NCTCOG's Land Use Modeling Workshop: *Meeting Minutes*

July 7 & 8, 2009

Meeting held July 7th & 8th, 2009, in NCTCOG's Six Flags Meeting Room, Arlington, Texas.

Minutes developed by Kara Kockelman, Brenda Zhou, and Sumala Tirumalachetty, with review by all participants.
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1. INTRODUCTIONS & BACKGROUND

Kara Kockelman (Professor of Transportation Engineering, UT Austin) welcomed all participants, who then introduced themselves.

NCTCOG's Director of Transportation, **Michael Morris**, kicked off the meeting by highlighting his view of the transportation planning context in most U.S. regions: In the past, adequate funds existed for building most of what was deemed needed. Currently, funds are clearly limited and regions are seeing more sustainable solutions. In the future, he anticipates inadequate funding, and a move to transportation system management, rather than building new transport facilities.

He noted that demographic drivers are critical to land use modeling, and there exist another 12+ sets of users who rely on NCTCOG's land use forecasts (not just transportation). Thus, the transportation planning group takes its inputs from the Research & Information Services Department, within NCTCOG. In this way, it finds itself at "arm's length" from related departments, resulting in less biased or self-serving transportation forecasts. In other words, the transportation planners cannot boost demographic inputs and argue for more transportation investment. Moreover, the State provides the region-level control totals (and county-level estimates), of jobs and households, which provides added protection for the agency.

He also pointed out that the Dallas-Fort Worth metroplex is bigger than the state of Maryland. So they do need large-scale forecasting (which many refer to as statewide modeling), but, of course, they also seek great detail (common to urban systems modeling). In sum, the NCTCOG is looking forward to behavioral-based, possibly equilibrium-based, models with high geographic resolution. They are interested in evaluating the cumulative effects of transportation, including walking and bicycling. It is important that transportation's negative externalities be reflected in any new tools. He expects transportation solutions will shape many facets of land use.

John Promise (NCTCOG's Director of Environment and Development) indicated that he is very interested in local built environment decisions, and how these relate to travel decisions (such as walking and biking).

Brian Gregor (Senior Transportation Analyst, Oregon DOT) asked whether NCTCOG does land use planning, and **Duane Dankesreiter** (NCTCOG's Manager of Research & Information Services) responded they do not have the ability to do more local, fine-tuning of plans and scenarios for cities (e.g., how various local-level land use policies may play out), but they would like to do so.

Robert Johnston (Professor Emeritus of Environmental Science & Policy, at UC Davis) commented that *NCTCOG may want and really need to add energy consumption, carbon restrictions, economic development, prices, imports and exports to their land use models (LUMs).* He added that California today is doing demand side management and small-region land use management evaluations, in light of current and coming climate change legislation.

John Gliebe (Assistant Professor of Planning, Portland State University) asked what the state of Texas is doing, and **Michael Morris** indicated they do very little travel demand management, but the state's demographic office provides the control totals. **Karl Eschbach** (Texas's State Demographer, at U.T. San Antonio) commented that there is no transportation and land use feedback in their forecasts. He noted that Texas' Water Development Board also puts out population and jobs projections, starting from his office's demographic numbers. COGs and MPOs can do what they want, but typically they use the State Demographer's numbers.

Duane Dankesreiter's presentation: NCTCOG is now running 2040 forecasts at 5-year (model) intervals for a 12-county region. Peripheral counties' appraisal districts are only now becoming familiar with GIS, so they have the region's weakest data, in terms of land use designations, parcel boundaries, and assessed values. He noted that district-/superzone-level forecasts are allocated based on weights to the region's thousands of traffic analysis zones (TAZs), and local governments can choose to move such allocations around (across TAZs) within each district. The NCTCOG has an approximate 3-year turn-around from base data assembly to results that are ready for policymakers to apply. *They feel that the inability to anticipate infill and redevelopment is ITLUP's biggest weakness.* NCTCOG also turns to building permit data (which can estimate population and housing relatively accurately). Data on employers with 80+ workers are available. And NCTCOG relies on local development plans, which vary from city to city.

Arash Mirzaei (manager of NCTCOG's Transportation Department) provided a **presentation** describing NCTCOG's 4-step travel demand model (TDM), which offers significant transit management details as well as feedback from network assignment results back to trip distribution.

Robert Johnston commented that he *hadn't heard NCTCOG participants mention travel demand management tools (like tolls and parking charges)* yet, and they did not seem to be very interested in pursuing VMT reductions for the region. This seems to contrast clearly with the present interests and pursuits of many West and East Coast regions and states.

2. PRESENTATIONS BY DEVELOPERS (OR KEY USERS) OF OPERATIONAL LAND USE MODELS

2.1 **TRANUS presentation** by **Brian J. Morton** (a TRANUS user, and Senior Research Associate at the Center for Urban and Regional Studies, University of North Carolina Chapel Hill)

TRANUS is a truly integrated transportation and land use model (LUM). It is aggregate in the sense that it operates at the zonal level. It has error terms for real estate sectors. *Brian finds its GUI very attractive and example models helpful.* TRANUS also offers energy estimates. Vehicular emissions (e.g., oxides of nitrogen and volatile organic compounds) were estimated using TRANUS's link-level traffic volumes and average speeds and a separate emission factor model. The model is driven by basic jobs (given exogenously). When assessing future development scenarios, the user can steer growth toward preferred zones by strategically increasing (or decreasing) zones' land supply.

Their one-county case study (Mecklenburg County, NC) used TRANUS for 12 economic sectors, 3 household sectors (differentiated by income), and 3 land sectors (commercial, other business, and residential). This application has 8 "neighborhood types" (which were identified with factor and cluster analyses) for 373 zones. External trip tables were fixed, and they chose to exclude internal freight/commercial travel because they originally could not get the model to reproduce base-year land use patterns and then later they just kept these trip types out.

This particular application also did not use TRANUS's floor space, land substitution, and elastic trip generation options. The UNC users initially could not get TRANUS outputs to resemble base-year conditions, due to convergence issues, though they tried about 100 different approaches. Finally, a relatively simple fix provided by insights from the model's developer (Tomás de la Barra) resolved the issue almost overnight, and land-use outputs matched baseline data.

