

# Modular Building Construction

Utilizing modern industrial technology, modular homebuilding offers the promise of building a higher quality home, faster and at a lower cost. Dr. Mullens uses his 20 years of experience in the industry to examine the theory and practice of modular homebuilding, identifying its strengths and weaknesses and introducing a structured engineering design approach for configuring a high performance modular factory. The book integrates three invaluable sources of knowledge: 1) the practices and experience of current modular producers, many of whom are industry pioneers who helped create and develop the industry, 2) emerging best business practices, such as lean production and mass customization, that are transforming the industry, and 3) current scientific research findings that provide additional insight. The goal of this book is to equip stakeholders inside and outside the industry - factory designers, product designers, operating managers, investors, and researchers - so they can design and operate high performance modular factories. This book is directed to several groups: 1) industry professionals that are responsible for owning, designing and operating a modular factory, 2) advanced undergraduate and graduate students that are studying residential construction, construction science, construction

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management, building technology or industrial engineering and who are enrolled in courses addressing prefabricated homebuilding, and 3) faculty and students that are engaged in academic research involving prefabricated homebuilding. The book is rich in technical detail. Graphs of benchmarking results document production performance across the industry. Individual production processes are described. A conceptual Value Stream Map is developed to show how product can flow between production processes to create the overall production system. Common production layouts are provided with commentary, including material handling and storage options. Numerous photos are used to document layout and equipment choices.

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infancy. Good design requires a knowledge of modular production, installation and interface issues and also an understanding of the economics and client-related benefits which influence design decisions. Looking at eight recent projects, along with background information, this guide gives you coverage of: generic types of module and their application vertical loading, stability and robustness dimensional and spacial planning hybrid construction cladding, services and building physics fire safety and thermal and acoustic performance logistical aspects – such as transport, tolerances and safe installation. A valuable guide for professionals and a thorough introduction for advanced students.

The Modular Building Institute (MBI) along with Clemson University developed Introduction to Commercial Modular Construction over two years with the goal of introducing the reader to an innovative and exciting construction method. This book discusses the modular building process compared to traditional site-built construction and is designed to help the reader understand terminology and concepts of modular building including client needs, design, fabrication, transportation, and installation.

Design in Modular Construction CRC Press  
The Future of Modular Architecture presents an unprecedented proposal for mass-customized mid- and high-rise modular housing that can be

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manufactured and distributed on a global scale. Advocating for the adoption of open-source design based on a new modular standard, the book shows how the construction industry and architectural practice may soon be radically reshaped. By leveraging the existing intermodal freight transport system, global supply chains can be harnessed to realize the long-held promise that housing will be a well-designed and affordable industrial product. We are on the cusp of a transformative change in the way we design and build our cities. Author David Wallance argues that modular architecture is profoundly intertwined with globalization, equitable urbanism, and sustainable development. His book addresses these timely issues through a specific approach grounded in fundamental concepts. Going beyond the individual modular building, Wallance forecasts the emergence of a new type of design, manufacturing, and construction enterprise. Written in an approachable style with illustrated examples, the book is a must read for professionals in architecture and design, city planning, construction, real estate, as well as the general reader with an interest in these topics.

Despite the relative simplicity of design and construction of modular single-family dwellings, the same cannot be stated for multi-story modular buildings, especially in relation to structural modeling and design of these buildings. There is potential for

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tackling complexity of these projects by leveraging a successful technology and process that is being widely adopted in other sectors of construction industry, and that is Building Information Modeling (BIM). Structural analytical modeling is one of the areas that can benefit from BIM to enhance the design quality; reduce time and cost of the design; and mitigate the complex design activities. Because of lack of interoperability between tools, BIM users cannot take advantage of this BIM use properly, especially in modular building projects that their special needs are not addressed in the currently available information exchange standards. The primary goal of the proposed research is to develop an information framework and its supporting infrastructure to encourage design and construction of mid- and high-rise buildings using factory-built modular units. Achieving this would provide the industry with an option for economical, energy efficient, sustainable, and more affordable construction. In this research, product-related information that may be generated or used at different stages of projects is studied. In addition, process-related information flow throughout project phases is investigated. Moreover, interpretation of structural design/analysis model of these buildings from their architectural building information model is researched. This research has been carried out through accomplishing several objectives. First the

