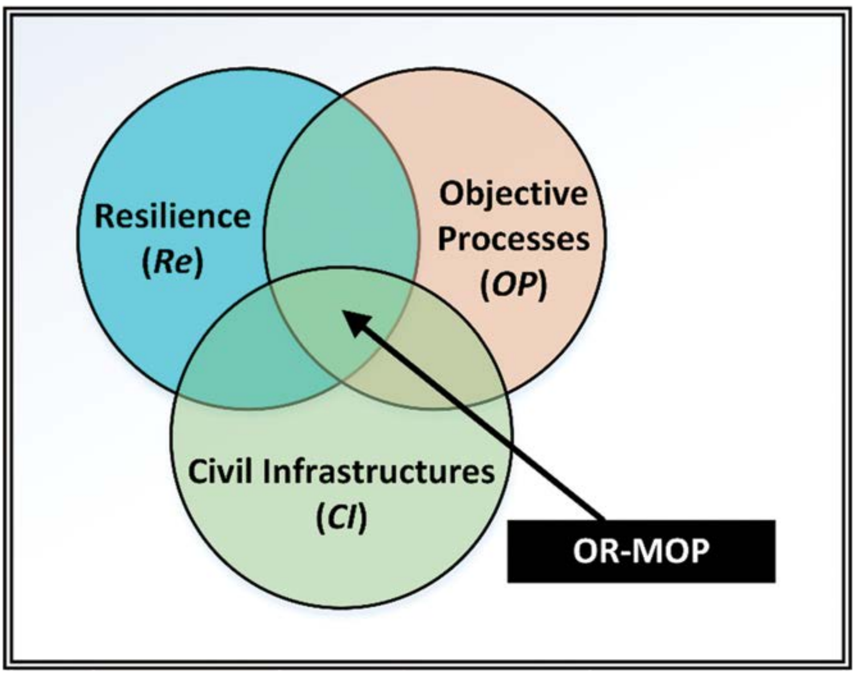

Figure 1. Confluence of domains of the OR-MOP.

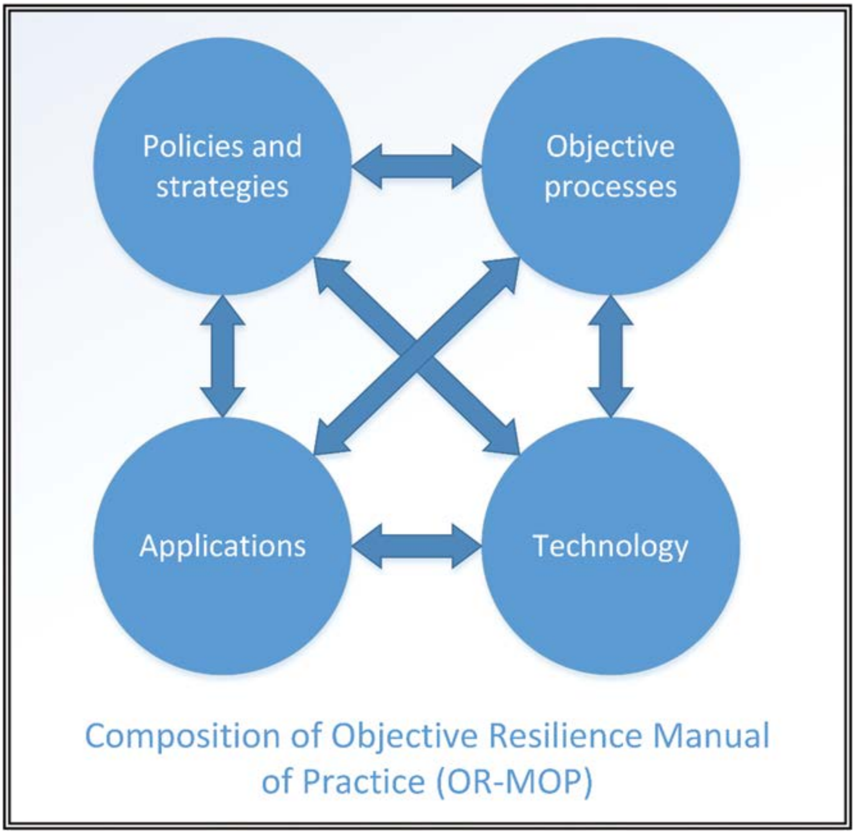

Figure 2. Composition of the OR-MOP.

strategies that can provide for resilient assets and communities. Recognizing that any successful objective process needs to start with the definitions of its subjects, we offer an overview of the many definitions of resilience in the first chapter of the OR-MOP. The chapter also introduces a unifying theory for resilience definitions (TRDs) regarding the interrelationships between the components of some of the popular resilience definitions. The TRD should streamline objective applications of resilience. Chapters 2 through 6 provide different outlooks of policies and strategies, as applied to resilience. Chapters 2 through 4 explore relevant policies and strategies of organizations, codes and standards, and the federal government, respectively. Chapter 5 presents a review of objective modeling considerations from policy/strategy viewpoints. Chapter 6 offers a discussion of resilience management. All chapters will propose a set of recommended practices at the conclusion of each chapter. See Figure 3 for a map of the organization of the book.

