MANUALS AND REPORTS ON
ENGINEERING PRACTICE 149

Objective Resilience
Applications

ASCE

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

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Objective Resilience

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Objective Resilience

Applications

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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)

Joseph Brennan, R.A. (New York), AIA, is an architect and digital practice evangelist who has worked on projects in various capacities for SHoP Architects, Populous, and Gensler. In addition, he is currently an adjunct assistant professor at Columbia University's Graduate School of Architecture, Planning, and Preservation and has taught design technology–focused courses at various institutions in New York. In addition to practice and teaching, Joseph has mentored students at Columbia University, as well as emerging businesses through the New Museum's New Inc. Incubator program.

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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

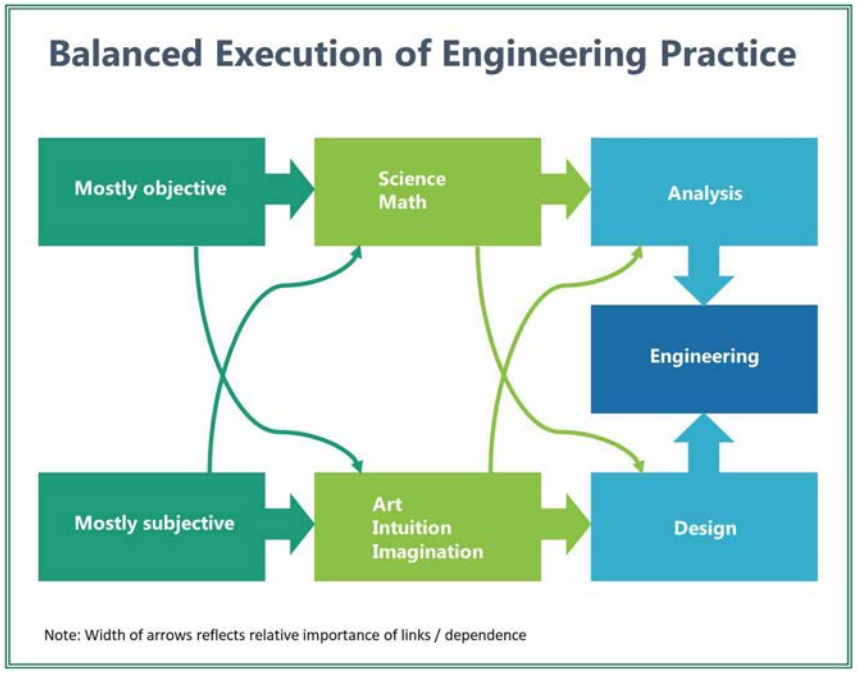

Figure 1. Balanced Execution of Engineering Practice.

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 some applications related to community and asset resilience. It aims at providing a comprehensive set of practices, after presenting and discussing the basis for those 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.

Mohammed M. Ettouney, Ph.D., P.E., F.AEI, Dist.M.ASCE
February 2021. West New York, New Jersey

INTRODUCTION

There are several popular definitions for resilience, including NIAC (2009), NSC (2011), or Office of the Press Secretary (2013). For example, NIAC (2009), defines 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 (for example, 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 behind 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 need for comprehensive and practical objective views of asset and community resilience, the Objective Resilience Committee (ORC) of the Engineering Mechanics Institute (EMI) 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 follows:

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

Owing to 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 examines objective resilience from different viewpoints. Figure 2 illustrates the general subjects of the four books.

