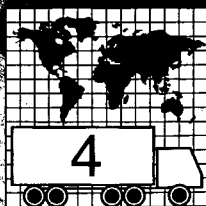
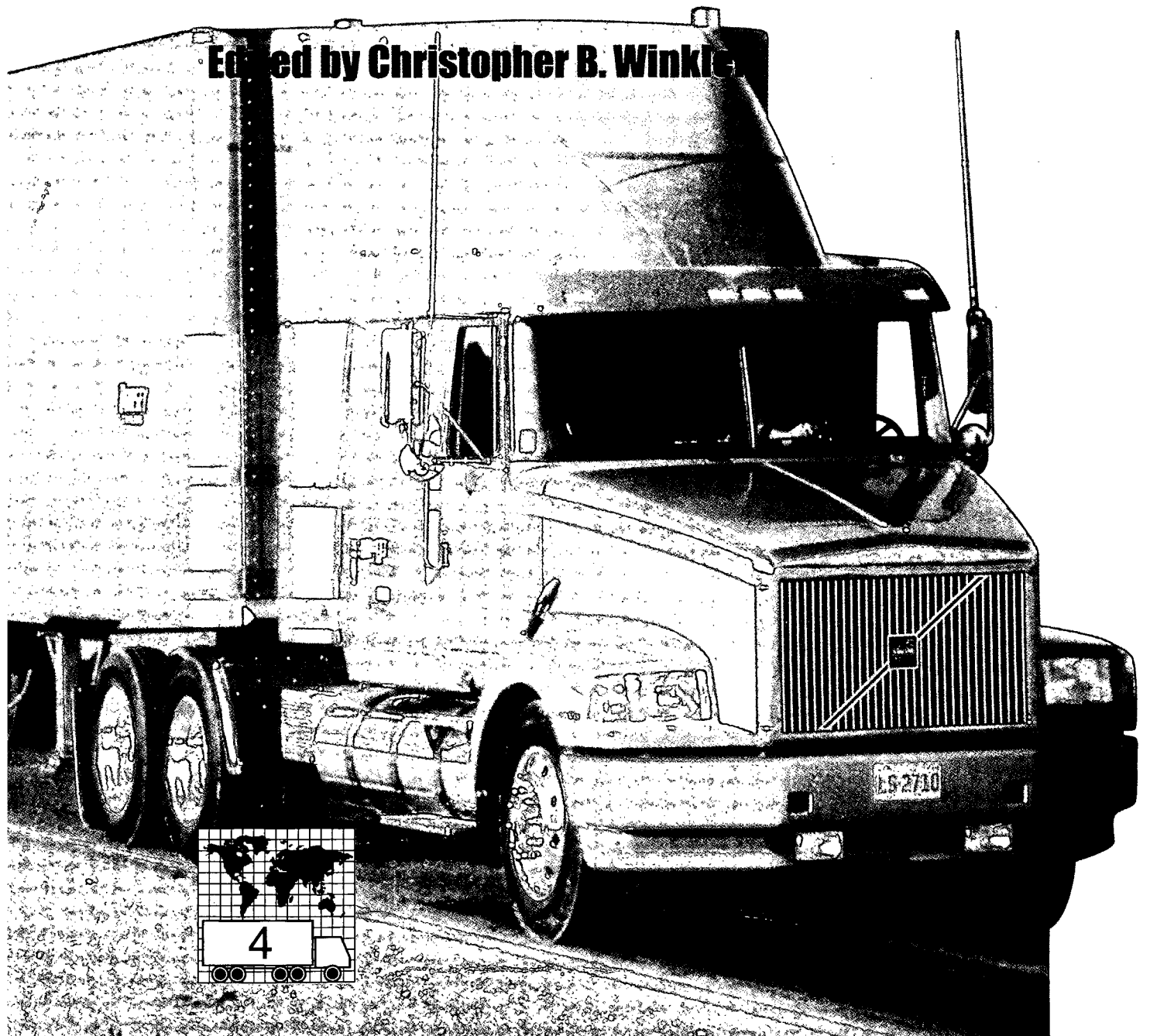


# Road Transport Technology—4

Proceedings of the  
Fourth International Symposium on  
Heavy Vehicle Weights and Dimensions

