
Space, time, economics and asphalt

**An investigation of induced traffic growth caused by urban
motorway expansion and the implications it has for the
sustainability of cities**

Doctor of Philosophy in
Sustainable Futures

By Michelle E Zeibots
2007

Statement of original authorship

I certify that the work in this thesis has not previously been submitted for a degree, nor has it been submitted as part of the requirements for a degree, except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of candidate:

Michelle Elaine Zeibots

Acknowledgements

I would very much like to thank my supervisors, Professor Stuart White (Director of the Institute for Sustainable Futures) and Dr Glen Searle (Director of Planning), for their encouragement and guidance throughout the course of my candidature. Their insights and support have made my PhD journey less arduous. I would also like to thank Dr Chris Riedy for his reading of thesis drafts and carefully considered suggestions about structure and presentation, all of which have enhanced the lucidity of the final product.

I am particularly indebted to Associate Professor Peter Petocz from the Department of Statistics at Macquarie University. I had the opportunity to collaborate with Peter on some of the statistical analysis presented in Chapter Five. Our collaboration is ongoing and I look forward to being able to resolve the issues that our analysis to date has raised.

Associate Professor Cynthia Mitchell — who heads the postgraduate research program at the Institute for Sustainable Futures — provided a wonderful environment in which to undertake a transdisciplinary thesis of this kind. Ann Hobson's advice on layout and ways of wrestling with the beast called Microsoft Word was particularly helpful. Pat Skinner's careful proofreading has eliminated many mistakes and reduced a great deal of potential irritation for readers.

I am also indebted to Dr Tim Pharoah, Jason Torrance, Dr Tim Rayner, John Elliot and Paul Moore for their willingness to discuss urban motorway development and induced traffic growth analysis in the UK.

I very much need to thank Peter Mills for his interest in transport and systems theory as well as his willingness to read and discuss several of my chapter drafts. Dr Hugh Outhred was also generous with his time and knowledge of systems theory. Mary-Jane Gleeson provided invaluable support with her insights into NSW State Government politics and documents relating to the M4 East Motorway proposal in Sydney.

My good friend Dr Felix Laube provided a sounding-board for ideas as did Dr Rolf Bergmaier. I am indebted to them both for their great love of transport as well as their insights into the Swiss Federal Railway system.

I would also like to acknowledge the assistance given to me by RailCorp and the Transport Technology section of the Roads & Traffic Authority of NSW. In particular, Garry McDonald, Cynthia Wallace, Adrian Lewis and Ian Kearnes assisted me with rail data. Ray Daltry, Barry Armstrong and Dorothy Ferry assisted me with road traffic data.

And last, but surely not least, I would like to thank my father John Zeibots, whose love of science and organic chemistry inspired me as a child; my mother Ruth Zeibots, who loved me and supported me through the really difficult periods in a way that only mothers can; my sister Simone Zeibots, who talked me through my worst doubts and some of the more interesting aspects of system feedback processes in geological rock formations, and my brother Richard Zeibots, who made sure the lights in my house worked during the last, long, dark, tea-time of the write-up.

