April 3, 2014

The Next 50 years in Travel Analysis: What We Need to Know

- **Internet Survey, Jan 14-March 17, 2014**
- **Workshop 151, January 12, 2014.**

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This summary has two sections. The first is a summary of an **INTERNET SURVEY** of professionals focusing on estimates of 'reasonable accuracy' for travel demand models, and issues likely to be addressed in the next several decades. The second is a summary of **WORKSHOP 151,** held January 12, 2014 at the Annual Meeting of the Transportation Research Board, which focused on issues in travel demand modeling for the next 50 years.

Internet Survey

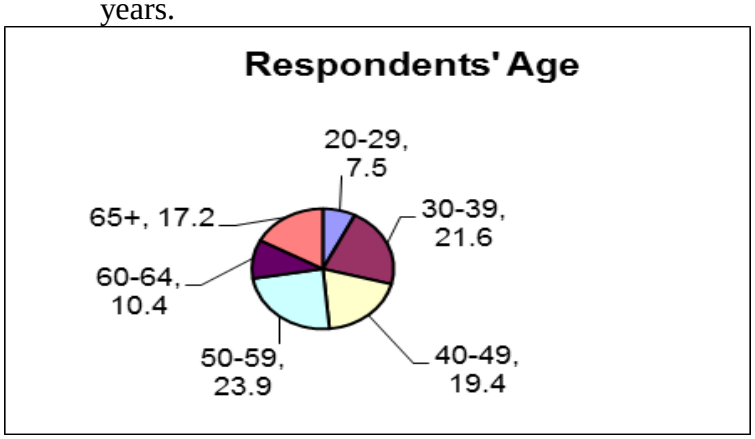
Background:

As part of the Workshop on Travel Analysis Methods, held January 12, 2014 at the Annual Meeting of the Transportation Research Board, Washington, DC, the TRB Committees in the Travel Analysis Section sponsored an internet survey of committee members and friends, focusing on issues for travel modeling, and expectations for modeling accuracy.

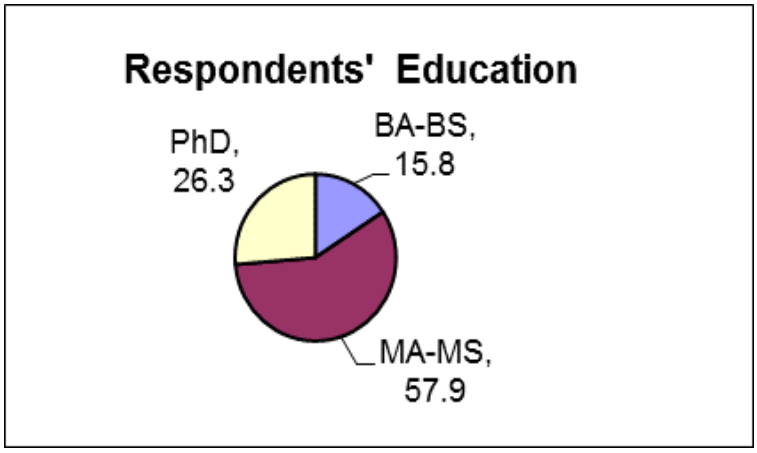
Survey Dates: January 14, 2014-March 17, 2014
Audience: Members and friends of TRB committee in Travel Analysis Section, TMIP list members, and additional contact lists.
Responses: 135

Respondent Characteristics

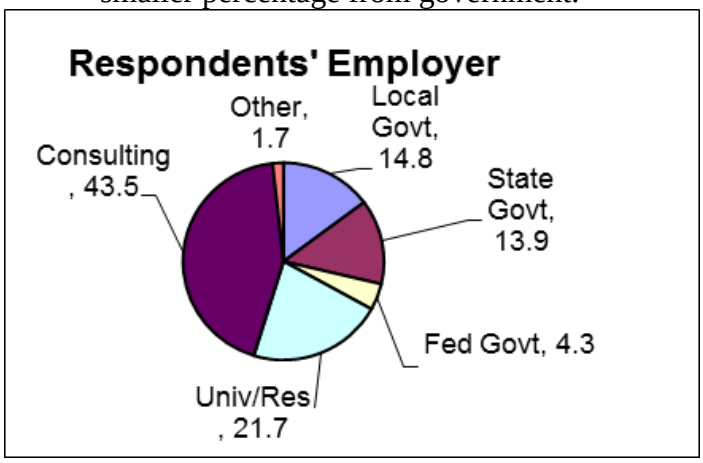
- **Age:** Respondents were uniformly split by age, with the highest percentage 50-59 years.