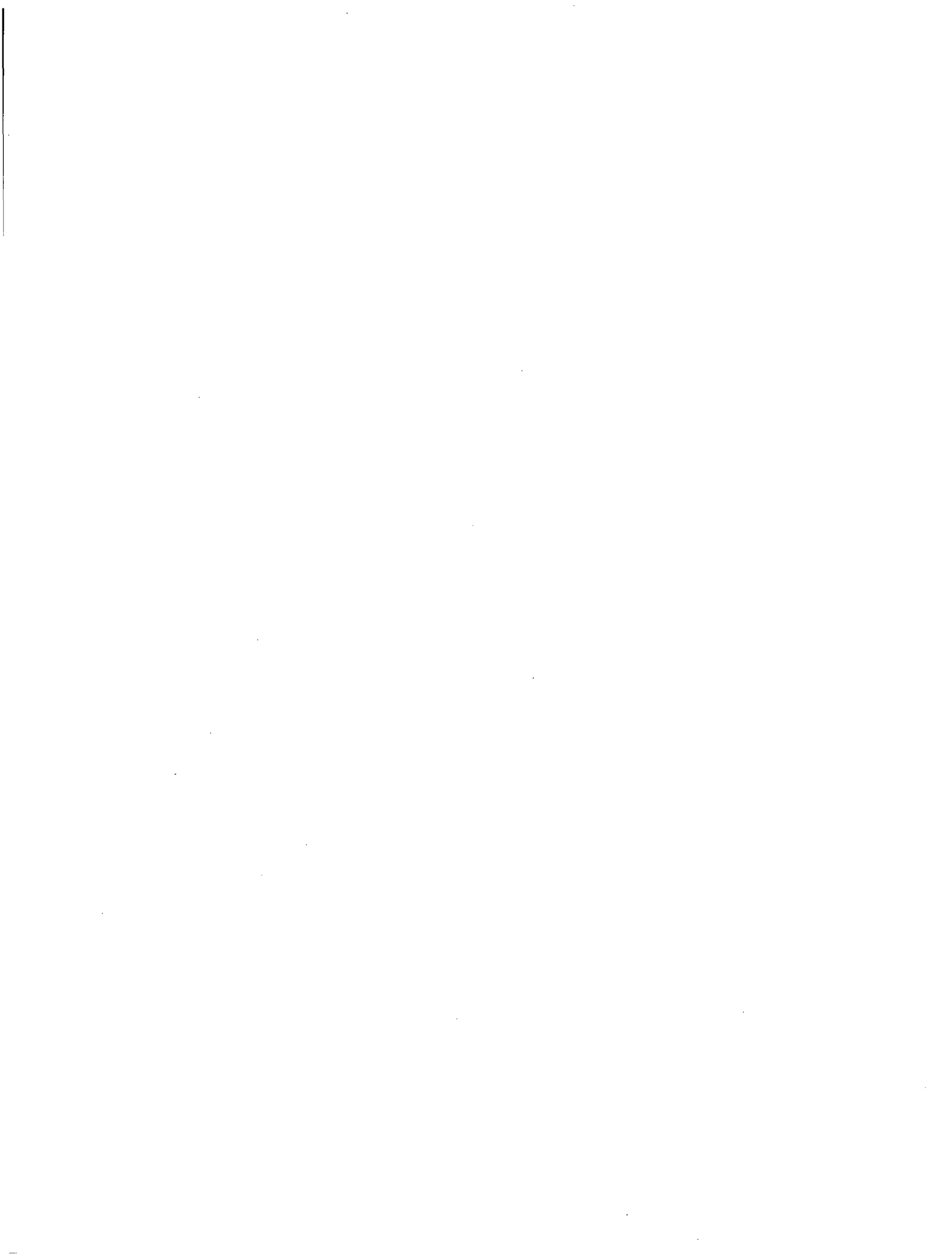
Edited by Christopher B. Winkle





# **Road Transport Technology—4**

Edited by Christopher B. Winkler



# **Road Transport Technology—4**

Proceedings of the Fourth International Symposium on Heavy  
Vehicle Weights and Dimensions

Organized by the University of Michigan Transportation Research  
Institute in cooperation with the International Forum for Road  
Transport Technology

Ann Arbor, USA, June 25–29, 1995

Edited by Christopher B. Winkler

University of Michigan  
Transportation Research Institute

Published by the University of Michigan Transportation Research Institute, 2901 Baxter Road, Ann Arbor, Michigan 48109-2150, USA.