This thesis is dedicated to the memory of

Mary-Jane Gleeson

1964 – 2007

who loved cities, the people who live in them and fought hard to

improve the transport systems that support them

Table of contents

1 URBAN MOTORWAYS AND SUSTAINABILITY: INTRODUCTION TO THE RESEARCH PROBLEM	1
1.1 Cities and sustainable development.....	5
1.1.1 Models and conceptions of sustainable development	7
1.1.2 Urban inputs: oil dependency in cities	14
1.1.3 Urban outputs: greenhouse gas emissions and global climate change	17
1.1.4 Urban exchange: trade between cities and economic sustainability.....	20
1.1.5 Principles for sustainable urban transport development	23
1.2 Access and urban transport	24
1.2.1 Three city typologies	25
1.2.2 Accessibility and congestion in auto-based city systems.....	31
1.3 Urban motorway development and induced traffic growth	33
1.3.1 Definition of induced traffic growth: a contested phenomenon	33
1.3.2 The ‘counter-productive’ nature of urban motorway development.....	40
1.3.3 Research questions about induced traffic growth and the implications it has for the sustainability of cities	46
1.4 Positioning the research problem and contribution using General Systems Theory as an intellectual framework	47
1.4.1 Positioning the research within conventional disciplinary boundaries	47
1.4.2 General Systems Theory (GST): an alternative to reductionism.....	50
1.4.3 What type of system is a city and what role do transport networks play?	53
1.5 The thesis structure: review, observation, theory and application.....	54
1.5.1 Review: the strange life and controversial times of an urban system feedback process.....	54
1.5.2 Observation: before and after Sydney’s M4 Motorway	56
1.5.3 Theory: a systems theory of cities and travel.....	57
1.5.4 Application: combining observation and theory to address emerging sustainability problems	58
2 THE CONTROVERSIAL LIFE AND TIMES OF AN URBAN SYSTEM FEEDBACK PROCESS: POLITICS AND INDUCED TRAFFIC GROWTH STUDIES.....	60
2.1 A soft systems model of the motorway decision-making system.....	64
2.1.1 The <i>science</i> of soft and hard system distinction	65
2.1.2 Development of a soft system model of the decision-making process to approve or reject an urban motorway proposal	69
2.2 A road through the madding crowd: the structure of urban motorway conflicts	79
2.2.1 SACTRA, Roads to Prosperity and the last link in London’s M25 motorway	80
2.2.2 Induced traffic growth in the context of Sydney motorway proposal assessment procedures ..	97
2.2.3 Changes to commodities of power: motorway building in Zürich under the Swiss system of direct democracy	108
2.3 When governments fall: political crisis as a cause for change in accepted transport science	116
3 BEFORE AND AFTER THE MOTORWAY: EMPIRICAL ANALYSES OF INDUCED TRAFFIC GROWTH.....	122

3.1 The standard norms of empirical science and their application to testing for induced traffic growth.....	124
3.1.1 Boundary conditions.....	125
3.1.2 Data types, controlling for variation and the repeatability of results	127
3.2 SACTRA and the generation of traffic.....	130
3.3 Testing for induced traffic by observing changes to traffic volumes across screenlines	134
3.3.1 Purnell, Beardwood and Elliott’s studies of London motorways	134
3.3.2 Crow and Younes study of the Rochester Way Relief Road	142
3.3.3 Cairns, Hass-Klau and Goodwin’s analyses of induced traffic growth in reverse and the closure of Hammersmith Bridge	146
Conclusions	152
3.4 Induced traffic growth studies using travel survey data.....	152
3.4.1 Wilcock’s survey of the Rochester Way Relief Road near London.....	153
3.4.2 Kroes, Daly, Gunn and van der Hoorn’s study of the Amsterdam Ring Road.....	155
Conclusions	158
3.5 Induced traffic growth studies using aggregate VKT data and time series regression	159
3.5.1 Hansen and Huang’s time series regression analysis of changes to highway capacity and VMT in California.....	160
3.5.2 Prakash, Oliver and Balcombe’s arguments against the induced traffic growth hypothesis ...	163
3.5.3 Cervero’s path analysis	164
Conclusions	168
3.6 Induced traffic growth studies in Australia.....	168
3.6.1 Luk and Chung’s analysis of Melbourne’s South Eastern Arterial	169
3.6.2 Mewton’s analysis of the Sydney Harbour Tunnel and Gore Hill Freeway	175
Conclusions	178
4 THEORETICAL EXPLANATIONS OF INDUCED TRAFFIC GROWTH... 179	
4.1 Calculation procedures for demand modelling.....	184
4.1.1 Traffic is like water: an overview of four-step and assignment modelling.....	185
4.1.2 Activity models	188
4.1.3 Incorporating induced traffic growth in demand models	189
4.2 Explanations for induced traffic growth using microeconomic evaluation	189
4.2.1 Microeconomic evaluation of speed–flow–cost relationships	190
4.2.2 Marginal utility theory and economic happiness.....	194
4.3 The Mogridge conjecture and the Downs/Thomson paradox	202
4.3.1 Downs’ law of peak-hour traffic congestion.....	204
4.3.2 Thomson’s great cities and their traffic.....	208
4.3.3 Criticism of the Mogridge conjecture.....	213
4.4 Conclusions	218
5 BEFORE AND AFTER THE MOTORWAY: AN EMPIRICAL ANALYSIS OF SYDNEY’S M4 MOTORWAY.....	219
5.1 Typology of the Sydney transport network	220
5.2 Sydney’s M4 corridor	227

