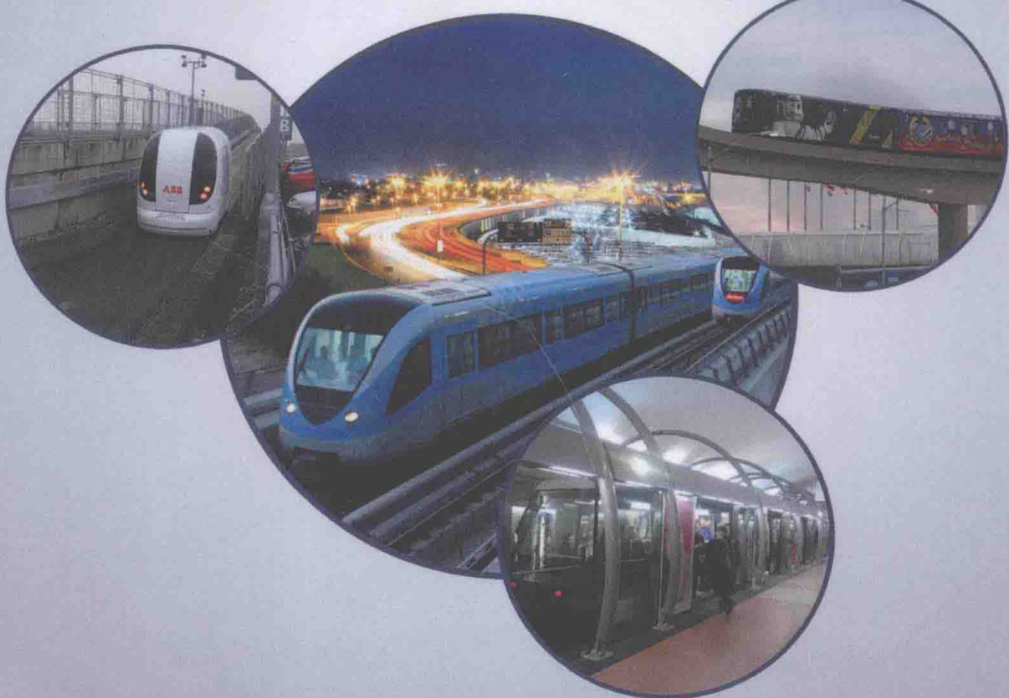
IEEE Press Series on Systems Science and Engineering

MengChu Zhou, Series Editor

Automated Transit

Planning, Operation, AND Applications



Rongfang Liu

IEEE PRESS

WILEY

AUTOMATED TRANSIT
Planning, Operation, and Applications

RONGFANG (RACHEL) LIU

Systems, Man, & Cybernetics Society
IEEE PRESS
WILEY

For general information on our other products and services or for technical support, please contact our Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Wiley also publishes its books in a variety of electronic formats. Some content that appears in print may not be available in electronic formats. For more information about Wiley products, visit our web site at www.wiley.com.

Library of Congress Cataloging-in-Publication Data is available.

ISBN: 978-1-118-89100-1

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

This book is dedicated to the three men in my life:

ZHONG:
My rock, who supports anything I am willing to explore;

LYNDALL:
My conscious, who shows me that there might be
another side to any story;

CHARLIE:
My lucky star, who makes me believe that
there are always roads under my feet ...

FOREWORD

The science of automated transit is relatively young. Although people have explored travel options since the early days of history, it is only in the last 50 years or so that engineers and scientists have unveiled transportation options that are fully automated. From driverless autos to personal rapid transit designs to full-functioning extended people mover systems, we are learning to give up the driver's seat and trust the power of smart technology.

When we began Lea+Elliott in the 1970s, specializing in automated people movers was an anomaly. Some engineers could not understand why we would focus on such a niche market. At that time, the industry was mostly focused on transporting passengers quickly, safely, and efficiently between terminals in large airports. Today, as we work on nearly every people mover system in the world, we know that the early technology provided the impetus for systems that are literally changing how we think about travel. For example, consider Honolulu, HI. Today, the City and County of Honolulu, in cooperation with the Federal Transit Administration (FTA), is implementing a 20-mile-long automated metro rail system that will serve 21 passenger stations. It will be the first automated metro light rail system in the United States since JFK AirTrain and will truly change lives for people within its reach.