The team had to constrain land demand functions and iteratively adjust travel demand parameters to make TRANUS's land use model to converge and to accurately reproduce baseline travel data (vehicle counts and mode choice). They followed a trial-and-error process of searching for parameters. Brian remarked that TRANUS's Users' Guide is *not* an applications guide. (Note: Since the presentation/workshop, de la Barra has published an applications guide.) TRANUS has an embedded travel demand model (TDM), and therefore cannot link to other or more advanced TDMs (e.g., activity-based TDMs). The embedded TDM requires only 3 steps – trip generation, mode choice, and network assignment – because the trip distribution stage is handled directly in the core spatial input-output model. TRANUS cannot restrict development at the level of parcels because it is a zone-based model. There is an on-line user group available, with response times ranging from 1 hour to 1 day to 1 week. The hardest work is to convert parameters obtained from actual data into TRANUS parameters.

Their current application includes a smart growth scenario in 2010, 2020, 2030, 2040, and 2050, and they are working on a business-as-usual scenario. Due to more than a doubling of population and jobs by 2050 in the region, the model was signaling excess demand in land markets and hypercongestion on the network side. To achieve equilibrium in the land markets and to prevent excessive congestion, a scenario's changes in land supply, transit capacity, and highway capacity must be iteratively developed.

Development of the Mecklenburg County model including the neighborhood typology took the (part-time) efforts of *4 faculty members and 4 graduate students (all with no earlier experience in LUMs) over 4 years*. Brian highly recommends that *NCTCOG have any modeling tool's developer directly engaged in its pursuits*, because too much time and effort will be wasted without the developer in the loop. He feels that UNC should have had Tomás de la Barra on board since the initial stages.

Brian wondered why NCTCOG wants only one model. LUMing is quite complex, and no model is perfect. Therefore, it is *very useful to have more than one framework*, so users can evaluate the stability and robustness of model predictions. He expects NCTCOG's cost to implement will be roughly $1 million.

Kara Kockelman wondered about scalability and parameter transferability of TRANUS to a 14-county DFW region. **Tomás de la Barra** replied that computing times might be about the same, but post-analysis is always time consuming, and may take much longer. Since similar trends are observed in land development patterns, he feels that most coefficients may transfer reasonably well.

Brian Gregor commented on TRANUS: He likes the ease of use (e.g., user-friendly and logical GUI), and the embedded two-step TDM is a very nice feature. The (pre-compiled) code is somewhat accessible, so one can wrap in other modules via DOS calls and can report results via the R language, for example. He is *not a fan of the model's scaling of systematic utilities* (not just for flow assignments, but also route choices). He was able to turn it off to avoid "sawtoothing" instabilities he noticed in the network assignment stage several years back, but was unable to do so with the activity location portion of the model. Freight is modeled from zone to zone, so he prefers ODOT's newer model (called "CT" for commercial transport, which is part of their 2nd generation SWIM2 [statewide integrated model], as developed by PB's Rick Donnelly with Doug Hunt & John Abraham [and takes PI's {***p****roduction* allocation and activity **i**nteraction module in PECAS} economic flows, into volume flows & then trucking logistics]), which offers higher spatial resolution. He feels that labor's travel cost is not yet properly handled in TRANUS, because the model assumes these costs are paid by industry (the employers) rather than by households (the workers).

Editor's Note: The *current version of TRANUS allows users to turn off the scaling*, at least on some routines. The model needs to be calibrated with the scaling turned off for this to work.

Rick Donnelly (PB Inc.) commented that ODOT spent $770,000 to model intercity activities. There are many data issues, along with scaling of the model's of utilities, which impact model calibration. *He feels that NCTCOG will enjoy much higher payoff by paying attention to the model's specification of land use & travel behaviors than by increasing the number of zones. He believes that spatial disaggregation does not offer meaningful benefits (or realistic results, perhaps).* He noted that they started with 250 zones for all of Oregon, which was the largest application of TRANUS at that time. And he believes that TRANUS probably needs to be used at different spatial and sectoral scales of application to address different questions. Such an approach facilitates interpretation of results, allowing modelers to focus on more important model behaviors. The starting values can be borrowed from other case studies, and the calibrated parameters are likely to be similar. *Rick also recommends an agency's use of 2 or more integrated models*, since that approach was very illuminating in their Oregon work (in terms of appreciating & enhancing model specifications, while diagnosing data & other problems).

Tomás de le Barra (TRANUS' developer) commented that use of fewer zones (or a limitation on zone numbers) is a strength of TRANUS, because it simplifies outputs, interpretation and application in policymaking.

2.2 PECAS presentation by **Kevin Stefan** (recent graduate of the University of Calgary, and a PECAS development team member [as an employee of HBA Specto Inc.])

Key features of PECAS are an AA (Activity Allocation) module, which leads into the SD (Space Development) and TR (Transport) modules. The AA module tackles the questions of: (1) location choice of firms and households, (2) how much production is needed from each firm/worker, and (3) where firms & households purchase their inputs and where they sell their outputs. At SD's core is a 3-tier nested logit model to determine where development occurs, how land use changes, and how much built space (square footage) is required. Rents are based on a base/generic price by zone (from the AA module), multiplied/adjusted by more local adjustment factors (reflecting parcel level details). (And, as **John Abraham** later noted [via email], it turns out to be quite important to consider inputs and outputs jointly.)

The Sacramento application of PECAS has about 1500 "technology options", in terms of sq.ft. per household and job types (as chosen by different households). Their model has fixed technical coefficients for most industries (i.e., inelastic demand per unit of output), and these come largely from IMPLAN. However, the model also allows for elastic response in the important areas of space development and labor production decisions (where price & supply data are better too). Production location is nested within a firm's technology selection as well as 'buy and sell' allocations/decisions (to exchange zones). Results are aggregated back to the zone level, for use in the next year's AA application.

Note: *Exchange zones will be either at the point of production or point of consumption, depending on the good type.* These are not new or theoretical locations; they are all existing zones.

Kevin indicated that relatively new 121-page documentation is now available for PECAS and is available on request. The code is set up for use across multiple computers (in order to reduce run times). Calibration is now automated, to quickly ascertain roughly 1500 (phew!) alternative specific constants (ASCs) across all the technologies, and 1 ASC for each zone by industry, with scale parameters for all logit nests. (Note: After the meeting, Kara followed up with John Abraham to get the URL for free *PECAS software download: http://svn.hbaspecto.com/svn/pecas/PECASSoftware/jarFiles, and documentation can presently be found at http://files.hbaspecto.com/pecasdocuments/.*)

SCAG is developing PECAS for its 18-million-person region. Other cities using PECAS are Sacramento, Baltimore, Oregon, San Diego, Atlanta, & Mumbai.