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Product Architecture Model (PAM) for multi-story modular buildings was developed. The PAM is a structured breakdown of building elements and their related attributes and properties. The next objective was information exchange standardization in these projects focusing mainly on structural aspects. To achieve this, an Information Delivery Manual (IDM) and Model View Definitions (MVDs) were developed based on the characteristic and workflow of modular building projects. To achieve the first two objectives, a comprehensive literature review was carried out, and a series of site visits and interviews with industry experts were conducted. The final objective was to facilitate the structural design of complicated structures of modular buildings by developing a mechanism and a supporting platform to interpret structural design/analysis model of modular buildings directly from the architectural BIM. Although the developed PAM, IDM and MVD are focused on structural and general architectural aspects of modular buildings, they could be expanded and/or modified to supports other BIM application areas in these projects. The methodology proposed in this research for development of information exchange standards could be used for representation of current information exchange standards to come up with an integrated set of standards for building industry. This would be achieved as a result of using the same PAM for development of the information

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exchange standards. In addition, the interpretation methodology presented for generation of modular buildings could be implemented in other engineering design/analysis areas in both modular and site-built construction. Implementation of the Interpreted Information Exchange (IIE) concept can significantly facilitate engineering analysis BIM uses by decreasing implementation cost of MVDs in BIM authoring tools and automating the model modifications that are required to make an imported model ready for analysis. Moreover, the platform developed for testing the structural model interpretation process is a general purpose platform, which could be utilized for all-purpose BIM information extractions and implementation of different automated interpreted information exchanges.

This book highlights current research and developments in the area of Structural Engineering and Construction Management, which are important disciplines in Civil Engineering. It covers the following topics and categories of Structural Engineering. The main chapters/sections of the proceedings are Structural and Solid Mechanics, Construction Materials, Systems and Management, Loading Effects, Construction Safety, Architecture & Architectural Engineering, Coastal Engineering, Foundation engineering, Materials, Sustainability. The content of this book provides necessary

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knowledge for construction management practices, new tools and technologies on local and global levels in civil engineering which can mitigate the negative effects of built environment.?

Research institutions have or are planning to build, expand and renovate animal research facilities to keep up with the demands of biomedical research caused in part by growth in the use of genetically altered rodents and the upsurge of research in infectious diseases. Properly designed facilities greatly facilitate effective management and high-quality day-to-day animal care that is required to optimally support animal research and testing. There are multiple solutions to address the myriad of factors that influence the design and construction of animal research facilities. There is no “best design applicable for all facilities and arguably not even a single “best design for a given facility. For this reason, *Planning and Designing Research Animal Facilities* is not intended to be a “how to book. The goal is to cover the basic programmatic requirements of animal research facilities, provide ideas for meeting those requirements while, hopefully, stimulating the creative process in which designers in consultation with those who work in animal research facilities generate even better ideas. That is how progress has been made and will continue to be made. Facilitates communication between the parties involved in planning and

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designing animal facilities by providing contemporary information, and stimulating creativity that will help lead to wise decisions and advance the knowledge base for planning, design and constructing animal research facilities

For a number of years, modular construction — the use of prefabricated elements in architecture — has once again become a subject of lively discussion and debate. Long written off as monotonous, today's building components are actually highly differentiated and capable of supporting and enhancing the architect's creativity. Numerous structures work with prefabricated components; for single-family homes the figure is ninety-eight percent, and modular systems are available that meet high aesthetic standards. This book provides an overview of the various different systems and their possible uses, particularly in the areas of housing, office, and industrial buildings. It explains the processes and components of modular construction and the behavior of the various materials when this construction approach is used. The authors offer strategies for planning and designing with prefabricated systems so that the architect can use them productively. Numerous drawings explain the principles of modular construction, while built examples forge a link between those principles and the practical activity of building.