In such a rapidly changing transit environment, Dr. Rongfang (Rachel) Liu is the logical person to create this book on the state of automated transit—and to show where it will lead us in the days to come. As a professional engineer, licensed planner, and professor in the Department of Civil and Environmental Engineering at New Jersey Institute of Technology, Dr. Liu brings so much more to the transit discussion. Her vast research has been published in many books, book chapters, and transportation journals. Her additional skills in modeling and expertise in intermodal research further round out her understanding of this complex and multi-faceted transportation technology. I trust that her knowledge and perspective, provided in these pages, will offer insights to help you better understand the sophisticated systems that make automated transit so fascinating. Her thoughts may well spur your thoughts which just might take automated transit technology to the next level. Enjoy!

JACK NORTON

President/CEO
Lea+Elliott, Inc.
Dallas/Fort Worth, TX

PREFACE

The idea for this book was conceived a few years ago when I wrote a book chapter titled "The Spectrum of Automated Guideway Transit and Its Applications," which is published in the *Handbook of Transportation Engineering* (Kutz, 2011). I have accumulated a large amount of information and felt that there are so much more can be said but has not been included in the chapter due to the length limit. In fact, so much was misunderstood or misconstrued for automated guideway transit (AGT) all together for the past half of a century.

As the Committee Chair for AP040: Automated Transit Systems (ATS), Transportation Research Board (TRB), I have been working with my committee members and an array of stakeholders, which include transit and Airport Automated People Mover (AAPM) operators, local and federal government agencies, and private entities such as Google, CarShare Inc., and Ride Scott. Continuing dialogs among the automated transit community made the critical needs paramount. I felt strongly that it is time to have a thorough examination of the automated transit technology development and its applications.

Furthermore, the promises and expectations created by the "future transportation" starting in 1970s need to be evaluated after more than four decades. The successful implementations of automated transit in various international locations, such as Paris, Toronto, London, and Kuala Lumpur, and the apparent lack of automated transit applications in the urban environment in the United States warrant in-depth analyses. The ultimate lessons learnt via various not so successful concepts, ideas, and programs are also valuable for an emerging new paradigm, such as automated transit or driverless vehicles, to grow and prosper.

The rapid development of driverless cars by Google and others not only grabbed the attention of the US Congress, which held a hearing on "the future role of autonomous vehicles in US transportation" in October 2013, but also created a perfect opportunity to have a thorough examination of automated transit applications and their impact and implications for our society. As pointed out by an anonymous proposal reviewer, "It is the right time to have a book on automated transit system (ATS). There are many different automated transit systems worldwide. A book on this topic will be of interest to transportation professionals, researchers, and some graduate students to learn basic concepts, technologies and successful examples related to ATS."

The basic structure of this book follows typical technology development document that begins with a brief definition of the automated transit, Chapter 1, and their historical development in Chapter 2. After a thorough description of the technical specifications in Chapter 3, the manuscript highlights a few representative applications from each sub-group of automated transit spectrum in Chapter 4. The case studies around the world not only showcase different technologies and their applications but also identify the vital factors that affect each system and performance evaluations of existing applications in Chapters 5 and 6. Chapters 7 and 8 of the the book is devoted to planning and operation of automated transit applications in both macro and micro levels. The last two chapters of the book highlight the lessons learnt from the past experiences and try to project the new paradigm shift from the current, conventional transportation systems.

ACKNOWLEDGMENTS

My sincere appreciation goes to many people who contributed directly and indirectly to the fruition of this book. First, I am indebted to many members and friends of Automated Transit Systems (ATS – AP040) Committee, previously Major Activity Center Circulation Systems, Transportation Research Board. During my 6-year term as the committee chair starting in 2008, some in-depth discussions and dialogs on the directions and structure of the committee have propelled me to explore the historical development of automated transit technology and engage wide ranges of stakeholders, which provided a rich background to shape my general view of automated transit development.

Second, I would like to express my gratitude to the visionary leaders who organized the Automated Vehicle Symposium (AVS), especially those who contributed to the Automated Transit and Shared Mobility Track (ATSM), which are co-sponsored by the same TRB ATS committee. The exponential growth in AVS attendees during the past 5 years and pointed discussions and/or arguments have instigated further research, clarification, and selection of book contents.