5.2.1	Analysis of the M4 Motorway and Western Sydney road network	228
	Data: annual average daily traffic volumes	229
	Method: comparative traffic counts on Screenline 12	255
	Results: confirmation of the induced traffic growth hypothesis	260
5.2.2	Analysis of the Western Sydney rail network.....	261
	Data: passenger journeys on the Sydney CityRail network	262
	Method: time series regression.....	266
	Results: method too insensitive to isolate a signal.....	268
5.2.3	Conclusions	272
5.3	Anatomy of a motorway ramp-up period.....	273
5.3.1	The ramp-up period for the M4 Motorway section from Mays Hill to Prospect.....	274
5.3.2	The Sydney Harbour Tunnel.....	276
5.4	Conclusions	277
6	A SYSTEMS THEORY OF INDUCED TRAFFIC GROWTH.....	278
6.1	The material structure of urban systems	280
6.1.1	The structure of positive and negative system feedback processes	282
6.1.2	Travel time budget constancy and the control of urban systems	285
	The empirical evidence for travel time budget constancy	286
	The nature of the system controller of the transport system	290
6.1.3	Induced traffic growth as a form of positive system feedback	293
6.1.4	The relationship of travel time budget constancy and induced traffic growth to other urban transport parameters	298
	Speed and journey distances.....	298
	Urbanised area and relative distance to the urban centre	299
	Urban density	302
	Population size	304
6.1.5	The travel time budget fuzzy controller hypothesis	306
	Summary.....	308
6.2	Phase transitions between city typologies	309
6.2.1	The mechanics of urban systems	310
	Congestion.....	312
	Network geometry and new capacity.....	314
	Segregated carriageways	318
6.2.2	Phase transitions	323
	Summary.....	324
6.3	Leverage points in the urban system: where small shifts produce big changes... 324	
7	MOTORWAYS AND THE SUSTAINABILITY OF CITIES.....	329
7.1	Oil dependency and energy economics	332
7.1.1	Peak oil and current global production.....	333
7.1.2	Energy Profit Ratios	338
7.1.3	Alternative transport fuels: their quality and quantity	341
7.1.4	Adaptation of urban transport systems in response to oil depletion.....	343
7.2	Climate change and the city	345
7.2.1	The relationship between urban systems and the natural processes of climate change	347
7.2.2	Communication links and material solutions.....	348
7.2.3	Induced traffic growth and its implications for climate change and the sustainability of cities	351
7.3	The city as an economic engine	352

7.3.1	Cities as units of economic organisation.....	353
7.3.2	Cities engaged in trade and competition	356
7.3.3	Changes to urban structure and access caused by motorway development.....	357
7.4	Political decision-making systems and sustainability.....	358
8	CONCLUSIONS	360
	APPENDIX A	364
9	REFERENCES	365

List of Figures

Figure 1.1 The three pillars of sustainability model	8
Figure 1.2 Changes to decision-making frameworks for ecological sustainability	10
Figure 1.3 Oil production scenarios	15
Figure 1.4 Fuel use for private cars vs urban density	16
Figure 1.5 CO2 emissions from urban passenger transport (private and public transport)	18
Figure 1.6 Comparative advantages for infrastructure costs in low-and high-density cities.....	21
Figure 1.7 Average VKT and percentage of metropolitan GDP spent on transport (1995).....	22
Figure 1.8 Walking-city typology	25
Figure 1.9 Walking-city building form	26
Figure 1.10 Transit-city typology.....	27
Figure 1.11 Transit-city building form.....	28
Figure 1.12 Auto-city typology	29
Figure 1.13 Auto-city building form.....	30
Figure 1.14 Road space and congestion costs in US cities (1982–1996).....	32
Figure 1.15 AADT volumes for Sydney’s M4 Motorway and Great Western Hwy ...	34
Figure 1.16 VKT vs road length per capita for 78 international cities (1995)	36
Figure 1.17 Definitions of existing and induced traffic and trips.....	39
Figure 1.18 Estimation of marginal cost savings arising from a proposed urban motorway	42
Figure 1.19 Metropolitan GDP spent on operating private transport vs road space (1995).....	44
Figure 1.20 Metropolitan GDP spent on total passenger transport vs road space (1995)	45
Figure 1.21 Disciplines supported by General Systems Theory	51