Published in cooperation with the International Forum for Road Transport Technology, Box 189, Carleton Place, Ontario K7C 3P4, CANADA.

First edition, 1995

Library of Congress Catalog Card Number: 95-61707

ISBN: 0-9648624-0-9

© Authors, 1995

All rights reserved. Except for fair copying, no part of this publication may be reproduced, stored in a retrieval system or transmitted by any means, electronic, mechanical, photocopying or otherwise, without the prior written permission of the head of Research Information and Publications, University of Michigan Transportation Research Institute, Ann Arbor, Michigan 48109-2150, USA.

Papers and other contributions are published on the understanding that the author of the contribution is solely responsible for the statements and opinions expressed therein and that its publication does not imply that such statements and or opinions are or reflect those of the organizers or publishers.

Cover art by Kathleen Richards. Cover photograph courtesy of Volvo GM Truck Corporation.

Printed in the United States by the University of Michigan Printing Services.

# Preface

*Christopher B. Winkler*

University of Michigan Transportation Research Institute, USA

---

The Fourth International Symposium on Heavy Vehicle Weights and Dimensions took place at the University of Michigan in Ann Arbor on June 25 through June 29, 1995. The symposium was a function of the International Forum for Road Transport Technology.

The members of the technical committee of the symposium were C.B. Winkler (Chairman, USA), J. Aurell (Sweden), R. Cantieni (Switzerland), D. Cebon (UK), J. de Pont (New Zealand), M. Huhtala (Finland), B. Lord (USA), C.G.B. Mitchell (UK), R.A. Pearson (Australia), J. Preston-Thomas (Canada), L. Strawhorn (USA), P.F. Sweatman (Australia), N.C. Ware (USA), and J. Woodrooffe (Canada).

One hundred and eleven individuals attended as delegates to the symposium. They came to Ann Arbor from twenty-one countries: forty-three from the United States; twenty-one from Canada; nine from Australia; five each from New Zealand and Sweden; four from the United Kingdom; three each from Brazil, France, and the Netherlands; two each from Norway, Switzerland, and Taiwan ROC; and one each from Austria, Bangladesh, Belgium, Finland, Germany, Hungary, Korea, South Africa, and Venezuela.

The symposium was opened by Robert Welke, Chief Engineer/Deputy Director of the Michigan Department of Transportation (USA). Mr. Welke presided over Sunday's opening plenary session, which included four additional keynote speakers: George Reagle, Associate Administrator for Motor Carriers, Federal Highway Administration, U.S. Department of Transportation (USA); Burkhard Horn, Head of the Road Transport Research Programme, OECD (United Nations); John Hurlstone, Chairman of the National Road Transport Commission (Australia); and Richard Turner, Director of the Freight Transport Association (UK). Over the following four days, an additional sixty-seven formal presentations were given in a mixture of plenary and parallel technical sessions and panel discussions. The symposium closed with two endnote presentations given by Robert Ervin, Head of the Engineering Research Division, University of Michigan Transportation Research Institute (USA) and Byron Lord, Chief of Engineering Application Division, Federal Highway Administration, U.S. Department of Transportation (USA).

An essential purpose of this series of symposia is to promote the intermixing of various elements of the road transport community. On one hand, these meetings seek to bring together members of the vehicle and infrastructure

technical communities, and on the other hand they are intended to attract both policy makers and technical people. To enhance the interchange between these several groups, the presentations of the fourth symposium generally were *not* organized by topic. Rather, papers covering several topics were typically included in each individual session.

To enhance the utility of this document, however, the written papers have been reorganized by topic and, therefore, are not presented according to session as is traditional in technical proceedings. The sixty-eight papers herein are divided into three major topic areas: policy, regulation and economics; infrastructure technology; and vehicle technology. Each of these areas is subdivided into a number of more specific topics.

