Urban Travel Forecasting: 
A 50 Year Retrospective

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About the authors

Huw Williams and I met in 1972 at the University of Leeds. We didn’t look much like this 40 years ago.
Actually, we looked more like this.
Why write a Retrospective on Urban Travel Forecasting?

• By 2003, we had each spent 30 years or more conducting research in this field.
• The 50$^{th}$ anniversary of the origins of the travel forecasting field was approaching.
• Huw was taking his sabbatical, while I had just retired from the teaching faculty at UIC.
• And, it seemed like an interesting way to spend 2 or 3 years topping off our careers.
• Now, 9 years later, we have each read extensively, consulted with our peers and written several hundred pages.

• Our manuscript remains incomplete, but we have largely accomplished what we intended at the outset.

• Last December, an Invited Lecture in Hong Kong seemed like a fine place to begin to summarize what we have learned.

• Our seminar today is a 2nd ‘outline’ of our findings; we appreciate your comments, and your patience with its preliminary nature.
Dimensions of our review

- Research and Practice
- Travel Demand (Behavior) Models and Transportation Network Models
- United States and United Kingdom, and more generally Europe

With a concern for the:
- Constraints imposed by data and computers
- Roles played by the leading contributors
Contents of the Lecture

1. Emergence of the traditional approach – US
2. Further development of traditional approach – UK
3. Integrated network equilibrium models
4. Travel forecasting with individual choice models
5. Further extensions of the discrete choice approach
6. Activity-based travel analysis and forecasting
7. Tradition and innovation in US practice
8. Tradition and innovation in UK practice
9. Computing environment and forecasting software
10. Achievements and current challenges
Getting started – a look at the origins of terms

<table>
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<th>Traditional and evolving terminology of travel forecasting</th>
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Context of model formulation and use

• Forecasts for a future design year, relative to a base year, both for facility planning and for demand management;
• Tests of the impacts of alternative policies;
• Explanation and exploration of observed travel behavior;
• Design of model systems and evaluation frameworks, given computational feasibility;
• Design of transportation networks and patterns of activity location (land use).
Drivers of Change in Modeling

• 1950-1960s:
  – rapid increase in car ownership
  – population growth and urban decentralization
  – major road building, with declining transit use

• 1970-1980s:
  – environmental and financing restrictions
  – demand management
  – expanding rail transit systems

• 1990-2000s:
  – sustainability, non-motorized modes

• Developing regions now face these drivers of change all at once
1. The Formative Era – Practice - US

• Surveys and inventories: household travel, land use, road & transit systems
• Data processing and reduction → models
IBM 407 Accounting Machine

IBM 704 Computer
1. The Formative Era – Practice - US

- Surveys and inventories: household travel, land use, road & transit systems
- Data processing and reduction → models
- Representing travel through aggregation: (zones, 24 hour weekday, trip classes, ..)
- Partition of travel choices: frequency, O-D, route; no time of day, and often roads only
- Role of land use as the determinant of travel
- Early sequential procedure flowchart showing how to connect these ‘steps’
First known travel forecasting flowchart - 1957
Planning Process of the Chicago Area Transportation Study, Volume One, 1959
1. The Formative Era – Practice - US

• Early sequential procedure flowchart showing how to connect these ‘steps’

• Demand – network cost equilibrium intuitively solved with a simple feedback procedure

• Road network design:
  – expressway spacing formula
  – a strong orientation to road planning, with a secondary concern for transit

(Chicago Area Transportation Study)
Ring – radial system
Ring – radial system  

Grid – ring system
1. The Formative Era – Practice - US

- Demand – cost equilibrium solved with a simple feedback procedure
- An early attempt at road network design:
  - expressway spacing formula
  - a strong orientation to road planning, with a secondary concern for transit
- A failed early attempt to identify a desired land use pattern by forecasting the response of activity locations to road – transit network alternatives (Penn Jersey Transportation Study)
• Detroit (DMATS) – 1953-56
  – early gravity model experiments (J.D. Carroll, Jr.)
  – early attempt at computerized traffic assignment
• Chicago (CATS) – 1956-62
  – intervening opportunities model (M. Schneider)
  – shortest routes on large networks (E. F. Moore)
  – linked distribution & assignment (M. Schneider)
  – expressway spacing (R. Creighton, I. Hoch)
• Philadelphia (PJTS) – 1959-67
  – transportation networks imply land use patterns (R. Mitchell and B. Harris)
  – residential location model (J. Herbert and B. Stevens)
• U.S. Bureau of Public Roads – 1958-66
  – trip distribution by gravity model
  – capacity restrained assignment (G. Brokke et al)
  – zone-based trip generation & modal split