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As we stand on the cusp of a fundamental restructuring of the housing and building industries, this book provides timely insights into the promise of prefabricated housing. The idea of a more industrialised approach to house building is not a new one: since the 19th century, designers, inventors, engineers, builders, developers, and entrepreneurs have all been fascinated by the idea of the factory-built, modular home. But international housing affordability crises, emerging technologies, and concerns for more sustainable building practices have given a new urgency to the need to transform building construction in the 21st century. Richly illustrated and drawing on historical examples and contemporary design studies, the book takes the reader through the foundations of prefab, leading up to a discussion of contemporary problems and opportunities. It includes a broad international survey of leading companies and their products, and draws on research from an international team of experts in the field. This book suggests a future scenario for industrialised house building that will both challenge the existing industry and stimulate the public imagination.

This volume presents a compilation of research works in civil engineering. All manuscripts in this volume were presented during the 2nd International Conference on Architecture and Civil Engineering (ICACE 2018) which was held at Parkroyal Hotel,

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Penang, Malaysia on 09–10 May 2018. The editor(s) of the proceeding would like to express the utmost gratitude and thanks to all reviewers in the technical team for making this volume a success.

The classic visual guide to the basics of building construction, now with a 3D digital building model for interactive learning For over three decades, Building Construction Illustrated has offered an outstanding introduction to the principles of building construction. This new edition of the revered classic remains as relevant as ever, providing the latest information in Francis D.K. Ching's signature style. Its rich and comprehensive approach clearly presents all of the basic concepts underlying building construction. New to this edition are digital enhancements delivered as an online companion to the print edition and also embedded in e-book editions. Features include a 3D model showing how building components come together in a final project. Illustrated throughout with clear and accurate drawings that present the state of the art in construction processes and materials Updated and revised to include the latest knowledge on sustainability, incorporation of building systems, and use of new materials Contains archetypal drawings that offer clear inspiration for designers and drafters Reflects the 2012 International Building Codes and 2012 LEED system This new edition of Building Construction Illustrated remains as relevant as ever, with the most current knowledge presented in a rich and comprehensive manner that does not disappoint. off-site fabrication Off-site fabrication is a topic of international interest and provides an effective construction technique in terms of quality, time, cost, function, productivity and safety. It is adopted worldwide as the ideal means of producing an immense array of elements from structural members, cladding units, bathrooms to fully-finished modular buildings.

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This practical book provides a complete guide to the subject, covering the principles, applications and implications for design and construction. Numerous case studies and examples from around the world illustrate the flexibility and adaptability of off-site fabrication. Practitioners, researchers and students in civil and structural engineering, building and construction, construction management and related subjects, will find the book provides excellent guidance to the technology and its effective implementation.

Many areas of knowledge converge in the building industry and therefore research in this field necessarily involves an interdisciplinary approach. Effective research requires strong relation between a broad variety of scientific and technological domains and more conventional construction or craft processes, while also considering advanced management processes, where all the main actors permanently interact. This publication takes an interdisciplinary approach grouping various studies on the building industry chosen from among the works presented for the 2nd International Conference on Construction and Building Research. The papers examine aspects of materials and building systems; construction technology; energy and sustainability; construction management; heritage, refurbishment and conservation. The information contained within these pages may be of interest to researchers and practitioners in construction and building activities from the academic sphere, as well as public and private sectors. On-site construction methods are increasingly viewed as slow, inefficient, and bad for the environment. Modern modular construction on the other hand, using off-site manufacturing and on-site installation, solves inefficiencies in traditional construction methods, allowing buildings to be ready in days rather than months. It promises to transform construction into made-to-measure structural production off-