Many people and organizations deserve our sincere thanks and appreciation for helping make the symposium the success that it was. The chairman and the members of the technical committee wish to especially acknowledge the contributions of the following:

- Sponsoring organizations: Federal Highway Administration United States Department of Transportation; Great Lakes Center for Truck and Transit Research; University of Michigan Transportation Research Institute.
- Major sponsor: Volvo GM Heavy Truck Corporation.
- Sponsors: American Trucking Associations, ATA Foundation, Australian Road Transport Suppliers Association, Eaton Corporation, Independent Trailer and Repair, Midland-Grau Heavy Duty Systems, National Road Transport Commission of Australia, Navistar International Transportation Corporation, Road User Research, Rockwell WABCO Vehicle Control Systems, Shennen Publishing and Publicity Company.
- Session chairmen: Rod Addis, John Aurell, John Billing, Reto Cantieni, David Cebon, John de Pont, John Edgar, Bob Ervin, Paul Fancher, Tom Gillespie, Matti Huhtala, Bill Kenis, Kit Mitchell, Jon Preston-Thomas, Peter Sweatman, Nate Ware, and John Woodrooffe.
- Chrysler Center staff, especially Edith Baise, Terry Bennett, Renée Heath, Annette Petrusso, Jane Poling, and Nancy Wrosch.
- UMTRI staff, especially Ardith Bates, Scott Bogard, Annise Johnson, John Koch, Ben Powell, Kathy Richards, Bob Sweet, Jim Thomson, and Pat Waller.
- Special thanks to Peter Sweatman, Kit Mitchell, and Nate Ware.





# Table Of Contents

---

## KEYNOTE PRESENTATIONS

Truck Size And Weight Policy—Current Activity Of The FHWA .....	1
<i>G.L. Reagle</i>	
International Co-Operation On Infrastructure And Heavy Freight Vehicles Within OECD.....	3
<i>B. Horn</i>	
Australia's Approach To Uniform Road Transport Law.....	9
<i>J. Hurlstone</i>	
The Operators' View Of Emerging Size And Weight Policy In Europe .....	15
<i>R.K. Turner</i>	

## POLICY, REGULATION, AND ECONOMICS

### Road Versus Vehicle Costs

Efficiency Characteristics Of Tractor-Semitrailers .....	23
<i>E.S.K. Fekpe, J.H.F. Woodrooffe, and P.F. Sweatman</i>	
Relationship Between Road Track Cost And Heavy Vehicle Fuel Consumption .....	31
<i>J.I. Ghojel and H.C. Watson</i>	

### Assessing Road Damage And Costs

Effects Of Overloaded Heavy Vehicles On Pavement And Bridge Design In Taiwan.....	39
<i>C.J. Chou</i>	
Economic Impacts Of Axle Load Limits And Heavy Vehicle Configurations On The Performance Of Pavements In Brazil.....	47
<i>J.L. Fernandes, Jr., J.A. Widmer, and M.H.A. Sória</i>	
Impacts Of Increased Goods Vehicle Weight Limits: A European Case Study.....	55
<i>B.A. Frith, C.G.B. Mitchell, and W.H. Newton</i>	
Estimating Australia's Heavy Vehicle Road Wear Cost Responsibilities (Load Related Road Wear).....	67
<i>T.C. Martin</i>	
Assessing The Relative Road Damaging Potential Of HGVs .....	75
<i>T.E.C. Potter, D. Cebon, and D.J. Cole</i>	

### Economics Of Regulation In North America

Subsidies And External Costs In U.S. Surface Freight Transportation .....	83
<i>J.R. Morris</i>	
The Economic Effects Of The U.S. 1991 Size And Weight Freeze: Case Studies.....	93
<i>S.D. Nichols</i>	

## Implementing Size And Weight Regulations

Implementation Of Vehicle Weight And Dimension Regulations.....	107
<i>J.R. Billing</i>	
Regulating Heavy Vehicle Safety In New Zealand Using Performance Standards.....	115
<i>J. Edgar</i>	
Vehicle Size And Weight Limits—Attempts Towards Legislative Harmonisation Within The European 121Union .....	121
<i>R. Missen</i>	
Investigation Into The Feasibility Of Heavy Transport Routes In New Zealand .....	125
<i>L. Sleath</i>	
Applicability Of Performance-Based Standards To Truck Size And Weight Regulation In The United States.....	137
<i>J. York and T. Maze</i>	