• Alan M. Voorhees and Associates – 1962-69
  – transit forecasting model system (R. Dial)
  – creation of first travel forecasting model system: TRIPS (W. Hansen and T. Deen)

Alan Voorhees, 2000  Britton Harris, 2003  Ben Stevens, 1985
• Land use – transportation programs, 1959-68
  – preparation & evaluation of alternative plans for metropolitan land use and transportation in several regions (Boyce, Day and McDonald, review & synthesis)
  – attempts to apply land use models declared a failure by D. B. Lee, Jr. in his ‘Requiem for Large-scale Models.’
2. Transfer of US Practice to the UK

- Early traffic research (Wardrop, 1952)
- Consulting consortia initially transferred US modeling practice to London and Glasgow
- British practitioners, and young researchers, began to improve the Transport Model, as it became known, with substantial innovations:
  - variations in trip frequency at household level
  - empirical curves replaced by analytic functions for distribution and mode steps – entropy maximization
– generalized costs based on micro-behavioral foundations
– issues concerning the order of the steps and how to connect the steps:
  Dest → Mode, Mode → Dest, or Dest – Mode?
– definition of composite cost functions, model interfaces, and specification of nested models
– dispersion of route flows across routes
– line-based Public Transport representation
– trip-based benefit analysis for evaluation
Early contributors, 1960-75

• US-trained British engineers
  – Tony Ridley and John Wootton (UC Berkeley)
  – Brian Martin (MIT)

• UK-trained economists and mathematicians
  – Christopher Foster & Michael Beesley (Oxford)
  – Alan Wilson (Cambridge, and later Oxford)
  – David Quarmby (Cambridge, and later Leeds)

• London Traffic Survey/Transportation Study, 1962-68
  – Household-based generation (category analysis)
  – User benefit analysis – rule of one-half
  – TRANSITNET
• Math. Advisory Unit, Ministry of Transport
  – maximum entropy derivation of share models
    of logit form for trip distribution and modal split
  – generalized cost functions
  – examination of the proper sequence of models
  – increased emphasis on evaluation
• SELNEC Transportation Study (1967-72)
  included all major UK innovations to date
• Road Research Laboratory studies
• Next generation of British researchers:
  Michael Batty, Dirck Van Vliet, Huw Williams,
  Peter Batey, to name several
Proposed SELNEC Transport Model Structure (Wilson et al, 1969)

- **External Trips**
  - Trip Generation
  - Trip Ends
  - Trip Distribution
  - Modal Split

- **Planning Inputs**
  - Build networks and time/cost matrices

- **Network Description**
  - Trip Matrices by purpose and person type

- **Commercial Vehicle Trips**
  - Growth Factors
  - Bus trips
  - Total Link Loadings

- **Growth Factors**
  - Public transport person trips by purpose

- **Economic Evaluation**
  - Check capacity restraint, adjust link times
  - Operational Evaluation

- **Operational Evaluation**
  - Routes

- **Times and costs**

- **Total vehicle trips (exc. bus)**

- **Load trips**

- **Feedback**
Implemented SELNEC Transport Model Structure

Alan Wilson, 1970

David Quarmby, 2003
SELNEC Transport Model Structure

- Planning inputs
- Generation
- Distribution
- Modal split
- Assignment
- Flows on links of networks
- Trips by mode
- Trips by person type
- Networks
- Feedback
- MSA-3 iterations