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site, as found in advanced manufacturing. However, civil infrastructure construction currently lags behind manufacturing industries that have already embraced advanced automated processes. Advanced Design for Modular Construction presents the latest research and best practice in design for advanced modular building construction. The book describes how three-dimensional structural units can be prefabricated, assembled and finished under factory conditions. The title consists in twelve chapters covering all aspects of modular construction, including lean methodologies and techniques; intermodal transportation of building modules; accelerated responses in road transportation; performance of non-structural, beam-column and column-column connections; transport of building modules; analyses of structural robustness and reliability in modular buildings; fire performance; and composites for modular construction. This book provides state-of-the-art, practical guidance for the design of modern modular construction, allowing the completion of an entire building system offsite, speeding up, optimizing and economizing the production of civil infrastructure using the most advanced automated manufacturing processes. Presents the state-of-the art in the design of advanced modular construction Demonstrates how efficiencies can be gained from using automated manufacturing processes for modular construction Shows how modular construction speeds up, optimizes, and economizes the production of civil infrastructure Envisions the pivoting of on-site construction toward off-site made-to-measure structural production Covers each aspect of modular construction, including manufacturing, transportation, and structural integrity and robustness

"Prefab Architecture . . . is beyond theory, and beyond most of what we think we know about pods, containers, mods, and joints. This book is more than 'Prefabrication 101.' It is the Joy

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of Cooking writ large for the architecture and construction industries." —From the Foreword by James Timberlake, FAIA

## THE DEFINITIVE REFERENCE ON PREFAB ARCHITECTURE FOR ARCHITECTS AND CONSTRUCTION PROFESSIONALS

Written for architects and related design and construction professionals, *Prefab Architecture* is a guide to off-site construction, presenting the opportunities and challenges associated with designing and building with components, panels, and modules. It presents the drawbacks of building in situ (on-site) and demonstrates why prefabrication is the smarter choice for better integration of products and processes, more efficient delivery, and realizing more value in project life cycles. In addition, *Prefab Architecture* provides: A selected history of prefabrication from the Industrial Revolution to current computer numerical control, and a theory of production from integrated processes to lean manufacturing Coverage on the tradeoffs of off-site fabrication including scope, schedule, and cost with the associated principles of labor, risk, and quality Up-to-date products featuring examples of prefabricated structure, enclosure, service, and interior building systems

Documentation on the constraints and execution of manufacturing, factory production, transportation, and assembly Dozens of recent examples of prefab projects by contemporary architects and fabricators including KieranTimberlake, SHoP Architects, Office dA, Michelle Kaufmann, and many others In *Prefab Architecture*, the fresh approaches toward creating buildings that accurately convey nature and expanded green building methodologies make this book an important voice for adopting change in a construction industry entrenched in traditions of the past.

The definitive guide to measurement and estimating using NRM1, written by the author of *NRM1 The 'RICS New rules of measurement: Order of cost estimating and cost planning of*

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capital building works' (referred to as NRM1) is the cornerstone of good cost management of capital building works projects - enabling more effective and accurate cost advice to be given to clients and other project team members, while facilitating better cost control. The NRM1 Cost Management Handbook is the essential guide to how to successfully interpret and apply these rules, including explanations of how to: quantify building works and prepare order of cost estimates and cost plans use the rules as a toolkit for risk management and procurement analyse actual costs for the purpose of collecting benchmark data and preparing cost analyses capture historical cost data for future order of cost estimates and elemental cost plans employ the rules to aid communication manage the complete 'cost management cycle' use the elemental breakdown and cost structures, together with the coding system developed for NRM1, to effectively integrate cost management with Building Information Modelling (BIM). In the NRM1 Cost Management Handbook, David Benge explains in clear terms how NRM1 is meant to be used in familiar quantity surveying tasks, as well as a range of activities of crucial importance for professionals in years to come. Worked examples, flow charts, diagrams, templates and check lists ensure readers of all levels will become confident and competent in the use of NRM1. This book is essential reading for anyone working with NRM1, and is the most authoritative guide to practice available for those preparing to join the industry.

The various forms of prefabrication and structures based on building systems are enhanced by detailed technical drawings and color photographs to facilitate consideration of future architectural developments.