Figure 2.1 Hume’s Guillotine	66
Figure 2.2 The experience–action cycle	69
Figure 2.3 The process of Soft Systems Methodology	70
Figure 2.4 CATWOE elements.....	72
Figure 2.5 CATWOE elements of a decision-making system for urban motorway constructions.....	73
Figure 2.6 A soft system model of the political decision making process for urban motorway proposals	76
Figure 2.7 Conceptual overview of soft system model	77
Figure 2.8 GLDP primary road concept diagram.....	81
Figure 2.9 Community severance from London motorway construction and projected traffic volumes for the GLDP motorway network	83
Figure 2.10 Role of votes in the zone of political activity	88
Figure 2.11 Impact of political conflict on zone of technical input.....	89
Figure 2.12 Impact of empirical confirmation of induced traffic growth.....	92
Figure 2.13 Traffic jam on the M25 Motorway after opening of the last link and community protest over the M11 link road in East London.....	94
Figure 2.14 County of Cumberland Scheme, 1951	99
Figure 2.15 Actor agencies in the Sydney system.....	103
Figure 2.16 Soft system model of transport decision-making process in Zürich.....	110
Figure 2.17 Existing and proposed motorway sections in Zürich.....	113
Figure 2.18 Phases in the life-cycle of a paradigm, as proposed by Kuhn	118
Figure 3.1 Screenlines showing open and closed boundary conditions.....	126
Figure 3.2 Comparison of road space increases and traffic growth, Great Britain 1980–90.....	132
Figure 3.3 Location of road schemes analysed by Purnell, Beardwood and Elliott.....	135
Figure 3.4 Screenlines for Westway, Finchley Road and Old Brompton Road corridors	137

Figure 3.5 Traffic growth in Westway, Finchley Road and Old Brompton Road corridors	140
Figure 3.6 Rochester Way Relief Road and surrounding network.....	143
Figure 3.7 Hammersmith Bridge and other crossings along the River Thames	148
Figure 3.8 Amsterdam Ring Road.....	155
Figure 3.9 Observed changes in crossing time of the North Sea Canal	156
Figure 3.10 Elasticity results of near- and longer-term path model analyses.....	166
Figure 3.11 Melbourne’s south-eastern metropolitan area	170
Figure 3.12 12-hour traffic volumes for control sites	173
Figure 3.13 Sydney Harbour Tunnel and other bridge crossings of Sydney Harbour..	176
Figure 4.1 The Speed–Flow–Cost relationship	190
Figure 4.2 The effect of User Costs on road improvements	192
Figure 4.3 Addition of road space in uncongested conditions.....	193
Figure 4.4 Addition of road space under congested conditions.....	194
Figure 4.5 Average direct speeds of morning peak-hour journeys to the centre of London	203
Figure 4.6. The Downs/Thomson paradox: increasing road capacity vs. improving collective transport	208
Figure 4.7. Thomson’s five city topologies	210
Figure 4.8 Average direct speeds of morning peak-hour journeys to the centre of London	215
Figure 5.1 Sydney’s tram and railway network in 1923.....	221
Figure 5.2 Successive strategic plans for the Sydney Metropolitan Region, 1951 – 1995	223
Figure 5.3 Sydney Metroad System.....	225
Figure 5.4 Motorway plans for Sydney featuring the Sydney Orbital, 2000.....	226
Figure 5.5 Screenlines for the Sydney Road Network.....	227
Figure 5.6 Sequence of M4 Motorway section constructions	228