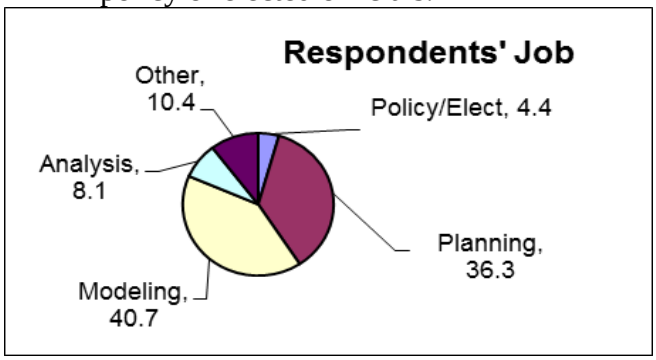
- **Education:** Respondents were largely MA-MS level, with a significant share of PhDs.



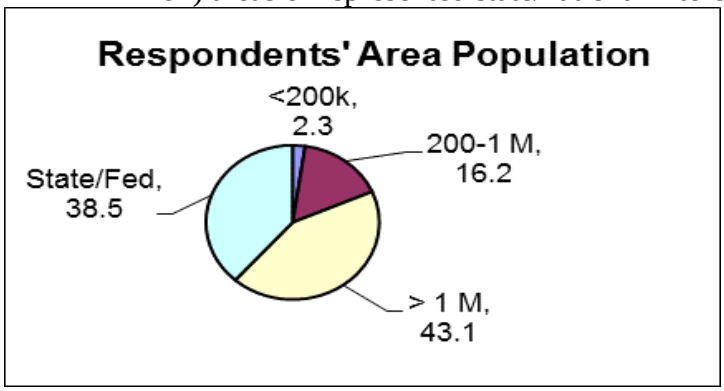
- **Employer:** Respondents were largely consultants and university-based, with a smaller percentage from government.



- **Job focus**: Respondents were primarily modelers and planners; a very few were policy or elected officials.



- **Area population**: Respondents were primarily from larger metropolitan (> 1 million) areas or represented state/national interests.



How accurate is a demand forecast 'reasonably expected' to be? (Note: this is NOT actual accuracy, but the accuracy that respondents said could be reasonably expected):

'Reasonable Accuracy' (Percent and SD) Expected for a Travel Demand Forecast				
Project type	**Calibration**	**1 year after opening**	**5 years after opening**	**20 years after opening**
New road, tolled	*	11+-6	15+-7	24+-14
New road, un-tolled	*	11+-6	16+-7	24+-13
(Bain, 2011)		*(15)*	*(25)*	*(42)*
Widen existing road, toll (e.g. HOT lane)	9+-5	10+-6	15+-7	23+-13
Widen existing road, un-tolled	9+-5	12+-8	15+-7	23+-12
(Bain, 2011)	*(7.5)*	*(10)*	*(15)*	*(32.5)*
Major arterial improvement, but no widening	10+-7	11+-6	16+-9	24+-14
New fixed transit line (CR, LRT, HR)	*	12+_7	16+-10	26+-18

*'Calibration' cannot estimate accuracy for un-built projects.

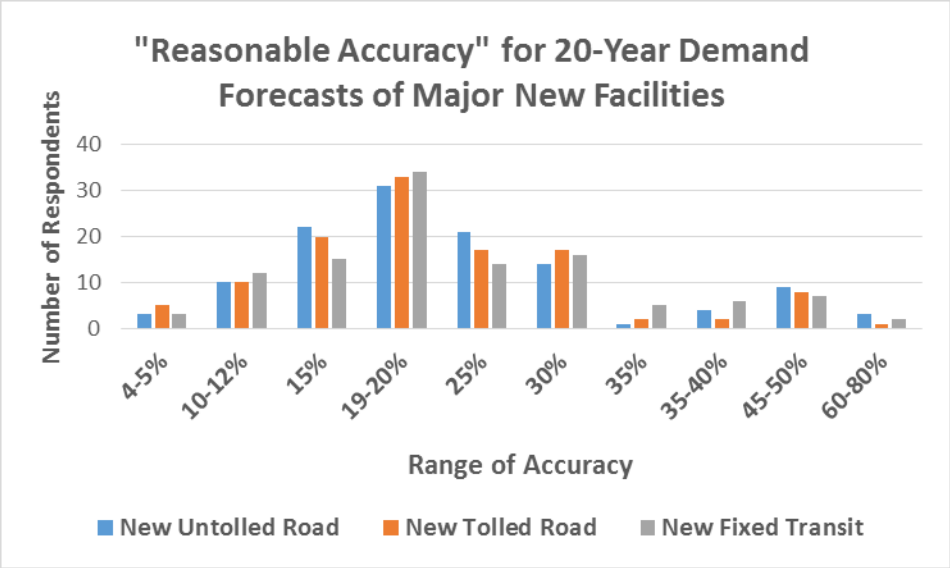
- For **calibration** (matching base year data), respondents set 'reasonable accuracy' at about +- 9-10%, with a SD of +-6%. This was consistent across all types of projects.