Written to benefit the consumer by an industry expert. Here is your guide to a successful modular building project. Get an insider's look at the complexities and tactics of the modular

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industry. Arm yourself with the information you need to make sound decisions by understanding the process from beginning to end. Stephen W. Menke spent thirty plus years in the commercial modular building industry. His extensive experience in a variety of roles serves as the framework for this one-of-a-kind guidebook! If you have been tasked with gaining more space and are considering modular buildings - this book is for you! 24 Chapters 145 Pages Including an Appendix with Valuable Project Documents. Subjects include: modular construction concepts; choosing the right modular representative and company; working with architects and engineers; codes and permitting; project planning and progression; owning vs leasing; contract and contract documents; safety; project completion and typical project pitfalls. Take your project from planning to completion with confidence using this guidebook!

Modular construction manufacturing (MCM) is superior to the current on-site construction system which is hampered by inefficiency and material and process waste. Modular buildings are potentially built through a more efficient and cost-effective method, but in the current manufacturing-based approach, a gap still exists between design and production. The increased interest in modular buildings demands special methods of design and manufacturing to support effective production operation. MCM provides opportunity to apply Lean for production efficiency in the plant. Lean is a concept first developed in the manufacturing industry which has been since adapted to the construction industry. Although the focus of Lean in both industries is the same, Lean principles vary between manufacturing and construction since these two industries differ in nature. Lean as the concept is applicable to any industries, taking into consideration that MCM has characteristics of both manufacturing and construction yet is distinct and should be seen in the class of its own. Given the

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distinct nature of MCM, the technical elements in "Lean production" and "Lean construction" are not sufficient to achieve the Lean goals for MCM industry, necessitating a modified framework by which to exploit the potential benefits of modular building. The focus of this research is to develop a framework that supports manufacturers' needs for design and which encompasses the integration of Lean into production process. In this research, Lean is adopted for the MCM industry in order to improve production process efficiency which is introduced as "Lean-Mod". To apply the proposed Lean-Mod strategies on a factory production line, an enhanced integrated approach of Building Information Modeling (BIM), Lean, and simulation is proposed. Integrating these concepts involves transferring generated data from a BIM model to the manufacturing phase, where Lean strategies are applied, and evaluating the production process scenarios through simulation modeling. The simulation model of production flow evaluates improvement from the Lean point of view and provides assessment of potential scenarios. The proposed methodology is validated by a case study--a residential modular factory located in Edmonton, Canada--and illustrates the effectiveness of the proposed methodology.

Petri nets are a well-known model for parallel systems, used for both applications and theoretical studies. They can be used for specification, modelling, and analysis, and offer a graphical representation and a clear view of concurrency. For the design of large systems, modular construction is indispensable, and considerable effort has been spent on studying the modular construction of Petri nets. This book studies the modular construction of nets, and in particular the top-down design of nets by action refinement. Suitable behavior descriptions are presented and special care is taken to justify these descriptions by showing that they are

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necessary under reasonable specification requirements. In particular, it is shown that partial-order semantics is necessary to support action refinement.

In recent decades, the rapid expansion of trade and investment among developing countries has resulted in a scenario wherein firms from developing countries account for an increasing share of capital, goods, and wealth in the global economy. Industry leaders from developing countries have observed that firms in developing countries need to identify and develop key supply chain capabilities in order to succeed in emerging markets. It is argued that customers in emerging markets are likely to have different needs and supply chain expectations as compared to customers in developed economies. Reaching into these emerging markets, understanding the customer diversity, and translating it into effective segmentation schemes are critical for the efficient design of supply chain operations. *Leadership Strategies for Global Supply Chain Management in Emerging Markets* is a pivotal reference source that provides vital research on creating efficient supply chain operations in emerging markets. While highlighting topics such as consumer behavior, global operations, and information transparency, this publication investigates the needs of consumers in emerging markets as well as the methods of designing effective operations. This book is ideally designed for supply chain managers, logistics managers, operations and warehousing professionals, industry practitioners, academicians, students, and researchers.