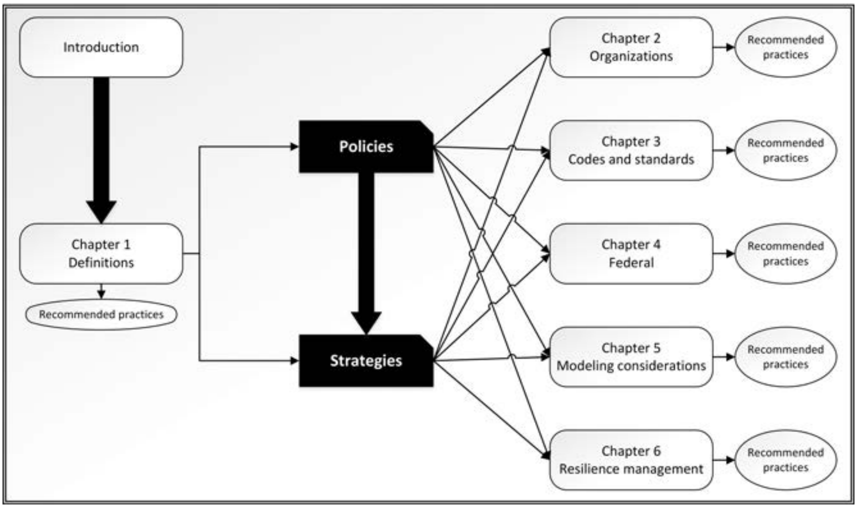

Figure 3. Map of this book (policies and strategies).

The intended readers of this OR-MOP include all civil infrastructure stakeholders, which may broadly include the following:

- Public and private civil infrastructure organizations (transportation, water resources, bridges, health care, and so on);
- City, county, and state officials;
- Emergency managers;
- Public safety personnel;
- Facility managers;
- Security consultants;
- Engineers, architects, and other design professionals;
- Educators; and
- Researchers.

Although there are wide range of objective complexities covered in the chapters, a deep knowledge of these objective topics is not required to achieve familiarity and benefit from the content. For readers who may not have the time to go in depth in each subject matter, it is suggested that they initially become familiar with the "recommended practices" at the end of each chapter. Each reader can then look at the chapter in depth to learn the reasonings/sources of these recommended practices.

Note that ASCE Manuals of Practice (MOPs) are developed by ASCE technical committees, such as the ORC, under the direction of an ASCE sponsor such as the Engineering Mechanics Institute (EMI). The distinguishing characteristic of an MOP, including this one, is that each one undergoes peer review by a Blue Ribbon Panel of experts before final approval is sought from the appropriate executive committee. Thus, the peer review by the Blue Ribbon Panel gives added weight to the MOP.

Mohammed M. Ettouney, Ph.D., P.E., F.AEI, Dist.M.ASCE

REFERENCES

NIAC (National Infrastructure Advisory Council). 2009. *Critical infrastructure resilience final report and recommendations*. Washington, DC: NIAC.

NSC (National Security Council). 2011. "Presidential Policy Directive/ PPD-8: National Preparedness." *Presedential Policy Directive*. Accessed May 26, 2018. https://www.dhs.gov/presidential-policy-directive-8-national-preparedness.

Office of the Press Secretary. 2013. "Presidential Policy Directive/PPD-21: Critical infrastructure security and resilience." *Presedential Policy Directive*. Accessed October 20, 2019. https://www.dhs.gov/sites/default/files/publications/PPD-21-Critical-Infrastructure-and-Resilience-508.pdf.

CHAPTER 1
ON THE DEFINITION OF RESILIENCE

S. Gerasimidis, M. Ettouney

1.1 INTRODUCTION

Natural and human-made hazards in recent years have led to disasters causing significant damage to communities and their infrastructure. The associated losses with these disasters have illustrated the need for designing civil infrastructure that can withstand such events with minimum disruption. The approach of investigating civil infrastructure against disasters in terms of losses and consequences, continuation of operations, and time to recovery (The terms "time to recovery," "rapid recovery," or just "recovery" have been used by different authors. We will use them interchangeably for the remainder of this chapter.) has been widely known as "infrastructure resilience." However, because several researchers and agencies have approached infrastructure resilience from various viewpoints, it is considered beneficial to provide a closer look at the definition of the term "resilience." This is the main objective of this chapter and one of the goals of the current Manual of Practice.

This chapter is not intended to be a complete inventory of all the definitions of resilience that have appeared in the literature. Not only would this be a pointless long inventory of definitions, it is the authors' opinion that it would lead to an outcome opposite of the intended one. The intention of the authors is to highlight some important definitions and identify common patterns overarching almost all definitions. Along these lines, this chapter does not aim at adding one more definition to the ones that already exist in the literature. The approach adopted herein is to provide useful key properties and common components among all measurements and definitions of resilience that can describe the concept of resilience for infrastructure systems, distinguishing resilience from