• Cowles Commission study on allocation of scarce resources (T. Koopmans, 1952-55)
• Formulation of network equilibrium and efficiency models with new tool of nonlinear programming and the Kuhn-Tucker theorem (Martin Beckmann, with McGuire & Winsten, 1956)
• Variable demand and network flow models with average and marginal cost pricing
• Models of network user-equilibrium with fixed demand (Jorgensen, Charnes, Prager, Gibert, Dafermos, Braess, 1954-70)
Michael Florian spoke with Martin Beckmann, after he received the Robert Herman Lifetime Achievement Award in Transportation Science in 1994.
• Convergent algorithms for cases of fixed and variable demand (Dafermos, Murchland, Evans, Florian and Nguyen, LeBlanc, 1968-73)
• Correspondence between Beckmann’s formulation and the sequential procedure explored mathematically (S. Evans, 1973)
• Nonlinear complementarity and variational inequalities (Smith, Dafermos, 1979-84)
• Implementation of models of activity location (land use) with endogenous travel costs (Erlander, Boyce & Lundqvist, 1977-92)
• Implementation and validation of combined travel choice and user-equilibrium models (Lam & Huang, Boyce & Bar-Gera, 1992-2000)
Suzanne Evans and Anna Nagurney at 2003 recognition of *Studies in the Economics of Transportation* by Beckmann, McGuire and Winsten

Martin Beckmann & Bart McGuire being honored for their *Studies* at San Francisco INFORMS in 2005
4. Individual Choice Models (~1965-75)

- Widening criticism of ‘traditional methods’ in late 1960s to 1973 – lack of behavioral basis at the level of individual travelers
- Discrete choice models based on random utility maximization (Quandt, McFadden)
- Early exploration of nested logit models (McFadden, Ben-Akiva)
- Economic-statistical properties of multinomial logit model (McFadden)
- Increased recognition of restrictive properties of multinomial logit (IIA property)
- Improved mathematical specification of systems of models (Manheim)
Daniel McFadden receiving the Nobel Prize in Economic Science from the King of Sweden in 2000

Moshe Ben-Akiva and Daniel McFadden in Stockholm in 2000
5. Discrete Choice Models (~1975-85)

• Nested logit with parameter restrictions (Williams, Daly-Zachary)
• General extreme value models, with nested logit as a special case (McFadden)
• Ordering of hierarchical choices, as an improved basis for traditional models (Williams and Senior)
• Individual choice models offered practical alternative to the sequential procedure (Richards and Ben-Akiva, Daly)
• Use of stated preference methods to supplement revealed preference data
6. Activity-based analysis framework

• Widening criticism of traditional procedures and discrete choice theory:
  – lack of behavioral basis
  – inability to represent observed complex tours

• Activity-based choices of households: response to time constraints and alternative plans (Hagerstrand, What about people …? 1970)

• Econometric approach (Ben-Akiva & Bowman)

• Rule-based approach based on satisficing behavior (Pas and Kitamura)

• Early fixed travel cost prototypes without endogenous travel costs/congestion effects) (Bowman & Bradley, Vovsha)
7. Tradition and Innovation in US Practice

- Lawsuit challenging the Bay Area model (Garrett & Wachs, *Transp. Planning on Trial*, 1996)
- Federal requirements for solving the sequential procedure with feedback, 1991
- Travel Model Improvement Program (TMIP) initiated by Federal Highway Administration
- TMIP funding reallocated to TRANSIMS, a microsimulation software development effort by Los Alamos National Laboratory
- Prototype use of activity-based models, and later integration with land use and dynamic traffic assignment simulation methods (Pendyala, Waddell and Chiu, *Urban Continuum*)
8. Tradition and Innovation in UK Practice

- Decline of travel modeling since the 1980s
- Increased technical guidance of government, partly a result of *Trunk Roads and the Generation of Traffic* (Standing Advisory Committee for Trunk Road Assessment, 1994)
- Incremental nested logit model applied in various situations
- Traffic management and microsimulation: SATURN, PARAMICS, VISSIM
- Integrated land use – transport models: MEPLAN, TRANUS, DELTA-START
- Innovations in goods movement models
9. Computing Environment and Software

• Mainframes to minis to microcomputers, 1951-2008
• Microcomputer revolution from the 1980s
Performance of Super-, Mainframe, Mini- and Micro- Computers, 1951-2008

- Strohmaier et al, Recent Trends in the Marketplace (2005)
- Dongarra, Performance of Various Computers (2007)
Apple Lisa, improved version of Apple II, 1983