- For '**1-year after opening'** the expected 'reasonable accuracy' increases slightly to about +- 11%, SD about 7%, again with consistency across project types.

- For '**5 years after opening**", the expected 'reasonable accuracy' increases to about +-15%, SD 7%, again with consistency across project types.

- For a forecast '**20 years after opening'**, the expected 'reasonable accuracy' increases to about +-24%, SD 13%, consistent across project types, but the range is slightly higher (+- 26%) for new transit projects.

- However, there is considerable **variation in the range of responses**. About 2/3 of respondents thought that the 'reasonable accuracy' range for a 20-year major highway or transit project should be between +-6% and +- 44%, with the most-frequent response +- 19-20%.



- The results generally parallel the findings of Bain's survey of 46 travel demand modelers (2011[1]) which reported somewhat wider 'reasonable accuracy'. Since both surveys went to the same/similar professional groups, the reasons for these differences need further study.

- Our results also find, as Bain did, little difference in accuracy estimates for different types of projects.

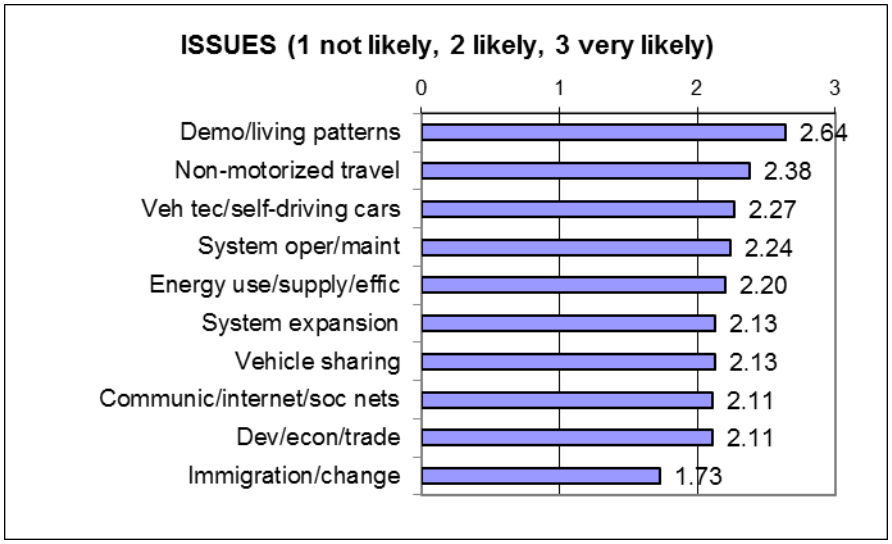
- We also found little variation in views about reasonable accuracy for different respondent age, education level, employer, job type, or region size. *The primary factor influencing expectations for 'reasonable accuracy' appears to be the length of the time horizon: longer forecast horizons have wider bands of 'reasonable accuracy'.*

- There were also numerous comments made by respondents, which are still being analyzed.

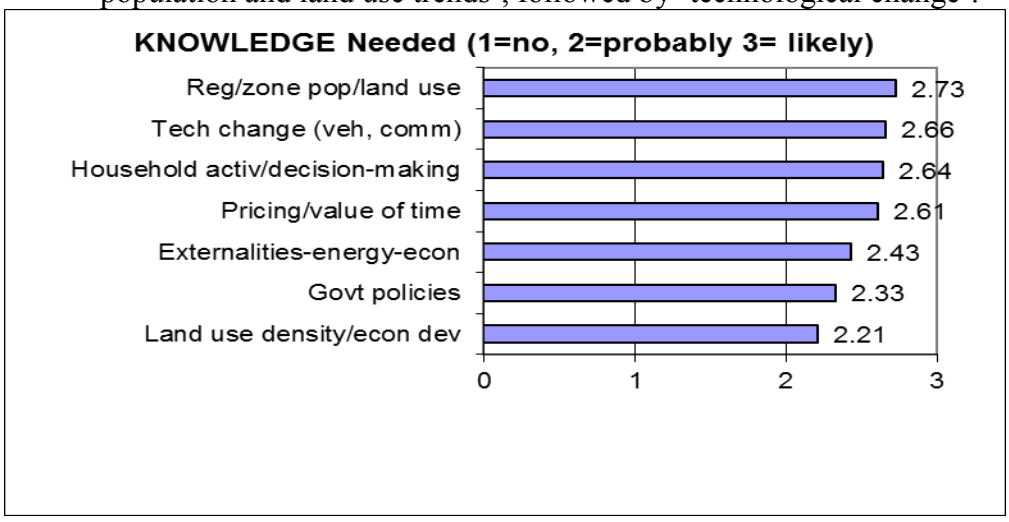
Issues, Needed Knowledge, and Moving Forward