Some SD applications have oscillation problems in model calibration, and the PECAS team is looking into this issue. Kara followed up after the meeting with John Abraham on this point, and he noted that their calibrated SD models do not appear to exhibit oscillation problems in solution convergence. (Oscillations have occurred in initial model setups.) The PECAS developers have added functionality to directly represent construction industry capacity, for a couple of reasons; and a side benefit of that improvement is that oscillations in construction amounts do not need to be addressed during calibration.

Data required for running PECAS include PUMS and SF3 block group data (for population synthesis) and the American Housing Survey files (for floor space synthesis). The team is working on tools for synthesizing land use when parcel level data are unavailable. And new versions of PECAS seek to estimate GHGs (from production, land use and transportation decisions) while reflecting the nature of carbon credit trading under a cap-and-trade policy.

John Abraham also noted, in a follow-up email, that PECAS' logit model calibration does not require an alternative specific constant (ASC) for each alternative, but those are used if one has any reason to believe that alternatives are perceived differently (in terms of their base attractiveness or size) John reports that their "best validated results" are "looking great", for Baltimore and Oregon. In terms of how regions obtain local trade & goods pricing data in order to calibrate the trade flow models, it will depend on the budget and the model's scope. Evidently, one can build rather different models depending on what data the region has available. (Presumably, this requires coding assistance by the Spectro team.) John notes that, since models should be continuously improved, it is usually a good idea to identify desired data and phases, as attempted for California.

Michael Morris was *worried that all the constants may anchor the PECAS model too much over time*. And **Brian Gregor** wondered how far one needs to halo out the region, to capture spatial input-output interactions.

Francisco Martinez was *worried about the uniqueness of PECAS solutions and guarantees on model convergence.* Since information on uniqueness is not very well knows, the solution region might be very flat and many sets of parameter values might be possible.

2.3 UrbanSim presentation by **Paul Waddell** (professor of City & Regional Planning, University of California at Berkeley)

Paul explained that UrbanSim's developer model has been completely redesigned. The model now uses Ram Pendyala's *population synthesis* code, and buildings can be assigned to parcels, gridcells, or zones. There are now three different configurations of UrbanSim, based on these three geographic units of analysis. The model should work with any type of geography/spatial units (grids or zones, blocks or tracts), and is integrated with ArcGIS, as well as open-source GIS tools, like Mapnik, to allow mapping results within the OPUS Graphical User Interface. Various types of accessibility index are now allowed (& computed internally), including site distances to the CBD, the time to reach a certain level of retail jobs or stores (from each site), and the commute times of individual households. Walking proximity measures at the parcel level (e.g., #persons within 600 meters) & regional access indices from the travel demand model's outputs remain in the model. As before, job numbers by industry are wholly exogenous to this model (unlike in PECAS, where outputs by sector are exogenous). Models for household evolution are being developed, and job-accessibility values for multi-worker households are handled differently (since multiple job sites are involved).

Paul remarked that *data integration is the trickiest & most costly part of getting UrbanSim up* & running. There are generally gaps in data sets, inconsistencies, and spatial mismatches that emerge. (Of course, this is true in general, for detailed spatial models, not just UrbanSim.)

In the most recent implementation of the real estate development process at the parcel level, *UrbanSim seeks to reconcile both the perspective of the developer (the "use looking for a site") and that of the land owner (the "site looking for a use")*. The new model also makes use of 'Development Templates' that allow users to describe any size, mix, and density of development, ranging from individual infill single-family housing, to strip-shopping centers, or large planned developments. Such templates help break up/partly develop larger parcels and meet open-space & density targets. The team is undertaking a systematic comparison of the model system using different levels of spatial aggregation (as starting geographies) and different algorithms for feedback among model components.

The model controls for demographics, construction costs, & land costs versus expected sales prices in order to estimate "return on investment" for the developer land use decisions. No price equilibrium exists here since the team believes that "prices don't do all the heavy lifting" and "traditional simplified market clearing assumptions are problematic". Paul referenced the work of Andre de Palma, Natalie Picard and himself (JUE 2007), where they find that constraints on home availability are very important in market outcomes.

Brian Gregor is skeptical about parcel based modeling because tax lots are not legal parcels and developments go beyond parcels. **John Gleibe** is working on "fragmentation indices" for developer decisions (probabilities that a parcel will meet a developer's/development's needs). Related to this, **Paul Waddell** feels we have to test zone-based versus parcel-based approaches (which they are doing, as noted earlier).

Finally, Paul noted that Seattle's/PSRC's UrbanSim model required about 2 years of development work for the first run, and it is now improving, due to in-house modeling efforts. More staff has been added at PSRC for this modeling project. They have spent less than $1 million so far. A key recommendation: *the MPO must have actively engaged staff to take ownership of the model.* UrbanSim also is being developed for Honululu and is expected to take around 2 years and $200,000.

2.4 Cube Land presentation by **Francísco Martínez** (Professor & MUSSA's model developer, University of Santiago, Chile)

Citilabs' commercially available Cube Land has *no travel demand model* (TDM), is zone based and very focused on land market equilibrium. It was developed as a research model for Santiago, Chile and offers many incentives for land use policy evaluations. Santiago staff recommended their LUM code (which is owned by the Chilean government) to Citilabs when Citilab staff were on site in Chile. That was the primary start of this collaboration. Francisco believes his model is much simpler than PECAS & UrbanSim. The model allocates land and dwellings to users exhibiting the highest willingness to pay, and there are *only three equations in the entire system*. These are the Probability of location, Bid, & Supply equations, as follows:

$$\text{Pr (loca } i) = \frac{N\varphi \text{exp } (\mu \cdot Bid_i)}{\sum N\varphi \text{exp } (\mu \cdot Bid_j)} + \cdots$$

$$\text{Pr (h located } i) = \frac{N\varphi \text{exp } (\mu \cdot Bid_{hi})}{\sum N\varphi \text{exp } (\mu \cdot Bid_{gi})}$$

where *Bid* = Income + Utility level (*b*) + Utility of site (based on endogenous + exogenous factors) + Subsidy or tax

$$\text{and } \varphi \text{ is the cutoff} = \frac{1}{1 + \frac{\eta}{1-\eta} \text{exp } (w(z-c))} = 1 \; if \; c > z \; \& \; \eta \; if \; c = z$$

where z the constrained variable (e.g., the bid) and c is the constraint level (e.g., income). Francisco later noted that this is called the constrained multinomial logit model (CMLM).