Next, my appreciation goes to the few selected colleagues and friends who have painstakingly reviewed the manuscript and provided valuable suggestions and improvements: Stanley E. Young, University of Maryland; William J. Sproule, Michigan Technological University; Gary Hsue, Arup, Inc.; Ingmar Andreasson, Royal Institute of Technology, Sweden; Wayne Cottrell, California State University at Pomona; Sam Lott, Kimbley Horn and Associates, Inc.; Naderah Moini, University of Illinois at Chicago; Jerry Lutin, New Jersey Transit, retired; Larry Fabian, Trans.21, Inc.; Peter Muller, PRT Consultant, LLC; Alex Lu, New York City Metropolitan Transportation Authority; Walter Kulyk, Federal Transit Administration, retired; Ruben Juster, University of Maryland; and Matthew Lash, Noblis Inc.

Last but not least, I wish to thank my colleagues in New Jersey Institute of Technology (NJIT), who granted me a 1-year paid sabbatical leave. The sabbatical leave not only shielded me from regular teaching load, daily commute, and trivia administrative duties but also liberated my mind and spirit to think deeply, reach widely, and explore freely. My sincere appreciation goes to my former students, Zhaodong (Tony) Huang, now with Ningbo University, and Hongmei Cao, now with Inner Mongolia University, who helped a great deal in compiling graphs, tables, and glossaries in conjunction with tedious document review and edit.

I have accumulated a large number of photographs, tables, and figures via previous research and project experiences and have tried to provide appropriate credit to the maximum extent possible. I regret any errors or oversights in crediting any material, if any. Of course, any other errors, omissions, and oversights are my responsibility and will be corrected once known.

RONGFANG (RACHEL) LIU

ABBREVIATIONS

AA	alternative analysis (7)
AADT	annual average daily traffic (6.3)
AAPM	airport automated people mover (2.1)
AB	automated bus (1.2)
AC	alternating current (2.4.1)
ACRP	Airport Cooperative Research Program (10.5)
AG	automated guideway (6.1)
AGRT	advanced group rapid transit (2.2)
AGT	automated guideway transit (1.2)
AGTS	automated guideway transit systems (6.3)
AHS	automated highway systems (8.3)
AIP	Airport Improvement Program (8.1)
ALRT	automated light rail transit (4.2)
APM	automated people mover (1.2)
APT	automated personal transit (1.3)
APTA	American Public Transportation Association (1.2)
ASCE	American Society of Civil Engineers (3)

ATC automatic train control (3.4)
ATSM Automated Transit and Shared Mobility (Front Matters)
ATN automated transit network (1.3.1)
ATO automatic train operation (3.4)
ATP automatic train protection (3.4)
ATS automated transit systems (1.2)
ATS automatic train supervision (3.4)
AV automated vehicle (1.3.2)
AVS Automated vehicles symposium (front matters)

BAA British Airport Authority (8.2)
BOT build operate and transfer (8.3)
BPMT billion passenger mile travelled (6.3)
BRT bus rapid transit (1.3)
BTS Bureau of Transportation Statistics (1.2)
BTRM billion train revenue miles (6.3)
BUPT billion unlinked passenger trips (6.3)
BVRM billion vehicle revenue miles (6.3)

CBTC communication-based train control (4.1.2)
CBD central business district (4.3)
CCF central control facility (3.4)
CEA cost-effectiveness analysis (6.5)
CES Consumer Electronics Show (8.2)
CFC consumer facility charge (8.1)
CCVS computer-controlled vehicle system (2.1)
CL Circle Line (4.2)
CVG Cincinnati/Northern Kentucky International Airport (5.1.1)

DB design build (8.3)
DBFO design, build, finance, and operate (8.3)
DBO design-build-operation (8.3)
DBOM design, build, operate and maintain
DBOT design-build-operate-transfer (8.3)
DC direct current (3.2)

DC destination choice (7.2)
DFW Dallas–Fort Worth International Airport (4.5)
DLB driverless bus (1.3.2)
DLLRT driverless LRT (4.2)
DLM driverless metro (1.2)
DPM downtown people mover (2.2)

EIS environmental impact statement (7)

FAA Federal Aviation Administration (8.1)
FRA Federal Railroad Administration (3.0)
FRR farebox recovery ratio (8.1)
FPS feet per second (3.1)
FPS^2 feet per second/second (5.1)
FTA Federal Transit Administration (1.3.2)