[1] R Bain, On the reasonableness of traffic forecasts: a survey of predictive capability. Traffic Engineering and Control, May 2011. At www.robbain.com

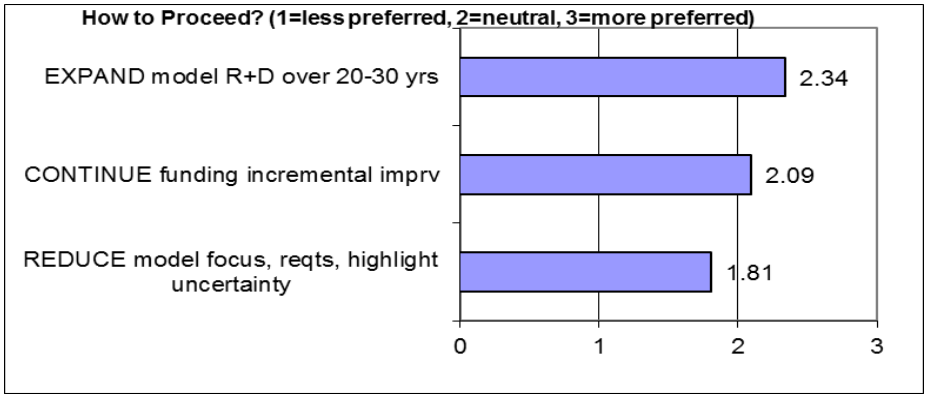
- **What issues are likely to be faced by travel demand modelers? (1-3 score)**
  Respondents thought that most issues were likely or very likely to need attention, but on average the highest ratings went to 'demographic and living patterns' and to 'non-motorized travel'.



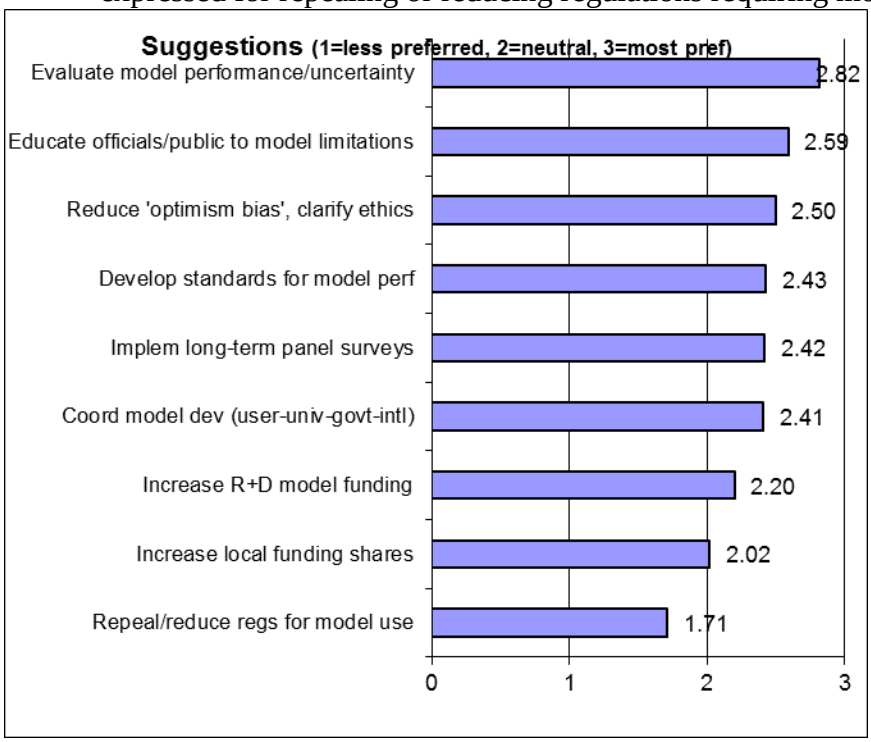
- **What knowledge is needed to address these issues (1-3 score)**
  Respondents, on average, gave the highest needed knowledge to 'regional/zonal population and land use trends', followed by 'technological change'.