The rent for the property is then calculated as,

$$Rent_i = E(\max Bid) = \frac{1}{\mu} \; logsum_h(\text{ H } \varphi \text{ exp}(\mu Bid_{hi})) + G + \frac{\gamma}{\mu}$$

At equilibrium $\Sigma(S \times \Pr(b)) = H$, so that all locators are located. Francisco later noted that the location is attained at intra-cluster equilibrium, where the utility level (b) of all consumers in a given cluster, despite their location, is identical.

The supply side is estimated by maximizing profits: $S = H \times \text{argmax}\ \pi\ (r,c,s)$, which yields the number of units supplied per dwelling type and location. The maximum profit model is also a constrained MNL model, which allows one to include all zone regulations as cut-off factors.

The zones/properties are then allocated by auctions, using logit probabilities constrained by income budgets. Prices are calculated as expected bids, and these are adjusted in order to clear the market (i.e., achieve system equilibrium). The model doesn't restrict the spatial resolution used or define the duration of the equilibrium period. Instead, this duration lasts as long as exogenous conditions remain. Bid parameters (and therefore prices) are adjusted until all households & firms are allocated to zones/properties.

This is a fixed-point problem with a *unique solution, via a fast & convergent algorithm. No other land use model may offer this stable solution.* Calibration relies on simultaneous estimation of all equations, which is a nice feature, for a single set of parameters.

The solution seeks to mimic a (long-run) equilibrium, rather than a dynamic disequilibrium. So the model may not work so well for short-term variations in policy, and continually changing outside forces. Instead, the model seeks a sense of where the land markets should head, everything else constant. No vacancies are allowed (equilibrium clears the market), and it is a one-shot equilibrium (which may be specified as a 1-year application, 10-year application, or any other interval).

Their first validation (using 1997 Santiago data) suggested that the original supply model didn't work well, so they replaced it (in 2001). To date, the model has been applied in Santiago only, using spatially aggregate zone systems (1991, 1997, 2001 data sets), rather than individual parcels (though the calibration is made at a parcel-family level with zone attraction variables).

There are no constraints in the number of zones, dwelling types and households and firms clusters. At a microscopic (parcel-level) scale, allocations of users represent a combinatorial optimization problem. It's a question of the resolution desired. As Francisco later noted, despite the disaggregation assumed, the solution is always unique, though computing times will be compromised; what most affects computing times is the number of regulations that constrains allocation and supply development. The Santiago model run time varies from 1 minute without zone regulations, to about 15 minutes for a full set of regulations.

Moreover, the location model includes consumers' interactions in location choices, like the willingness to live in neighborhoods among peers (which can result in socioeconomic segregation), or the attraction-competition among firms caused by agglomeration economies. These interactions are called location externalities and represent strong dynamics of economies. Roughly one-third of the variability in bid values explained by these externalities, another one-third from accessibility differences, and the other one-third other factors.

All three speakers state that their models can & do incorporate land use incentives policies (e.g., UrbanSim's new return-on-investment equations). **Robert Johnston** noted that in older Sacramento applications, using MEPLAN, he observed that if was much harder to get their desired location patterns via subsidies and penalties, than simply forcing half of the new development to locate within 1 mile of a light-rail transit line.

Karl Eschbach noted that Texas is growing at a rate of 1% per year, vs. 0.57% for the US overall. He noted that Texas is a relatively "young" state, and enjoys higher fertility rates among

Hispanics. 45% of Texas' in-migration is illegal, and half of the state's growth is in Dallas and Houston. He wanted to hear more about demographic forecasts.

Kara Kockelman feels it is too much to ask of modelers to do model macro-economics well, along with in-migration, changes in preferences, fertility rates, etc. – on top of land use and travel. However, she noted that modelers can run several scenarios to see which of those exogenous inputs has important impacts. And most models do allow different behaviors for different classes of households or firms. She noted that models of firmographics & demographics can go quite wrong (e.g., her own experience of large firms getting larger).

Paul Waddell noted that it's important to consider demographic dynamics, as a way to reconcile external data with what goes on in the model and to validate model outputs. Moreover, there is plenty of evidence that race and ethnicity impact location and mode choices. However, any focus on these factors requires a "political appetite", since race and ethnicity discussions tend to introduce some controversy.

Francisco says that demographic changes are a case of variability in inputs, and one could study such effects under a variety of scenarios, and analyze stability of the results. He also suggested that *modeling the uncertainty of inputs is important, so that planners can seek most robust sets of policies* – since we really don't know our future.

Brian Gregor's *LUSDR model is developer focused, and founded on an accounting of uncertainty*, for strategic planning and risk assessment. Brian Gregor would like to incorporate Genetic Algorithms in LUSDR, to seek optimal policy combinations in the future.

One more model to note: Elena Safirova et al.'s LUSTRE model is based on many of Alex Anas' theories/specifications, but used only in-house at Resources for the Future. It is interesting, as presented for a variety of Washington DC policy evaluations, but proprietary in nature.

3. CLOSED-DOOR DISCUSSIONS

All model developers left the room, along with NCTCOG employees, as model users remained for a closed-door discussion. This setup (for nearly 1 hour) facilitated more candid commentary by providing anonymity. A description of these discussions is as follows:

All/most clients seem to complain a lot about consulting/developers teams not providing adequate support for their model implementations. It is important to note that *users tend to get what they pay for* (e.g., UrbanSim & TRANUS are generously "free", with UrbanSim being open-source code) and MPOs (& others) must be clear about the size of their contract. Cube Land may now be able to offer a higher level of technical support than others, thanks to Citilab's professional involvement. In general, expert land use modeling teams are generally small scale shops; it is generally very hard to serve/support all interested parties without full time consultants (or professional software providers) who are able to run the models.

It was noted that the *developers' presentations lacked information on validation and performance*. This is an issue for all modelers, in travel & land use. Big changes are needed in the status quo.