IBM PC, model 5150, 1982
9. Computing Environment and Software

- Mainframes to microcomputers, 1951-2008
- Microcomputer revolution in the 1980s
- Origins of travel forecasting software
  - Urban transportation studies: CATS, PJTS, etc.
  - Bureau of Public Roads – distribution and assignment
  - US Dept. of Housing – transit planning package
  - Transportation Planning Exchange Group
  - Alan M. Voorhees and Associates – TRIPS, a combination of BPR and HUD packages
  - Control Data Corporation – TRANPLAN
  - Martin & Voorhees Associates, moved TRIPS to the UK
• US Department of Transportation
  – Urban Transportation Planning System, initially TRIPS, distributed and extended by the Urban Mass Transportation Administration
  – PLANPAC, a collection of programs developed by the Federal Highway Administration

• Legacy mainframe applications in 1970s
  – UTPS (Robert Dial) UMTA, US DOT
  – PLANPAC, FHWA, US DOT
  – TRANPLAN, James Fennessey, CDC
• Transition to microcomputers
  – Knowledgeable software developers began developing software for the IBM PC and Apple microcomputers in early 1980s
    • TRANPLAN, James Fennessey, DKS Associates
    • TMODEL, Robert Shull, Professional Solutions
    • MINUTP, Larry Seiders, Comsis
    • MicroTRIPS, PRC Voorhees/MVA Systematica
    • EMME/2, Michael Florian, INRO
    • QRS II, Alan Horowitz, AJH Associates
    • VISUM & VISEM, Tom Schwerdfeger, PTV AG
    • SATURN, Dirck Van Vliet, University of Leeds
    • A few others that did not survive in the marketplace
• Travel forecasting software systems today
  – *CUBE* (Citilabs, US) – evolved from TRANPLAN, TRIPS, MinUTP and TP+, and combining features of these legacy systems
  – *EMME* (INRO, Canada) – developed from research of Michael Florian, University of Montreal, and continues to be based upon research advances of Florian and his students
  – *TransCAD* (Caliper, US) – developed by Howard Slavin and his associates by seeking to incorporate the best available models
  – *VISUM* (PTV, Germany) – developed from research at University of Karlsruhe, and later adapted to US travel forecasting practice
• Specialized forecasting software systems
  – *ESTRAUS* (MCT, Chile)
  – *OmniTRANS* (OmniTRANS Int., Netherlands)
  – *QRS II* (AJH Associates, US)
  – *SATURN* (WS Atkins, UK)
  – *STRADA* (Japan International Cooperation Agency, Japan)
  – *TRACKS* (Gabites Porter Consultants, New Zealand)
  – *TRANUS* (Modelistica, Venezuela)
  – *UFOSNET* (RST International, US)
10. Achievements and current challenges

- The track record for academic research:
  - research was nearly non-existent in the 1950s, whereas practice was offering innovations
  - continuous improvements in foundations and understanding of models of specific choices
  - less success in advancing the demand-network equilibrium framework
  - lack of empirical validation and progress in understanding of how urban travel has changed over the past 60 years
  - successful use of the huge advances in computing power
  - who made the leading innovations?
• The track record for professional practice:
  – following its early innovations, contributions from practice slowed substantially
  – practitioners are able to apply their software tools, but often without understanding of their properties (black box vs. glass box)
  – few practitioners understand and are able to explain the properties of the models they apply, and sometimes offer misleading or invalid descriptions of model properties
  – is this situation a failure of their education?
  – difficulties of understanding model properties will only become greater in the future
• Partially unaddressed problems of our field:
  – disaggregation in time and space:
    • geographic scale (zones)
    • timing of travel (static vs. dynamic)
  – design of networks and activity location systems
    • basic normative properties of location and networks remain unstudied and unknown (e.g. land use density and network layout)
    • these questions were studied in the 1960s without success, perhaps because the models lacked sensitivity; is this still the situation today?
  – overly simplified assumptions of basic models
    • representation of travel delay at intersections
    • cross-elasticities of demand by mode and destination
• What are the ways ahead?
  – how should research and demonstration on design problems be undertaken? who decides?
  – at what scale should exploratory research be organized and funded?
  – likewise, at what scale should experimental implementations be undertaken in practice?
  – how should innovative thinking be rewarded?
  – who decides what research is supported?
  – how should progress be evaluated in another 25 years?
Questions and comments?