- **How to proceed?**
  Respondents thought that **expansion of modeling R+D** was the best way forward. Least preferred was a 'humility' approach reducing model focus and highlighting uncertainty.



- **Suggestions for proceeding?**
  Respondents gave highest ratings to efforts to '**evaluate model performance and determine uncertainty**', and to "**education of officials and the public regarding modeling limitations**'. On the other hand, there was little support expressed for repealing or reducing regulations requiring model forecasts.



We also found very little variation in these 'average scores' by age, education, employer, job type, or region size.

Willingness to participate in further study

- About 52 % (70) respondents indicated a willingness to explore the issues further through study of their own regions. This is a very good sign from the community of practitioners interested in investigating modeling accuracy.

These responses may be reflective of the respondent characteristics, being mostly from consulting and academia. The views of policy or elected officials are largely missing from the survey, and should be obtained by additional surveys.

Workshop 151, Transportation Research Board, Jan. 12, 2014

Background

The past 50 years have witnessed significant advances in travel analysis, modeling and forecasting (choice based models, activity models, dynamic assignment, land use integration, etc). But the basic paradigm (4-step process) used in much travel demand modeling is unchanged, even though policy topics have greatly expanded. Many fundamental questions (e.g. structure of household travel, land use and investment impacts, impacts of internet/GPS, and self-driving cars) are poorly understood and the impacts of other policies (e.g., car or bike sharing) cannot be easily evaluated. Recent reviews of model accuracy document high uncertainty in model estimates, and highlight technical and organizational weaknesses that likely cannot be fixed without new basic paradigms.

Why is this important? The purpose of travel analysis is to improve transportation investment decisions by improving the accuracy and relevance of forecasting and analysis tools. A 50-year old paradigm is not relevant for many current issues. Travel analysis should therefore update its paradigms to provide the best possible professional input for transportation decisions. This is a difficult undertaking. Other disciplines (biology, physics, hurricane forecasting, even highway research) have developed research plans to improve basic understanding and forecasting, but travel analysis targets short term research rather than long-term goals.

This Workshop discussed how travel analysis can substantially advance over the next 50 years. The Workshop did not produce new paradigms for travel analysis (that is too difficult a task); instead it identified various ways to develop such a paradigm in a coordinated and methodical way.

An agenda this ambitious might take 20-50 years to complete, and probably would need several additional organizing events/conferences to begin. The first step is to look in the mirror, recognize the current situation, and get talking. TRB's Travel Analysis Methods Section is the ideal organization to do this.

The Workshop took place on January 12, 2014, at Session151 of the Annual Meeting of the Transportation Research Board. About 200 participants were in attendance, and many commented afterwards that it was one of the best workshops they had seen. This Summary of the Workshop summarizes the speakers' remarks, and also includes results of a 'survey monkey' of professionals focusing on model accuracy and key issues.

Part I: What issues will we face? How should models be used? How can we accelerate technology transfer?

Rebekah Anderson, Ohio DOT

Rebekah Anderson opened the Workshop with a 'time warp' review of travel forecasting using examples of key documents. Beginning in the 1940s and through the 1950's and 1960's origin-destination and household travel surveys were conducted in virtually all of the US urbanized areas with greater than 50,000 population. These were quite well documented (e.g., FHWA Trip Generation Methods, 1977). But the methods being used – what we now call the 4-step process – were already in flux by 1974 (TRB Special Report 149), and seminal new methods (1975, Daytona Beach; 1976 NCHRP Project 8-12; 1978 NCHRP Report 183; and 1979, Destination Choice) based on choice theory were already being proposed. Progress in implementing these methods, particularly for mode choice was quite rapid, so that by 2008 (NCHRP Report 288) these methods were deemed state-of-good-practice.

Looking forward, the need for continued improvement is apparent. Better methods are needed for issues such as economic impact analysis, project rating and scoring, land use forecasting, truck-freight 'just-in-sequence', reliability, transit path algorithms, and micro-scale transit and highway planning. Guideline for model use are under development (NCHRP 8-94), but much more needs to be done to bring new methods into practice.

Steven Polzin, University of South Florida

Steven Polzin highlighted the major changes underway in transportation planning. As resources decline, the focus is responding to current demand and away from future demand. Weak theory and the profession's response (e.g., failure to see slowdowns in trip rates, decoupling of VMT and GDP, communications substitute, household structure and cross-household interaction, smart-vehicle technology, and changes in personal values) all have contributed to a lack of trust in forecasts and an increase in political considerations. For local planning agencies, the key issues now are equity/eligibility, funding given limited resources, and compliance with federal rules; less attention is placed on analysis, performance-based planning, and cost-effectiveness. Ironically this comes just as federal rules for performance-driven planning are increasing. Decision-makers often don't know the best options, and it is the profession's role to provide that. We need to be less timid in our assessments, but also recognize the inherent uncertainty in forecasting; often 1-2 digit accuracy is sufficient. The challenge for modelers will be how to provide *robust but simple models* that forecast reasonably well but not perfectly.