While TRANUS used to force a scaling of all utilities, the code has been altered & such scaling can be easily be avoided. *TRANUS may be the easiest model to apply here*.

Some models lack transparency, like PECAS. It is not clear how to estimate all parameters reliably and these are woven into the model system in a rather complicated fashion. Users end up having to "trust" the calibration system at a rather high level, which can be uncomfortable for many. In addition, some models, like PECAS, must simulate/fake data, so the results may be quite hard to sell to local planners because they generally will not trust the results. *Someone commented that a model will be a "giant waste" if local planners won't buy in to the results*.

Someone commented that UrbanSim is not being used in Salt Lake City though it has being developed, since the developers/users do not yet have confidence in its results.

The most expensive effort behind land use modeling is data gathering and cleaning. Therefore, NCTCOG may best start with MUSSA (Cube Land) and go to UrbanSim, or start with TRANUS and move to PECAS. It really depends on what questions NCTCOG most wants answered. *If an MPO can get some early results in*, based on a relatively simple model for the first 1 or 2 years (using, say, 100 to 200 zones, and about 10 industry sectors), then they may enjoy longer term funding & be able to expand the size & scope of the model, while shifting to a new, more complex model specification.

There is an issue in terms of how to get the proper data. Surveys on recent movers (households and firms) are valuable in modeling land use changes, and can be added to travel surveys. Land use data is difficult to obtain, as compared to traffic data, and quantifying errors in prediction is harder (vs. simply comparing traffic counts to predicted flows). Freight surveys are also needed, to model commercial trips. The most difficult-to-obtain data sets tend to be time series for households and businesses; at least one can approximate the evolution of land use patterns in a region by mining permitting/new-building data for new development. Data requirements of most operational LUMs are intense, so an MPO's data team is key in this process. It was suggested that MPOs hire as many interns as they can, to work on data collection and cleaning.

Some meeting participants felt that *only Portland's MetroScope and metropolitan level model appears to be truly operational*, in terms of its regular use for policy decisions & users having confidence in its results at relatively small geographic scales (e.g., 88 zones for tracking employment, and households/population modeled at the census tract level). However, Puget Sound Regional Council (PSRC) is making good progress with UrbanSim, in large part thanks to having an agency commitment and department directors with the vision and determination to pursue implementation. They spent considerable time (2+ years) at the beginning to gather their data, in hindsight more of that time could have been spent on model development, then refining data inputs once a working model is established. *It is valuable to have models that are sensitive to various policy decisions* (e.g., energy & climate change policy). These can serve better than ones that are simply "good predictors". In addition, a model's back-casting ability (i.e., starting predictions form a lag/past year) is important, even if only for a 3-year time step.

Models are evolving very fast, and this is tough on users. Models' data needs also tend to increase over time. And we tend to ask a lot more of these LUMs than we ask of TDMs. (For example, micro-scale LUMs consider the specific case of an undeveloped corner's becoming a gas station, whereas TDMs mostly seek traffic counts on already congested roadways.) Experts recommend long conversations between the client and expert modeling team, to be sure both understand what is needed and what is feasible.

LUM development is still at an early stage, probably where TDMs were at in the 1970s. LUMs cannot distinguish between 5% differences across scenarios (that is simply within the model's "noise"), but let's not forget that TDMs can give really bad link projections in 20 years too.

4. 5-MINUTE PRESENTATIONS BY & DISCUSSIONS WITH OTHER MEETING PARTICIPANTS

4.1 LUSDR presentation by Brian Gregor (Oregon DOT, LUSDR's developer)

Brian expects big travel changes to happen, due to climate change policies, including active travel demand management. Michael Wegener tends to agree: It is not incremental change but significant change on the horizon, and cultural norms and preferences (not pure economics) are very important factors for how we make the transition. Brian believes that models are useful for testing policies and also identifying land use opportunities (as well as evaluating alternative scenarios). He believes that LUMs need to reflect the uncertainties inherent in land use & other processes, in order to better represent the set of potential future conditions.

Brian also believes that models should be purpose-built, rather than all purpose. He highly *recommends R for rapid and agile model development*. Open-source R can be used as a daily desktop tool for data analysis, replacing some of the functions of other tools (such as Microsoft Excel). As a daily tool, users generally won't forget the program, and everyone can be a coder. He believes that "anyone can become a coder", but recommends that agencies regularly use younger staff for coding work; since most are able to pick it up rather quickly, on the fly.

4.2 3-D Visualization & Cube Land experiences by Michael Clay (Asst. Professor of Planning, Alabama's Auburn University)

Michael began by presenting a 3D visualization for Auburn. Such visualization is very important to the Alabama DOT and Auburn's MPO.

The Alabama DOT has a 20-year relationship with Citilabs, and they *recently selected Cube Land/MUSSA because their experience with PECAS was taking too long to get running. They found PECAS to be too data hungry & rather a moving target,* with code changes & such. So far, Cube Land is running fairly seamlessly, but they have been working out a few bugs to ensure calibration within Cube Land. Minneapolis is also very interested in Cube Land, but *no consultants appear yet ready to support Cube Land.*

4.3 Remarks by John Gleibe (Asst. Professor of Urban Studies & Planning, Portland State University)

John is quite familiar with a variety of LUMs (having lead UrbanSim's initial implementation projects for Honolulu's MPO, for example). He spent his 5 minutes highlighting key limitations of most, if not all, LUMs. He noted that some/many LUMs are too coarse for transit-project evaluation and the economic impacts of such investments (e.g., Portland's streetcar system). And he noted that the FTA found existing LUM specifications inadequate for evaluating the economic development impacts of transit projects. No LUM yet exists that meets the FTA's requirements/expectations. For example, many LUMs lump transit travel times & costs into a single accessibility index or logsum for the entire neighborhood/zone/parcel, so other modes' service levels get mixed in; as a result, transit's role in such indices is often negligible. Moreover, developer models do not recognize transit oriented development policies, and LUM property or land prices tend to be "symbolic" (computed for model use internally only, rather than reliable or locally accurate). And most LUMs cannot model mixed use development.

The formal meeting ended for Tuesday, July 7, with participants headed to dinner at a local restaurant. The following minutes come from the morning and mid-day of Wednesday, July 8.

To kick of the second day's discussions, **Kara Kockelman** reported on several highlights from conversations during the previous night's dinner.