This book on Applications discusses different applications of the resilience of assets and communities from an objective viewpoint. The first

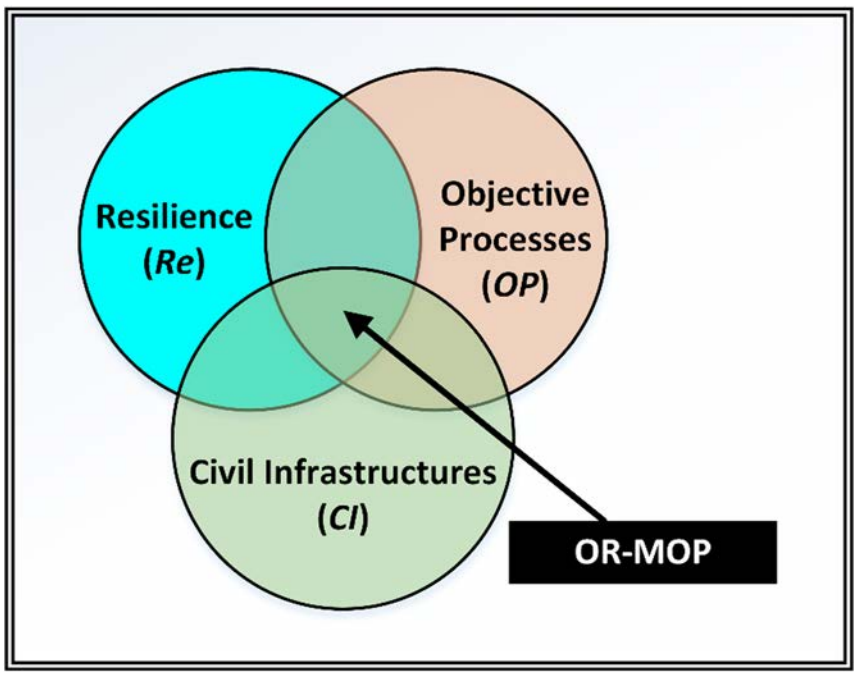

Figure 1. Confluence of domains of the OR-MOP.

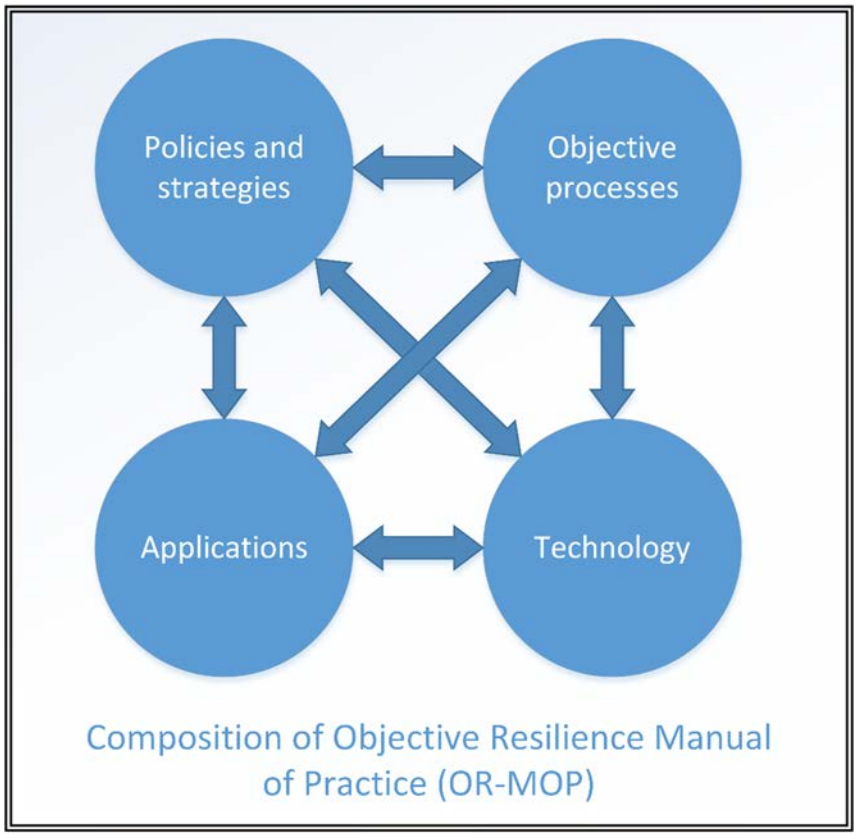

Figure 2. Composition of the OR-MOP.