Thomas van Vuren, Mott MacDonald Ltd., United Kingdom

Tom van Vuren focused on technology transfer from academia to practitioners. He characterized 'relevance' as the intersection of what planners/analysts want to say, and what the public wants to hear. While the profession views itself as a robust group capable of accurate and reliable analysis, the public's view of modelling experts is often one of technicians immersed in minutia. Among practicing professionals, little use is made of much university-based modelling research, partly because of its (perceived) irrelevance, partly because of the poor dissemination of University research through practice-relevant channels. Among the needed steps to improve its relevance are improved university-practitioner communication (both in terms of research needs and in

terms of research findings), reduced dependence on commercial software to turn academic research advances into practical tools, incentives for increased practice-focused academic research, such as funding streams or publication recognition, an R&D focus in the Continued Professional Development criteria for practitioners (such as ITE in the US or TPP in the UK), greater professional assertiveness and less 'sniping' at imperfect models, and more reporting of modelling successes (i.e. proving the value of modelling in decision-making).

Part II: What is the status and limitations of our knowledge? What do we need to know?

Chandra Bhat, University of Texas

Chandra Bhat suggested five major issues the profession will need to address in the coming decades: 1. *Immigration*: The US population is projected to continue to grow over the next few decades. But this is not because of population increase within the segment of US residents. Indeed, childbearing in the US has declined from 3.7 children/woman to 2.0 in just 50 years. Instead, the increase will mainly be due to the continued increase in the immigrant population. About 1/3 of the population growth in the past 20 years was due to immigration, primarily non-white Hispanic and Asian. But these trends are quite location-specific. The travel behavior of immigrants continues to be different from non-immigrants due to a variety of reasons tied to resources, mobility preferences and constraints, past behavior and cultural norms, and self-preservation and identity considerations, and these need to be studied and incorporated much better in our predictive models. 2. *Forecasts of population and vehicles.* Rates of growth for both population and vehicle use are slowing and perhaps even declining. These are also location-specific. Further, the composition of families and households, as well as passenger vehicle fleets, continues to change. We need detailed and good micro-simulation models of population, population composition, and vehicles for inputs to travel models. 3. *Model validation.* 'Calibration' (fitting a model to base-year data) is not 'forecast validity'. In this regard, there appears to be a widespread notion that if a model predicts ground counts in the base year well, it is the "ultimate" model. This notion effectively places a huge "reward" and the "showering of accolades" for showing accurate fit with ground counts, leading to the rather indiscriminate use of adjustment factors (or at least an environment that is not discouraging of the liberal use of adjustment factors). But, while a model with several adjustment factors may be a super-fit for the base conditions, it can be a disaster for forecasting. The obsession with the use of ground counts as the ultimate or dominating validation measure of model performance constitutes an Achilles heel in our pursuit of developing good forecasting models. There has to be emphasis on the logic and behavioral elements of the modeling system, with model validity being based on a smorgasbord of different sensitivity and data output checks rather than solely aggregate link ground count measures in the base year. 4. *Uncertainty*. Significant unknowns for the future include 'driverless' vehicles and communications technology. We need to recognize the inherent uncertainty in all forecasts, and accommodate this uncertainty in predictions. How this uncertainty is articulated in a relatively simple manner for decision-making remains a challenge that the

community should address head-on. 5. *Model complexity*. The movement toward more conceptually accurate modeling approaches (such as activity-based models or dynamic assignment models) is generally associated with more time-consuming and "cumbersome" models. This need not be the case. There are ways that more theoretically sound and new methodologies can lead to models that are computationally efficient. For example, rather than have a series of single discrete choices of participation in different activity purposes, one can model this with a more theoretically sound multiple discrete choice model of participation that recognizes satiation effects in activity participation while also predicting activity participation choices in one stroke.