One participant felt that some policymakers are very willing to ignore travel demand and land use model outcomes. In unfortunate cases like these, they may be as well be given a bunch of random numbers. Some indicated that such neglect of modeling results may be more common on the East Coast, rather than in West Coast applications. Another meaningful point of dinner discussion was the relative importance of microsimulating developers' siting/location decisions, rather than those of individual jobs and households. **Robert Johnston** then noted that the lumpiness of larger firms causes problems in LUM outputs, and forecasts will appear too smooth without this component treated discretely. When considering firms as discrete actors (rather than implicitly assuming that jobs can locate independently), LUMs can give very divergent forecasts. While such forecasts are generally reasonable, they tend to make many decision-makers/policy-makers uncomfortable.

Brian Gregor commented that he *has sensed no discomfort among Oregon's policymakers when presenting LUSDR's varied forecasts*. He does recommend limiting the number of time steps in a models. *He doesn't recommend producing results year to year, and he doesn't feel it's so useful to try & model households' transitions*/(i.e., no need to microsimulate each household's demographic evolution over time). **Sonny Conder** noted that Sonny's Metroscope model (for Portland's Metro) has been used to inform ballot measures, and people on both sides of an issue want this model to move toward their side (which may suggest it's doing a good job in prediction).

4.4 Remarks by Ed Shafer (of SANDAG)

Ed recommends that regions produce their own control totals, since these totals tend to play a major role in land use forecasts. San Diego has a 40-year old model working well for such totals (with upgrades), in terms of consistent population and job numbers by type. He is glad that they are going with PECAS because many US regions are using it, making it easier to borrow coefficients and coordinate across regions (& agencies).

Ed suggests that MPOs like NCTCOG should be focused on acquiring the data sets right away, regardless of the models to be used. He feels it is best to get someone to manage this process – and to be skeptical of purchased data sets. For example, the coverage on CoStar data can be off. Also, SANDAG'ers have used Craig's List (online) for another perspective on leasing. He mentioned that San Diego's job posting from a couple of years ago may be very useful (as an example) to NCTCOG, as it seeks people with the skills and knowledge required for data management.

Ed warned against setting up too many "firewalls" on staff assignments. These can protect staff from competing distractions (so that they can focus on model development) but also result in some inflexibility. He says SANDAG currently has 2 people developing their travel demand model (TDM) and related team members developing forecasts from PECAS for High Speed Rail scenarios. They typically spend 1 to 2 days a week talking to their consultant about what steps to take next, for modeling.

Duane Dankesreiter commented that it *may be very useful to set up a data workshop or webinar.*

4.5 Remarks by Rick Donnelly (of PB)

Rick stated that he is very much in agreement with Brian Gregor on LUM issues and directions, and he highly recommends Michael Wegener's paper on where the questions, methods & models are headed (as provided in the workshop materials).

Rick expressed some frustration because he was *not yet sure what NCTCOG wants from a LUM. The vision is unclear. Yet it is critical* to the choice of a model. In other words, what NCTCOG wants to obtain from a LUM really should determine what kind of model they should be using. He understands that NCTCOG needs a LUM to inform its TDM process, but the question of which methods to use involves far more detail.

Duane commented that NCTCOG's TDM group is the main user of LUM outputs, but many others are asking related questions. They're not clear which questions can be effectively answered yet. It depends on model capabilities.

Rick also believes that "*wetware" is far more important than software & hardware*. In other words, agencies like NCTCOG really need a terrific, creative modeling "motorhead" – regardless of the model chosen. And, if NCTCOG "really wants to get into this game", it *should expect to have a LUM staff that is just as large as its TDM staff. Essentially, the complexity of LUModeling dwarfs what we see in TDM.*

He *does not believe in a one-size-fits-all kind of model*, in part because a modeling group or agency will only be able to focus on a few key objectives in the next few years. For example, modelers might first pursue key external control totals, to provide important inputs and "context" for a second model system that then applies at a much finer geographic scale. A strong relationship with model developers who can help agencies target your efforts is also helpful.

He also *recommends that model teams be agile – seeking some quick successes, then pursuing incremental improvements*. To do this, NCTCOG *can start with a relatively simple model or simplify a complex model*. Examples include use of fewer zones, and/or something like MetroScope rather than PECAS. In Oregon, they started with TRANUS, but found they needed more sophistication with freight and economic questions, because it is a statewide model.

If they were starting fresh for Oregon, he feels that they would still do TRANUS again, and then probably shift to LUSDR, and then add capabilities for estimating greenhouse gas emissions. And then they would probably pursue a PECAS or UrbanSim approach, but only once they have lots of success along the way. NCTCOG may want a simple economic model, to bridge toward more complex models.

Bill Charlton (SFMTA) commented that San Francisco is using UrbanSim, and he feels it's right for the range of questions they would like to answer about the region.

Kara Kockelman wondered whether using a 200-zone version of TRANUS and then UrbanSim would suit NCTCOG best at this stage.

Paul Waddell responded that Detroit started county level household and employment totals (based on REMI outputs) and then used UrbanSim to allocate activities within each county. A 200-zone level would be "an interesting puzzle". The closest thing they have done (or are currently testing) is using zone level data (e.g., census tracts) and then allocating to parcels and buildings via UrbanSim modules. He feels that a bi-level approach may be worthwhile, but a 200-zone application is pretty coarse so NCTCOG could do something simpler than apply UrbanSim in such a case.

Robert Johnston noted that four major California MPOs are doing their own PECAS modeling. The 8-county San Joaquin MPO is having lots of air quality issues alongside important agri-industry development. They will take state-level PECAS results (80 zones for their region) and *allocate these values down to 50-meter grid cells using UPlan* (a suitability analysis technique described in the land use model summary file provided to workshop participants). He noted that there has been some calibration of UPlan as a positive (predictive) method, though originally it was designed for normative analyses (based solely on suitability scores assigned to parcel attributes by the user). *He does not think the past is like the future* (so calibration of models based on past behaviors may not be so useful), and he really prefers an ability to allocate activities from a planner's perspective. Robert also noted that he *trusts InfoUSA data* based on his past experiences.