Figure 5.7 Seasonal fluctuations in Average Daily Traffic volumes over 13 (four-week) periods for the Great Western Hwy (70.001) during 1985	231
Figure 5.8 Incomparable AADT counts for the M4 Motorway and Great Western Hwy (1983–1996).....	232
Figure 5.9 Comparison of ADT volumes for March and August for the Great Western Hwy during 1992 (TEC traffic stations)	234
Figure 5.10 AADT counts for the M4 Motorway (71.002) and Great Western Hwy (70.001) from 1983 to 1996 with comparable data types	235
Figure 5.11 Location of RTA and TEC traffic stations on M4 Motorway and Great Western Hwy	236
Figure 5.12 Roads on Screenline12 in Western Sydney Region	237
Figure 5.13 AADT counts for Windsor Road (88.046) from 1985 to 1996 showing axle pairs and vehicle numbers	240
Figure 5.14 AADT counts for Richmond Road (71.059) from 1985 to 1996 showing axle pairs and vehicle numbers	243
Figure 5.15 Intersection configuration of Elizabeth Drive and Walgrove Road on Screenline 12.....	247
Figure 5.16 Estimation of missing data at Elizabeth Drive intersection	250
Figure 5.17 AADT counts for six key trunk routes along Screenline 12.....	260
Figure 5.18 Rail and motorway trunk routes in Sydney’s western sector	263
Figure 5.19 Estimated passenger journeys for Western Sydney and Blue Mountains rail services (1988/89 – 1996/97)	264
Figure 5.20 Estimated passenger journeys for Richmond rail services (1988/89 – 1996/97)	265
Figure 5.21 Rail trunk routes in Sydney’s southern sector.....	269
Figure 5.22 Daily traffic counts for the GWH and M4 Motorway on Screenline 12..	274
Figure 5.23 Daily traffic volumes for the Sydney Harbour Tunnel and Sydney Harbour Bridge.....	276
Figure 6.1 Basic components of a system feedback process	282
Figure 6.2 Multiple system feedback processes	284

Figure 6.3 Average daily travel time budgets for a selection of international populations	286
Figure 6.4 Average journey-to-work travel time budgets for 23 cities (1990).....	287
Figure 6.5 Average travel time budgets by mode for South Yorkshire	288
Figure 6.6 Typical tasks that form a daily routine	291
Figure 6.7 Induced traffic growth feedback process nested within complex city system	294
Figure 6.8 Intrinsic and extrinsic system feedback processes	296
Figure 6.9 Average journey length and speed for the journey-to-work in 31 international cities (1990).....	299
Figure 6.10 Changes in transport speed and urbanised area in Berlin	300
Figure 6.11 Induced traffic growth feedback process and location decision feedback process	301
Figure 6.12 Average per capita travel time for all trips in Melbourne.....	302
Figure 6.13 Urban density and average travel times for the journey-to-work in 28 cities (1990).....	303
Figure 6.14 Travel time budgets and population size for Asian, European and US cities (1990).....	305
Figure 6.15 Travel time budgets for the journey-to-work in Sydney (2000).....	307
Figure 6.16 Statistical distribution shift due to population increases	308
Figure 6.17 Travel time contours for trips to Sydney CBD by car under ideal conditions (2000).....	311
Figure 6.18 Travel time contours for trips to Sydney CBD by car in AM peak period (2000).....	313
Figure 6.19 Travel time contours for journeys by car from Penrith before the opening of the M4 Motorway from Mays Hills to Prospect (1992)	315
Figure 6.20 Travel time budget contours for journeys by car from Penrith after the opening of the M4 Motorway from Mays Hills to Prospect (1992)	316
Figure 6.21 Travel time budget contours for journeys by car and rail from Penrith before opening of the M4 Motorway from Mays Hill to Prospect (1992).....	317

Figure 6.22 Travel time budget contours for journeys by car and rail from Penrith after the opening of the M4 Motorway from Mays Hill to Prospect (1992)..... 318

Figure 6.23 Travel time contours for journeys by train and walking to the Sydney CBD in the AM peak (2000)..... 319

Figure 6.24 Aerial view of Eastern Sydney showing high-density development at rail stations..... 320

Figure 6.25 Travel time budget contours for journeys by car and rail from Sydney CBD (2000)..... 321

Figure 7.1 Urban and global system nesting configuration 330

Figure 7.2 Conceptual structure of peak oil..... 334

Figure 7.3 EPR profile for oil and gas production (Louisiana, USA) 339

Figure 7.4 Feedback relationship between natural biosphere and human-made systems 347