Modular construction uses prefabricated building components called modules, which are fabricated in a factory, transported to a site, and then assembled together to create a building. A "module" is one of the building blocks used to construct a modular building and may be comprised of a load bearing structure, MEP components, interior finishes, and exterior

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cladding. This alternate way of building using prefabricated units leads to advantages such as: faster construction, cost savings, and sustainability benefits. Historically, modular construction has predominantly been used in the development of low rise, temporary, or portable buildings. However, recently this prefabricated building technology has spread into multi-story applications and a wider range of building types such as hospitals, residential complexes, and schools. As more high-rise buildings are being built using modular construction, new structural challenges must be addressed. Lateral and gravity loads increase with height and the design of building connections and their lateral force resisting systems becomes ever more critical. Although several case studies describing modular buildings are publicly available, there is a lack of detailed scientific data explaining their structural performance. This thesis attempts to shorten the knowledge gap by investigating the effect interconnections have on the behavior of a modular building. In this study modular interconnections are defined as the connections within modular buildings which link discrete modules together allowing them to act as a single structure. Modular interconnections are a keen area of interest as their design affects the global behavior of a modular building. To understand the effect different interconnections have on the stability of a modular building, a study is conducted where several building prototypes with various interconnections are modelled and analyzed.

Refugees who are currently making their way across Europe urgently require places to live. IN common with politicians, architects were also caught unawares by the largest wave of migration since the end of the Second World War. HOwever, are tent cities and containers the only solution in creating

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cheap accommodation and a dignified home as quickly as possible for displaced persons? One issue for discussion is the need to question existing standards in relation to mass housing. BOLD and unconventional ideas are called for if the intention is to steer the debate on temporary accommodation for refugees in a new direction offering high-quality solutions. From eccentric experiments all the way to projects which have already been realised, international design teams present their work between the twin poles of unconventional developments and life-saving shelters in this compilation of case studies spanning more than 200 pages. NOT all of these are applicable to the current refugee crisis, since that which digital nomads find hip constitutes harsh reality for others. YET alongside playful follies, we can find miniature architectural structures for the homeless as well as out patient medical stations which offer a response to social problems and space shortages. THE photographic material puts forward ideas as to how more can be done than the mere assembling of containers. SHOULD we not first consider notions bordering on the absurd in order to come up with a workable solution?

Architects have been intrigued by prefabricated construction since the early twentieth century. Recent advances in design, engineering and manufacturing processes have led to a significant

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expansion in the use of pre-assembled components, which are fitted to finished structures on site.

Collectively, such processes are becoming known as "offsite construction." A ground-breaking text, *Offsite Architecture* establishes the current – and future – state of thinking in this field. A range of the most highly regarded thinkers and practitioners from around the globe share their ideas and practical findings on offsite prefabrication, examining theory and practice, opportunities and challenges, successes and failures. A timely response to the growing interest in this method, the book provides the fundamental basis for a critical, reflective approach to offsite architecture. Contributions from both academics and professionals make *Offsite Architecture* required reading for practitioners as well as students taking courses in architecture, prefabrication, construction and engineering.

An attractive, lower-cost alternative to site-built homes, factory-constructed housing is becoming increasingly popular. New, more sophisticated methods of construction and strict federal, state, and local codes have resulted in safer, more attractive, and more affordable homes. Written by a specialist with over 20 years of experience in the field, *Factory-Constructed Housing Developments: Planning, Design, and Construction* fills the gaps in existing literature on the subject. Although some information on the design of small subdivisions and

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manufactured home communities can be found scattered throughout various government documents, until now there has been no single guide to the creation of new developments. This reference assembles and cites the existing literature, and adds to it useful information from the author's two decades of practical field experience. This one-stop reference explains the planning, development, and construction processes for factory-constructed housing, including everything from the roles of municipal boards, to roads and development configurations, to water and sewerage. The book also considers factors unique to manufactured home communities and modular home subdivisions. No other single volume contains the information in this book.

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