Francísco Martínez believes a top-down approach to modeling is best, to avoid combinatorial issues at lower levels of activity assignment, which can quickly lead predictions astray, as well as toward unstable model solutions. He believes that *land use systems are much more complex than transportation systems*, and suggested that *modelers should start in the aggregate – in both time and space*, at a meaningful level of aggregation. NCTCOG should also ask itself: how far does it want to go, in terms of spatial (& temporal) resolution/disaggregation. *If optimization is of interest* (based on addressing normative questions like what the "best" land use pattern for minimizing travel costs is), he feels higher-level models (like MUSSA/CubeLand) are probably best, offering more stable and faster results.

Tomás de le Barra cautioned that NCTCOG should not start with something too simple, because they will then be missing a lot. He noted that Brian Morton's Charlotte application is an example at an intermediate level.

Paul Waddell noted that *model evaluations and the benefits of incremental improvement are very important to the process of model development*. The starting point (at an intermediate level of aggregation, for example) should be one where modelers/agencies can do some longitudinal validation, and see how these results improve as the model is made more complex and whether such complications are worth the added investment. He noted that validation is generally very hard because it requires access to consistent, longitudinal data. NCTCOG can probably best start with a small area that has good data over many years. Seattle's PSRC presently is looking at anomalies over a roughly 6-year window and refining their model specifications. He feels that *longitudinal validation can usually get to the root of most problems*.

Tomás de le Barra noted that they have done 5-year validation in Sweden and a 10-year validation in Baltimore, using TRNAUS. This process results in model adjustment while providing users more confidence in model outputs.

Francísco Martínez commented that *5 years is probably far too short for static solutions of land use systems to respond to a shock* (which can have many dynamic repercussions). He noted that MUSSA and TRANUS do not track individuals, but rather they focus on general trends in counts and densities. He once validated MUSSA, which resulted in changes to his model's supply side. And *he never does what most people call "calibration". Instead, they perform parameter estimation* (based on one cross-section of data, rather than longitudinal information).

Michael Morris commented that NCTCOGers generally perform validation on TDM outputs, with over 15 performance measures to check. He wonders, what are the measures to check/validate in a LUM's demographic projections? He hasn't seen such checks, and he recommends that LU modelers create standards in this area, so that more people will invest in such models.

Paul Waddell responded that the long-term lags & time frames are a problem for LUM validation. While it is true that LU modelers need to define benchmarks and standards for available models, *most modelers will probably be best served by starting their model in a lag/past year and forecasting to a recent year, in order to compare predictions to actual values*, and then moving forward (with model improvements, and such).

Ed Shafer noted that it is not so simple to measure errors & diagnose model issues in these contexts. These are very dynamic systems, and much modeling is now at a fine level; both these features increase relative error rates. He feels that demographers actually do a pretty bad job of forecasting, especially at small geography. Demographers generally *do not give a number and a date together* (e.g., population will eventually double and it is a fool's game to say when). Land use modelers probably shouldn't give such information together either.

Sonny Conder said that TDMs tend to "overfit" to existing data and ignore path dependencies (so forecasts tend to jump away from actual flows in the first model year, rather than move away over time). He doesn't feel TDMs meet a very high standard of accuracy (e.g., validation generally emphasizes screenline counts and congested corridor's flows [which are pretty stable over time, thanks to congestion], rather than trip counts between two zones). He believes a 20-year forecast is a "joke". Behaviors are very path dependent, and one should not ignore recent, known flows and choices. In his work, LUM outputs fit reality pretty closely, but one questions whether their high R2 values (often over 0.95) are indicators of model robustness/fitness or overfitting. In his experience, all LUMs allow for path dependencies. In addition, they have done "backcasting" (moving forward from 1970, applying regional control totals at decennial years), with just 1% deviation or error per year overall (or about 20% at the level of Census tracts). *The main source of errors, actually, is uncertainty about policy makers' decisions.* There are a whole bunch of potential futures.

He also commented that "market clearing" mechanisms within a model simply ensure that all information in the system is used consistently and completely; it doesn't mean that the system solution is static, or that the system has quit evolving.

Mike Alexander (at the Atlanta Regional Commission) stated that he felt Sonny Conder's comments to be terrific, and very consistent with his perspective. He also pointed that *data collection and quality has been the biggest problem for ARC*. They have encountered problems with CoStar data, among others.

Rick Donnelly indicated that in their Oregon models, there are about 20 primary performance measures and 60 secondary that LUM outputs must meet. There are *many potential measures to track in LUM outputs, and these will vary by context*, and depend on policy analysis needs. One problem is that *policymakers do not believe that past trends will hold in the future*.

He noted that *model results are not true targets* for analysts to focus on, *but rather indications of how things are likely to move (relative to the base case) under different scenarios*. Moreover, TDMs have a few things going for them, in terms of prediction. These include the rigidity of the sytem/network. For example, *new transportation infrastructure tends to pale in comparison to the size of the current network. In contrast, land use patterns are not confined* and can change relatively fast, as populations grow and private investors make many decisions on their own. *The questions that we ask of LUMs are actually quite a bit more complex than what ask of TDMs.*

John Gleibe noted that LUM performance measures can be synchronized with those of TDMs. And, in his Honolulu modeling experiences coupling UrbanSim with a TDM for the 1995-2005 period, they could compare model forecasts to actual 2005 values.

Michael Morris commented that NCTCOG & other agencies really need to shift to policy solutions now (as compared to capacity solutions), due to money and other constraints, and they really need tools to help with this.

Robert Johnston suggested that in cases *with very new policies* (like a cordon toll), agencies generally need to turn to existing experiences (e.g., look at London) for estimates. Yes, data also remains an issue, for all models. Finally, the devil is in the desired details: *hitting traffic volumes is one thing, but getting the age and type of vehicles – and their emissions – right is problematic*.

Paul Waddell noted that *a little humility among all modelers would be useful, along with some standard performance measures* (e.g., population and jobs over 10 years at the tract level) for all LUMs (though he recognizes that all LUMs differ). Paul has a *J of the American Planning Assoc* paper out with 15-year forecast evaluations using UrbanSim. He also agrees that *LUMs are best used for evaluating relative changes in patterns, rather than absolute forecast values*.

Francísco Martínez feels that the system has a lot of memory/path dependence (e.g., thanks to the supply side of transportation & land use development). He noted that the term "backcasting" for many people really means unrolling backwards (e.g., to ascertain policies that would hit future greenhouse gas targets). That, of course, is very difficult (if not impossible) to do with LUMs & TDMs. Thus, he feels that forecasting from past years (to current year) is probably the best approach we have for model validation. (And this really is how pretty much everyone refers to "backcasting" in our world of TDMs & LUMs.) At the end of the day, would we invest money in land based on our LUM predictions? Probably not. We have much more faith in TDMs because lots more experience and more results have been gained to date.