three chapters explore community resilience. Chapter 1 investigates methods related to community resilience. Chapter 2 discusses objective processes as applied to blast hazard resilience as applied to community. Chapter 3 offers a case study of pandemics/healthcare of communities. Chapter 4 investigates the confluence of two important resilience-related applications: transportation systems and climate. The chapter looks at the resilience of transportation systems as severe climate-related hazards impact them. Chapter 5 provides an overview of the resilience of rapid transit systems (*RTS*) from several viewpoints, including multidisciplines, multihazards, operations, resources, as well as several man-made and natural hazards. Chapter 6 offers a study of climate resilience in relation to civil infrastructure. As expected from the definitions of resilience, its applications to assets and communities are numerous. A single book, or a series of books, cannot cover all of them. It is duly recognized that this book is devoted to only a small fraction of practical applications, but these

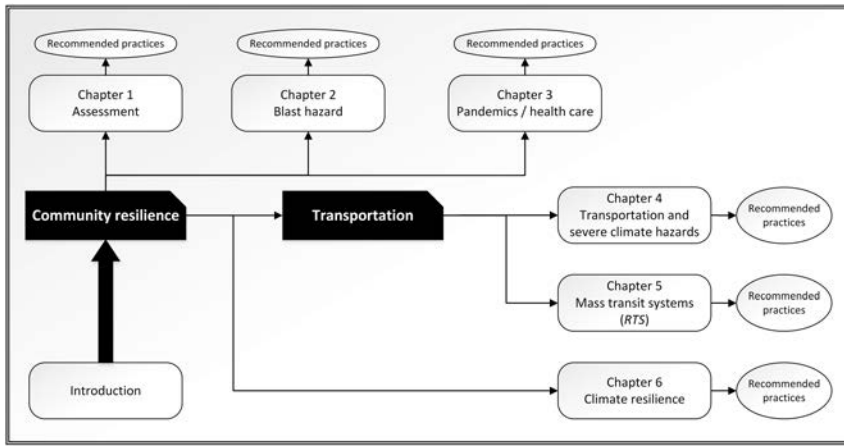

Figure 3. Map of this book (Applications).

may serve as templates for other applications. All chapters present a list of recommended practices at the conclusion of each chapter. See Figure 3 for a map of the organization of the book.

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

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

Although a wide range of objective complexities are 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 into 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 a 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.

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CHAPTER 1

TOWARD COMMUNITY RESILIENCE ASSESSMENT

Mohammad Aghababaei, Maria Koliou

1.1 EVOLUTION OF COMMUNITY RESILIENCE

Various systems form a community, including lifelines, critical infrastructure, households, and businesses, to name a few (Koliou et al. 2020). The first efforts in studying community resilience against natural disasters were on the components of a community rather than the whole parts of a community. In this chapter, a number of representative studies on the resilience assessment of the individual systems/components of a community are discussed. A summary of the reviewed literature is presented in Table 1-1.

Cimellaro et al. (2010b) studied the resilience of hospitals as critical infrastructure against seismic hazards. This study first defined the functionality of a hospital unit based on the waiting time that a patient who needs assistance spends. Later, they defined the functionality at the *community level* by considering a network of hospitals based on the quality of life which is expressed by the total number of healthy people after the disaster normalized by the total number of healthy people before the event. Using a set of sequential models, including intensity model, response model, fragility models, seismic loss models, as well as seismic resilience models, Cimellaro et al. (2010b) presented the resilience assessment procedure of a hospital network in the city of Memphis, Tennessee.

Adams et al. (2012) focused on the resilience of the transportation network by proposing two resilience measures to show the change in the performance of the network after a disaster. This study used geospatial truck location data that were collected from Freight Performance Measurement Initiatives to quantify this resilience measure. These two