Figure 7.5 Prud'homme's ladder of mobility 355

List of Tables

Table 3.1 Vehicles per day for Brentford High Street and Great West Road London .	131
Table 3.2 24 Hour two-way traffic flows before and after opening of Westway	136
Table 3.3 24-hour two-way flows in Westway, Finchley Road and Old Brompton Road corridors	139
Table 3.4 Summary of before and after studies by Purnell, Beardwood and Elliott	142
Table 3.5 Traffic counts for western screenline, Rochester Way Relief Road (18-hour, two-way veh/day)	144
Table 3.6 Traffic counts for eastern screenline, Rochester Way Relief Road (18-hour, two-way veh/day)	144
Table 3.7 Traffic counts for transverse roads crossing the Rochester Way Relief Road (18-hour, two-way veh/day).....	145
Table 3.8 Traffic before and after closure of the Hammersmith Bridge in February 1997	149
Table 3.9 Average daily traffic volumes for seven bridges	151
Table 3.10 User responses to the Rochester Way Relief Road	154
Table 3.11 Traffic counts across the North Sea Canal in Amsterdam (24-hour flows, vehicles per day)	158
Table 3.12 Growth rate (per year) for arterial roads in Melbourne’s south-east corridor (1985–1995).....	171
Table 3.13 Corridor counts and growth rate (1985–1995)	174
Table 3.14 Results from Mewton’s regression analyses	177
Table 5.1 Annual passenger trips in the Sydney Region 1946–1981.....	222
Table 5.2 AADT counts for the M4 Motorway and Great Western Hwy showing values from permanent and sample traffic stations from 1983 to 1996.....	233
Table 5.3 Rigid and articulated truck traffic composition (2002).....	238
Table 5.4 AADT counts for Windsor Road (88.046) from 1983 to 1996.....	239
Table 5.5 AADT counts for Richmond Road (71.059) from 1983 to 1996	242

Table 5.6 AADT counts for Power Street (71.096 and 71.172) from 1985 to 1996 showing axle pairs and vehicle numbers.....	244
Table 5.7 AADT counts for Eastern Road (71.067) from 1983 to 1996	245
Table 5.8 AADT counts for Elizabeth Drive (64.033) from 1983 to 1996.....	248
Table 5.9 AADT counts for Walgrove Road (65.013) from 1983 to 1996	249
Table 5.10 Calculation of AADT for 64.022 for 1993	251
Table 5.11 AADT counts for Elizabeth Drive (64.022) from 1983 to 1996.....	251
Table 5.12 AADT counts for Bringelly Road (64.097) from 1983 to 1996.....	254
Table 5.13 AADT for six key trunk routes along Screenline 12	256
Table 5.14 AADT counts for rigid and articulated heavy vehicles on trunk routes along Screenline 12 using M4 conversion rates for Richmond Road.....	257
Table 5.15 AADT counts for rigid and articulated heavy vehicles on trunk routes along Screenline 12 using Windsor Road conversion rates for Richmond Road	258
Table 5.16 AADT for six key trunk routes along Screenline 12 (using Windsor Road heavy-vehicle conversion rates)	259
Table 5.17. Trip rates for rail ticket types.....	264
Table 5.18 P-values, R-square values and coefficients of M4 from cubic regressions .	268
Table 5.19 P-values, R-square values and coefficients of M4 from regressions with lagged variables for the WSRL and IRL	270
Table 5.20 P-values, R-square values and coefficients of M4 from regressions with lagged variables for the WSRL and IRL using Bankstown data to control for service level changes	271
Table 6.1 Logistical features of different transport modes	314
Table 6.2 Places to intervene in a system	325
Table 7.1 EPR values for a range of energy sources	343
Table 7.2 Responses to greenhouse gas emissions from the transport sector	349

Abbreviations and units

AADT	Annual Average Daily Traffic
AAPG	American Association of Petroleum Geologists
ABS	Australian Bureau of Statistics
ADT	Average Daily Traffic
AGO	Australian Greenhouse Office
AP	Accounting Period
ASPO	Association for the Study of Peak Oil
ARIMA	Auto-Regressive Integrated Moving Average
ARR	Amsterdam Ring Road
BRL	Bankstown Rail Line
BRF	British Roads Federation
CART	Citizens Against Route Twenty
CBA	Cost–Benefit Analysis
CBD	Central Business District
CO ₂	Carbon Dioxide
DOTARS	Department of Transport and Regional Services
EPR	Energy Profit Ratio
EU	European Union
Gb	Giga barrels