Mark Bradley, Resource Systems Group

Mark Bradley noted several key unknowns: 1. *model cost-effectiveness*. The newer models (land use, activity, and dynamic assignment) have undergone a lot of development, but there is relatively little evidence from practical applications so far. The perception is that they are complicated to use and to operate, leading to specialization of users. Improved software is needed to improve their accessibility to practitioners. 2. *Dynamics of travel*. We also need to know more about the dynamics of travel demand in land use, demand models, and traffic assignment. 3. *Age cohorts*. We assume constant future behavior for various groups, e.g. elderly and Millennials, but these are clearly changing. Good longitudinal data is needed to sort out generational changes. 4. *Habit.* Many travel choices are lifestyle 'habits' that change rarely/slowly. Longitudinal data can help identify short-term and long-term adaptations. 5. *Prediction of change.* Models can be 'over-fit' in calibration but perform poorly in forecasting. Controlled experiments (difficult to do) can help evaluate various approaches to forecasting. A suggested long-term research program to look at these issues should include 1. Select 4-5 regions, gather 20+ year data on land use, household surveys, network characteristics. 2. Use emerging data to assess model abilities. 3. In the meantime, use tools like scenario analysis to evaluate effects of income and demographic change. In addition to forecasting, a very important use of models is in understanding how different types of policies would perform in different future scenarios. This could lead to different policy decisions. 4. Initiate research to use strategic, scenario-based modeling of speculative issues such as 'driverless vehicles', pedestrian -bike infrastructure, vehicle sharing, and climate change.

Kay Axhausen, IVT-ETH Switzerland

Kay Axhausen noted that historically the transportation profession was optimistic about the effect of adding capacity, but now limits are being reached. The cost of system expansion is now 5 times greater than in the 1970s, and in slow-growing regions, additional capacity may not be needed, even though interest groups favor it. On the other hand, in faster-growing regions, significant investment mistakes can still be made. Model needs have shifted from a focus on 'growth' to a focus on 'stability' and VMT slow-downs; and to a focus on the within- and between-day dynamics. Current models are probably adequate for political evaluations in fast-growth areas, but not for areas of slow or no growth, and generally for policies favoring sharing resources, such as car pooling, car sharing, and taxi services. Academicians have done well conducting transportation research and particularly activity based modeling but rarely consider computational time; in practice, however these considerations are paramount.

Deborah Niemeier, University of California at Davis

Deb Niemeier focused on the limitations of current knowledge as it cut across three categories: 1. '*Known knowns'* include such factors as the impact of travel time and reliability, operational aspects of modeling, and use in practice. For example, travel behavior in mode choice is quite well understood, but the models have become so technically complex that only a few understand them. In addition, there is seemingly a very low correlation between what the models produce and the main policy decisions that are made. 2. '*Known unknowns'*, such as the technical capacity within local planning agencies, lag times between actions and response, and new issues such as climate change. 3. '*Unknown unknowns'* such as impacts on income inequality, and the effects of extreme events. Using an analogy to transportation cost-benefit analysis, she noted that the marginal cost of decision uncertainty likely declines with increasing quantity of modeling effort, but the marginal cost of model development and use likely increases with modeling effort. The marginal cost of a lower-cost modeling alternative shifts the 'optimum' point (where the cost of model development equals the cost of decision uncertainty) to the right, but how far is unknown.

Antonio Paez, McMaster University, Canada

Antonio Paez identified several key limitations of current knowledge: 1. *Habit versus choice* in decisions, particularly when and how various choices become 'habits', and how adaptations are made. 2. *Self-selection* in choices and how it affects our modeling and forecasting capabilities. 3. *Psychological factors* influencing choices and perception of alternatives. 4. *Interactions* within and between households, businesses, and social networks. To understand these issues better we need real-time studies of situations, e.g. 'forecasts' of today's behavior. More difficult will be assessments of 'autonomous vehicles' and vehicle sharing. It will probably not be possible to develop a unified 'grand model' covering all circumstances, but a 'nimble' model addressing major issues is possible.

Part III: How should we proceed?

Kostas Goulias, University of California at Santa Barbara

Kostas Goulias noted the vast number of papers, studies and research efforts in journals and reports. Major gaps such as 'discrete choice' modeling have been effectively bridged. Although in many cases the 'science' is still not there, in the sense that theories have been proven, he expressed optimism about the future of travel demand modeling over the next 50 years.