## Weigh-In-Motion

Australian High Speed Weigh-In-Motion —An Overview .....	143
<i>C. Koniditsiotis, R. Buckmaster, and P. Fraser</i>	
On-Site WIM System Calibration; An Overview Of NCHRP Study 3-39(2).....	153
<i>T. Papagiannakis and K. Senn</i>	

## Vehicle Monitoring

Site-Specific Truck Load Study.....	159
<i>S. Kim, A.S. Nowak, and A.F. Sokolik</i>	
A System For Monitoring Overloaded Vehicles.....	165
<i>P.A. Nordengen and M.C. Hellens</i>	
Characteristics Of Heavy Traffic On Various French Roads.....	175
<i>D. Pillot</i>	

## Vehicle Manufacturing

Truck Manufacturing In The World Market Of The Twenty-First Century .....	183
<i>J. Hebe</i>	

## INFRASTRUCTURE TECHNOLOGY

### Modeling Pavement Response And Performance

Field Response And Dynamic Modeling Of An Asphalt Concrete Pavement Section Under Moving Heavy Trucks .....	189
<i>K. Chatti, J.P. Mahoney, C.L. Monismith, and T. Moran</i>	
Modelling Whole-Life Pavement Performance.....	201
<i>A. Collop and D. Cebon</i>	
Simulation Of The Response Of Cracked Flexible Pavements To Surface Loads.....	213
<i>M.S.A. Hardy</i>	
Calibration Of A Mathematical Vehicle Dynamic Model.....	221
<i>W.J. Kenis and J. Hammouda</i>	

### Pavement Performance

The Effect Of Wheel Loads On Pavements .....	235
<i>M. Huhtala</i>	
Strain Measurements In Flexible Pavements Under Heavy Vehicle Axle Loads.....	243
<i>B.D. Pidwerbesky and B.D. Steven</i>	
Effect Of Heavy Vehicle Weights On Pavement Performance.....	253
<i>C.L. Saraf, G.J. Ilves, and K. Majidzadeh</i>	
Effect Of Vehicle Axle Loads On Pavement Performance .....	263
<i>B.M. Sharma, K. Sitaramanjaneyulu, and P.K. Kanchan</i>	

## Spatial Repeatability

Spatial Repeatability Of The Impact Forces On A Pavement And Multiple Sensor WIM—Research Element 5 Of The OECD IR6 DIVINE Project .....	273
<i>B. Jacob</i>	
Spatial Correlation Of Dynamic Wheel Loads .....	281
<i>P.A. LeBlanc and J.H.F. Woodrooffe</i>	
A Demonstration Of The Theory of Spacial Repeatability .....	291
<i>T. Moran, M. Sullivan, J. Mahoney, and K. Chatti</i>	

## Road Loads And Simulators

A Study Of Dynamic Wheel Loads Conducted Using A Four-Post Road Simulator .....	301
<i>B.T. Kulakowski, D.A. Streit, R.J. Wollyung, and W.J. Kenis</i>	
Replication Of Heavy Truck Dynamic Wheel Loads Using A Road Simulator .....	309
<i>T. Moran, M. Sullivan, D. Menmuir, and J. Mahoney</i>	
Measurement Of Heavy Vehicle Dynamic Wheel Forces Using A Bolt-On Transducer .....	317
<i>W. Yang, C. Doedhar, D.A. Streit and B.T. Kulakowski</i>	

## Dynamic Wheel Loads And Pavements

The Impact Of Vehicle Dynamics On Pavement Performance .....	323
<i>J. de Pont and B. Pidwerbesky</i>	
Implementation Of Road Profiles For Vehicle Dynamic Simulation .....	333
<i>W.J. Kenis and J. Hammouda</i>	
Dynamic Pavement Loads And Road Wear: Scientific Questions The OECD DIVINE Project Is Intended To Answer .....	341
<i>C.G.B. Mitchell and R.R. Addis</i>	
An International Research Program Into The Vehicle/Pavement Interaction: OECD DIVINE Project .....	351
<i>P.F. Sweatman, R.R. Addis, and C.G.B. Mitchell</i>	