GDP	Gross Domestic Product
GHE	Gore Hill Expressway
GLC	Greater London Council
GLDP	Greater London Development Plan
GRI	Global Reporting Initiative
GRP	Gross Regional Product
GST	General Systems Theory
GWH	Great Western Highway
HBR	Homes Before Roads
HMSO	Her Majesty's Stationery Office
IBRD	International Bank for Reconstruction and Development
ICLEI	International Council on Local Government Initiatives
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRL	Illawarra Rail Line
ISF	Institute for Sustainable Futures (University of Technology, Sydney)
ISTP	Institute for Sustainability and Technology Policy (Murdoch University)
LATA	London Amenity and Transport Association
LMAG	London Motorway Action Group
MIIM	Macquarie Infrastructure Investment Management

MP	Member of Parliament
NGO	Non-government Organisation
NRMA	National Roads and Motorists Association
NS	Natural Step
NPV	Net Present Value
OD	Origin and Destination
PTRC	Planning Transport, Research and Computation
RRL	Richmond Rail Line
RTA	Roads & Traffic Authority of New South Wales
RWRR	Rochester Way Relief Road
SACTRA	Standing Advisory Committee on Trunk Route Assessment
SARS	Severe Acute Respiratory Syndrome
SDP	State Domestic Product
SEAC	State of the Environment Advisory Council
SHLM	State Highway Lane Miles
SHB	Sydney Harbour Bridge
SHT	Sydney Harbour Tunnel
<i>SMH</i>	<i>Sydney Morning Herald</i>
SSD	Sydney Statistical Division
SSM	Soft Systems Methodology

STPP	Surface Transportation Policy Project
TBL	Triple Bottom Line
TDC	Transport Data Centre
TPDC	Transport and Population Data Centre
UITP	International Association (Union) of Public Transport Providers
UK	United Kingdom
UN	United Nations
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
US	United States (of America)
USGS	United States Geographical Survey
VKT	Vehicle Kilometres Travelled
WCED	World Commission on Environment and Development
WSRL	Western Sydney Rail Line

List of sole and joint publications by the author

Laube, F. B., Kenworthy, J. R. and Zeibots, M. E. 1998, 'Towards a science of cities: city observation and formulation of a city theory' in *Siedlungsstrukturen, räumliche Mobilität und Verkehr: Auf dem Weg zur Nachhaltigkeit in Stradtregionen?* Institut für Regionalentwicklung und Strukturplanung, Berlin.

Zeibots, M. E. 2002, 'The macroeconomic structure of cities: indicators for sustainable urban infrastructure development', paper presentation to *Regional cycles: regional economy towards sustainability*. Hosted by the International Council for Local Environment Initiatives, Leipzig, November 1.

Zeibots, M. E. 2003, *Before and after opening of the M4 Motorway from Mays Hill to Prospect: an empirical analysis*. Working Paper, Institute for Sustainable Futures, University of Technology, Sydney.

Zeibots, M. E. 2003a, 'How do cities work and why is transport so significant? Regional sustainability and the search for new evaluation tools' in conference proceedings of *Second Meeting of the Academic Forum of Regional Government for Sustainable Development*. Perth. September 17–19.

Zeibots, M. E. 2003b, 'Before and after Sydney's M4 Motorway: did it make the city more sustainable?' in conference proceedings of *State of Australian Cities National Conference*, Parramatta, December 3–5.

Zeibots, M. E. 2004, 'Rethinking transport evaluation methods: do we have the best tools to help us make cities more sustainable?' in conference proceedings of *Third Meeting of the Academic Forum of Regional Government for Sustainable Development*, Cardiff, March 22–25.

Zeibots, M. E. & Petocz, P. 2005, 'The relationship between increases in motorway capacity and declines in urban rail passenger journeys: a case study of Sydney's M4 Motorway and Western Sydney Rail Lines' in *28th Australasian Transport Research Forum*, Sydney, September 19.

Conference presentations

Zeibots, M. E. 2004, 'Sydney's Transport: a foundation for what kind of future?' presentation to *Bursting at the seams? Social sustainability and Sydney's future* hosted by the Council of Social Service of New South Wales. Parramatta, 1–2 November.