David Hartgen, The Hartgen Group

David Hartgen summarized his recent review of the accuracy of travel demand models and their relevance for public decision-making (*Transportation*, 40.6, Nov. 2013). Only a few studies of model accuracy have been performed, but they find that the likely inaccuracy in a 20-year forecast of a major road project is ±30 percent at minimum, with some estimates as high as ±40–50 percent over even shorter time horizons. Models

tend to significantly overestimate traffic and underestimate costs, particularly for toll roads. Forecasts of transit costs and ridership are even more uncertain and also significantly optimistic. The greatest knowledge gap in US travel demand modeling is the unknown accuracy of US urban road traffic forecasts. The major weaknesses leading to these problems are non-behavioral content, inaccuracy of inputs and key assumptions, policy insensitivity, and excessive complexity. In addition, the institutional and political environments that encourage optimism bias and low risk assessment in forecasts are also reviewed. Major institutional factors, particularly low local funding matches and competitive grants, confound scenario modeling efforts and dampen the hope that technical modeling improvements alone can improve forecasting accuracy. The fundamental problems are not technical but institutional: high non-local funding shares for large projects warp local perceptions of project benefit versus costs, leading to both input errors and political pressure to fund projects. To deal with these issues, the paper outlines two different approaches. The first, termed 'hubris', proposes a multi-decade effort to substantially improve model forecasting accuracy over time by monitoring performance and improving data, methods and understanding of travel, but also by deliberately modifying the institutional arrangements that lead to optimism bias. The second, termed 'humility', proposes to openly quantify and recognize the inherent uncertainty in travel demand forecasts and deliberately reduce their influence on project decision-making. However to be successful either approach would require monitoring and reporting accuracy, standards for modeling and forecasting, greater model transparency, educational initiatives, coordinated research, strengthened ethics and reduced non-local funding ratios so that localities have more at stake.

Kenneth Cervenka, USDOT

Ken Cervenka emphasized that his remarks were personal observations, and should not be interpreted as statements of current or proposed USDOT policy. He noted that forecasting accuracy *should* matter because modeling results are a key element of project assessments that almost always involve taxpayer dollars. Forecasters should be encouraged to regularly observe, analyze, and report findings regarding accuracy. The goal is not about 'perfection' or 'punishment,' but about learning lessons, building understanding, and improving the forecasting process whenever possible. Other disciplines (for instance, hurricane forecasting) have plans to significantly improve methods, and have set specific 'goals' (e.g. 50 percent improvement in accuracy within 10 years). The conduct of predicted-versus-actual tests, for both highway and transit projects, should be encouraged, particularly for comparison of different years and for situations where observed travel has changed. The goal should be to identify errors in travel prediction using real-world network and demographics, and to understand the impact of unexpected events. Newer "advanced" models claim conceptual elegance, policy sensitivity and disaggregated results, but there is little evidence so far that the predictions are consistently more accurate than what can be obtained from simpler analytical tools. The challenge to the profession is to use the appropriate tool for a specific planning need. In the interim, we can use multiple forecasts (scenarios), simplified methods, transferred-parameter methods, and other techniques to improve our confidence in forecasts. Forecasts should usually be based on conservative assumptions to reduce the risk of large errors, particularly when the situation is uncertain and complex

or when bias is likely. MAP-21's emphasis on performance-based planning encourages appropriate investments in data so that performance measure outcomes can be tracked, which makes it easy to also track the forecasts. Recent activities (e.g., before-and-after studies and traffic assignment-feedback studies by FTA; Cincinnati back-cast forecast analysis by TMIP) are examples of continuing efforts to improve modeling for future generations.

Eric Miller, University of Toronto

Eric Miller identified several issues challenging travel demand modeling: 1. 'Complete mobility' options such as autonomous vehicles and vehicle-sharing; 2.Urban growth resulting in larger and more complex regions worldwide. 3. Availability of 'big data' and how to take advantage of it. 4. Impact of climate change. 5. Economic development. 6. Political challenges. Regarding the capabilities of models, activity-based models are disaggregate and agent-based, but this actually simplifies modeling rather than making it more complex. The profession needs to invest time and effort to make models better as analysis tools. This requires better collaboration and coordination between model developers and users. We also need to follow the scientific method, testing theories rigorously and revising them willingly. Model 'calibration' is not 'validation'. We need to do less 'forecasting' and more 'understanding', based on empirical evidence. If we take seriously the problem of improving models we will continue to make progress.

Part IV: Summary

Ram Pendyala, Arizona State University

Finally, Ram Pendyala summarized the Workshop by concluding that travel demand modeling was not 'in the doldrums', as Eric Pas famously asked two decades ago. Spirited development of activity models, including some real-world tests, was ongoing, and incremental research, while sometimes disjointed, was nevertheless increasing understanding of many travel-related phenomena. But modelers need to become – and remain – relevant through continued interaction with practicing professionals. The Transportation Research Board, through its committees and research program, continues to provide one of the most extensive sources of model advancements. He suggested that perhaps a National Cooperative *Modeling* Research Program, on the lines of NCHRP and NCTRP, might be formed. There is also a role for the University Transportation Research program in higher-risk research, and for international cooperation. The goal should always be to bring proven results to practice, so that better transportation decisions are made.