## Bridge Loading And Response

Vehicle/Bridge Interaction For Medium Span Bridges—Research Element 6 Of The OECD IR6 DIVINE Project .....	355
<i>S. Barella and R. Cantieni</i>	
Short-Span Bridge Friendly Suspensions—Research Element 6 Of The OECD DIVINE Project .....	365
<i>R.J. Heywood</i>	
Fatigue Load Spectra For Bridges .....	377
<i>J.A. Laman and A.S. Nowak</i>	
Dynamic Effect Of Truck Loads On Girder Bridges .....	383
<i>H.H. Nassif and A.S. Nowak</i>	

## Geometry And Other Issues

Measurement Of The Lateral Distribution Of Heavy Vehicles And Its Effects On The Design Of Road Pavements .....	389
<i>R. Blab and J. Litzka</i>	
Truck Length And Weight Issues: Passing And Turning At Intersections .....	397
<i>P.S. Fancher, Z. Bareket, and M.R.A. Russo</i>	
Geometric Considerations Of Long Combination Vehicle Maneuvers On Roadway Intersections In Brazil .....	405
<i>M.R.A. Russo and J.A. Widmer</i>	

## VEHICLE TECHNOLOGY

### Vehicle Dynamics Simulation

Simulating In-Service Heavy Vehicle Suspension Dynamics .....	415
<i>J. de Pont, K. Thakur, and M. Costache</i>	
Axle Tramp Contribution To The Dynamic Wheel Loads Of A Heavy Truck .....	425
<i>S.M. Karamihas, T.D. Gillespie, and S.M. Riley</i>	

Simulation Modeling And Performance Standards For Combination Vehicles .....	435
<i>S. McFarlane, P. Dovile, and P.F. Sweatman</i>	
Study Of An Active Suspension For Improved Ride Quality And Reduced Dynamic Wheel Loads.....	441
<i>F. Oueslati, S. Rakheja, and S.Sankar</i>	
Dedicated Simulations Of Heavy Road Vehicles .....	453
<i>C.H. Verheul</i>	

### **Articulated Vehicle Behavior**

Standard Test Procedures For The Lateral Stability Of Heavy Vehicle Combinations.....	463
<i>J. Aurell and C.B. Winkler</i>	
Path Compliance In Lane-Change Tests Designed To Evaluate Rearward Amplification.....	473
<i>J. Preston-Thomas and M. El-Gindy</i>	

### **Stability And Safety**

A Study Of The Aligning Forces Generated From A Tridem Drive Axle Group.....	483
<i>E. Amlin, P. Klawer, and D.V. Hart</i>	
Impact Of European Size And Weight Policies On The Characteristics Of Heavy Vehicles .....	493
<i>J. Aurell and T. Wadman</i>	
Headway Control Systems And The Heavy Commercial Vehicle—A Case Study .....	507
<i>Z. Bareket and P.S. Fancher</i>	
Computer Optimization Of Heavy Truck Suspension Parameters.....	517
<i>D.W. Blue and B.T. Kulakowski</i>	
Evaluation Of Self-Steering Axles For Semi-Trailers .....	525
<i>G. Corbin, J. Grandbois, and M.J. Richard</i>	
Urban Truck Crashes—What Really Happens .....	537
<i>P.F. Sweatman and K.W. Ogden</i>	
Stability In The Real World—Influence Of Drivers And Actual Roads On Vehicle Stability Performance.....	545
<i>D. White and K. Thakur</i>	

### **Brakes And ABS**

Further Experience With Anti-Lock Brake Systems.....	551
<i>J.R. Billing, C.P. Lam, and S. Vespa</i>	
Statistical And Mechanical Analyses Of Brake Adjustment Criteria For Heavy Trucks.....	563
<i>P. Fancher, Z. Bareket, D. Blower, and K. Campbell</i>	
Heavy Truck Brake Adjustment—Problems And Solutions.....	575
<i>H. Seiff</i>	

### **Tires**

A Combined Cornering And Braking Test For Heavy Duty Truck Tires.....	583
<i>M.G. Pottinger, W. Pelz, C.B. Winkler, and G.A. Tapia</i>	

### **ENDNOTE PRESENTATIONS**

Technical Issues—The Way Forward.....	593
<i>R.D. Ervin</i>	