Newspaper articles

Zeibots, M. E. and Zhukov, G. 1996, 'Sydney's traffic snarls' in *Sydney Morning Herald*, 9 September.

Zeibots, M. E. 1999, 'Heading off along the road to nowhere' in *Sydney Morning Herald*, 4 January.

Zeibots, M. E. 2000, 'On the right track' in *Sydney Morning Herald*, 20 October.

Abstract

This thesis investigates the implications that urban motorway development has for the sustainability of cities. It does this by focusing on the sudden increase in road traffic that follows after the opening of additional motorway capacity, known as induced traffic growth, and asking whether induced traffic growth affects the ability of an urban system to sustain its essential economic functions. The investigation also addresses how urban systems impact on the biosphere.

Induced traffic growth, and the urban motorway development responsible for it, are often cited as a threat to sustainability because they are seen to increase fuel consumption and air pollution without necessarily improving accessibility within a city. Opponents to urban motorway construction claim that it merely represents a reshuffling of system elements, such that the spatial relationships between transport and land-use are changed, but the amount of time spent travelling, and the number of economic exchanges made by people, remain much the same. Motorway development advocates refute these claims, arguing that motorway construction reduces travel times, cuts emissions and fuel consumption and increases economic activity, thereby enhancing sustainability.

While it should be possible to resolve these issues through a program of empirical analysis, the phenomenon remains contested, raising questions about why and how its contested status affects transport decision-making and transport science. These questions are answered in this thesis by first investigating the social and political context in which debate over induced traffic growth has taken place. To do this, Soft Systems Methodology is used to investigate the way in which conflicts over urban motorway development have been resolved in London, Sydney and Zürich. The comparative analysis highlights differences between the rules of the political decision-making systems in each of the cities, and how these distribute power to different groups within society. While the history of conflicts is similar in each of the cities, more power is given to special interest groups from industry in London and Sydney. By contrast, the system in Zürich gives more power to resident populations through its system of

direct democracy. Consequently, urban motorway development, the induced traffic growth it gives rise to and the impacts they have on city operations are acted upon in Zürich to the extent that transport policy has focused more on the development of comprehensive public transport systems. This leads to the conclusion that the contested status of induced traffic growth is more a product of the socio-economic goals of particular interest groups within society than it is of shortcomings in the empirical record or essentially unresolved theoretical issues.

With the political context as background, the thesis then reviews the empirical analyses and theoretical explanations for the phenomenon. First, a review of past empirical analyses is undertaken to identify the grounds that have been cited to refute the induced traffic growth hypothesis. Two key areas are identified. The first involves difficulties with distinguishing the sources of induced traffic growth from traffic reassignment. The second concerns the absence of traffic data for routes that are potential alternatives to a new motorway from which traffic reassignment may have taken place. A case study of the M4 Motorway in Sydney is presented with data for all arterial through-routes that cross relevant screenlines, thereby overcoming several of the shortcomings identified in the review. This case study adds to the general literature of case studies that corroborate the induced traffic growth hypothesis, but provides the first substantial documented case for an Australian city.

A review of the theoretical explanations for the phenomenon finds that while both microeconomic evaluation and standard modelling procedures provide accounts for the phenomenon that meet institutional expectations of technical veracity, neither constitutes a substantial description of the causal mechanism for the phenomenon, leaving unanswered questions about some findings in the empirical record. This conclusion prompts the development of a systems-based explanation for induced traffic growth that defines it as a form of multiple system feedback processes controlled by a travel budget time constant. By accounting for the phenomenon and its effects in this way, an explanation is provided for changes to travel behaviour and patterns of land-use development that reveals how urban motorway development affects urban systems in an holistic way.

The final section of the thesis combines the insights gained by examination of the politics of the transport decision-making system with empirical analyses and theoretical explanations for induced traffic growth, to produce a general systems view of cities and their place within the earth's biosphere. This treatment considers the problems of oil depletion and global climate change, and the effects that urban motorway development has on the ability of urban systems to adapt to changes in the system environment brought about by these problems. The thesis concludes that urban motorway development and the processes that it triggers, which are embodied in the phenomenon of induced traffic growth, can undermine a city's comparative ability to sustain the accessibility needs of its residents.