GAO General Accounting Office (1.3.1.2)
GN guideway network (7.3)
GO general obligation (8.2)
GPS Global Positioning System (1.1)
GRT group rapid transit (1.2)

HR heavy rail (6.3)

IEC International Electrotechnical Commission (1.3.1)
IVTT in vehicle travel time (7.2)

JFK John F. Kennedy (4.6)

KMPH kilometers per hour

LCC life cycle cost (5.3.3)
LHR London Heathrow Airport (2.4.2)

LIMs	linear induction motors (3.3)
LIRR	Long Island Railroad (4.6)
LPA	locally preferred alternatives (7.1.3)
LRT	light rail transit (6.3)
LRTP	long range transportation planning (7.2)
LVM	Las Vegas Monorail (4.4)

MAC	major activity centers (2.3)
MDBF	mean distance between failures (6.2)
MDT	Miami-Dade Transit (6.3)
MG	Monorail and Automated Guideway (6.1)
MPH	miles per hour (1.3.1)
MPMT	million passenger miles travelled (6.3)
MPO	metropolitan planning organization (7.2)
MR	monorail (6.1)
MRT	mass rapid transit (4.2)
MSF	maintenance and storage facility (3.6)
MTA	Maryland Transit Administration (8.1)
MTBF	mean time between failures (6.2)
MTKM	million train kilometers (6.2)
MTRM	million train revenue miles (6.3)
MTTR	mean time to repair (6.2)
MUPT	million unlinked passenger trips (6.3)
MVRM	million vehicle revenue miles (6.3)

NEL	North East Line (4.2)
NEPA	National Environmental Policy Act (7)
NFPC	National Fire Protection Code (3.4)
NHTSA	National Highway Traffic Safety Administration (1.1)
NJ TRANSIT	New Jersey Transit (8.1)
NTD	National Transit Database (2.3)
NTSB	National Transportation Safety Board (3.0)

OAK	Oakland International Airport (3.2)
OCC	operational control centers (4.1.2)

O-D origin and destination (5.2.3)
O&M operation and maintenance (3.4)
OVTT out-of-vehicle travel times (6.2)

PA public address (3.1)
PANYNJ Port Authority of New York and New Jersey (4.6)
PATH Partners for Advanced Transit and Highway (1.3)
PCM passenger car miles (6.1)
PFC passenger facility charge (8.1)
PFI private finance initiative (8.3)
PHX Phoenix International Airport (3.6)
PLMT place miles traveled (6.5)
PMT passenger miles travelled (6.1)
PPHPD passengers per hour per direction (5.2.3)
PPP public-private partnerships (8.3)
PRT personal rapid transit (1.2)

RATP Regie Autonome Des Transports Parisiens (4.1.1)
R & D research and development (8.3)
RER Reseau Express Regional (4.1.1)
ROI return on investment (8.3)
RP revealed preference (10.3)
RTA Regional Transit Authority (2.4.2)

SAE Society of Automotive Engineers (1.1)
SAV shared autonomous vehicle (7.3)
SBT Singapore Bus Transit (4.2)
SEA Seattle–Tacoma International Airport (6.2)
SFO San Francisco (3.2)
SMRT Singapore Mass Rapid Transit (4.2)
SOV single occupancy vehicle (3.0)
SP stated preference (10.3)
SS&PS Systems Safety and Passenger Security (6.3)

TIP transportation improvement programs (7.2)
TNC transportation network companies (8.3)
TOD transit oriented development (9.2)
TPA Tampa International Airport (6.2)
TRB Transportation Research Board (1.2)
TRM train revenue miles (6.1)
TVMs ticket vending machines (4.4)
SEA Tacoma International Airport (6.2)

UAACC user allocation of annualized capital cost (6.5)
UK United Kingdom (8.2)
ULTRA urban light transit (2.4.2)
UITP Union International de Tramways (6.3)
UMTA Urban Mass Transportation Administration (2.2)
UPT unlinked passenger trips (6.1)
USDOT United States Department of Transportation (7.1)
UTA Utah Transit Authority (8.1)

VAA vehicle assist and automation (1.3.2)
VAL vehicle automated léger (automatic light vehicle) (2.2)
VMT vehicle miles travelled (6.1)
VRM vehicle revenue miles (6.1)

CONTENTS