Dimitry Messen responded that the robustness of model results is more meaningful than model fits. For example, we can drop observations from data sets and see how it affects predictions, which is similar to *sensitivity tests* with changing policy scenarios. LUMs need to demonstrate that they are capturing the structural relationships that exist.

Tomás de le Barra noted that TDMs benefit greatly from the existence of travel surveys (which are at the disaggregate level of the decision maker), and it would be great to see such survey efforts on land development and location choices. He suggested adding questions to travel demand surveys.

Kara Kockelman suggested that *to travel demand surveys we can easily add questions like when & why did you move here, where did you come from (suggest this work for NCTCOG's next survey)*, & where did you work before. NCTCOG can get mover surveys (as she has done for Austin), but it's especially important right now that we achieve a better sense of the behaviors of firms and developers, since there is so little literature in those domains. She noted that travel choices change much faster than land uses, which adds to the difficulty of land use forecasting in certain ways (including data collection methods). Finally, she noted that we are mostly recommending the use of *LUMs to evaluate differences* across policy scenarios, rather than presume we can hit the mark in absolute predictions for each scenario.

Paul Waddell & Mike Morris both commented that the *absolute values remain a very important question for policymaking* & hopefully we can get those close to actual – especially for variables like greenhouse gas emissions, for example.

Brian Gregor commented that *LUMs are helpful not just in predicting the future but in examining normative questions*: for example, how can we affect behaviors in order to reduce greenhouse gas emissions, & is the desired outcome even feasible? This style of LUM use is extremely valuable and necessary.

4.6 Remarks by Mark Simonson (Puget Sound Regional Council)

More than a firewall, they developed a "bomb shelter" to protect their employees from other tasks. They have 4 analysts and 2 supervisors (Maren Outwater [who recently moved on] & Matthew Kitchen). *Washington State passed its Growth Management Act (GMA) in 1990*, resulting in urban growth boundaries (UGBs), similar to Oregon's policies. At that time, DRAM/EMPAL could not answer their key questions about UGBs & related issues, so PSRC chose to shift to a different land use modeling approach. PSRC and member jurisdictions now do most of their technical work with parcel-level data inputs. Under the GMA, cities and counties must consider all options for managing growth before extending the UGB in their comprehensive plans. The new, parcel-based version of UrbanSim will therefore be very useful for modeling key assumptions (such as parcel values, zoning constraints, likelihood of redevelopment, etc.) to see if the region can accommodate year-2040 growth. *PSRC underestimated the time needed to pursue LUM building & deployment* and they should have been more efficient early on in the data assembly phase. The process of model validation is basically to find issues that crop up in predictions & find and then solve the problems. It is also important to compare old and new models' forecasts. UrbanSim is helpful in simulating the urban system's response to policies, to see how the agency's visions or targets are (or are not) met.

Kara Kockelman commented that the *UGB scenarios* for her & her students' Austin applications (using various LUM specifications) *are the only policy scenario that stifles sprawl while reducing system VMT more than heavy gas taxes and congestion pricing*. In other words, UGBs can have very beneficial effects on regional VMT and the like, not just land use patterns. She believes Washington State is very fortunate to have such policy. The resulting population and jobs densities make a mode like rail a reality and may be the most direct route to sustainable urban futures. They also are relatively simple to explain &, in certain ways, implement.

Mark Simonson noted that Washington State cities get to argue for their own growth numbers after the associated county gets its total population and job increase estimates. *The PSRC must see if the cities' comprehensive plans can accommodate growth through 2030.* They are starting to see difficulties in hitting these targets, and it is not yet clear what policies the cities will adopt. Some neighborhoods are pushing back on the higher density targets.

Robert Johnston noted that some neighborhoods trying to accommodate population through higher density are asking for traffic calming, to mitigate traffic concerns, and that seems to be enough for them. But he also finds it *very helpful to just tell residents that 84% of land in the city/region won't see/require any increase in density/redevelopment*. Moreover, their visioning exercises (charettes) suggest that people (at least those who participate in this process) really want density. The models used at this stage are very helpful (e.g., UPlan).

4.7 Remarks by Gordon Garry (Sacramento Area COG)

Gordon wondered: What are NCTCOG's priorities, and how do LUMs and TDMs inform those? He said the tools are really not there. The number of developers is small and the supply of analyst with experience is even more limited. NCTCOG will be pursuing a multimodal system, and the TDM and LUM analysts must be multifaceted: their team really should have urban & spatial economists, demographers, emissions analysts, etc. – not just engineers.

Large regions like DFW have loads of stakeholders/customers, and they are your partners. The key to a successful TDM process is forming partnerships and getting as much help as possible by engaging agents and giving them a stake in the process and outcomes. This also helps the stakeholders understand any limitations in the methods for more proper use of results. It is also important to determine what your communication tools are with these people. Scenario planning with guiding questions is very useful. These are all subject to resource constraints (time, money, and policy support). Sacramento is implementing visioning via official and unofficial policies of the region's localities, and using PLACES (a normative framework for outcome evaluation), PECAS (for LU forecasts), and four-step TDM models (which run fast and can be run in public workshops).

Planning has not become any easier over time, unfortunately. But Sacramento-area policymaking (at least in Sacramento) has really evolved to a very solid basis with lots of agencies & others using their approach to long-range planning. This has enabled policymakers & stakeholders to feel much better about their choices. It seems to be worth the investment of time, money & staff resources; they are producing a great many results for their partners throughout the region.

They had $500,000 lined up initially, but they have spent more than $4 million. Partnerships have resulted in higher benefits of such investment, while attracting more resources (from partners). Much of this money would have been spent on something in-house anyhow. Lots of MPO & local programs form a nexus here, with lots of interested parties. NCTCOG will need to get used to being a pioneer, for the region & for Texas.

John Abraham noted that SACOG has been developing datasets for multiple uses so that the PECAS model development process has gone smoothly in that region. They have had to double HBA Specto's staff (in Calgary), but now also have a development lab at UC Davis to help get students ready to meet demands of new regions, as more regions become customers of such LUMs. *It is important to build capacity in expertise*, to support such innovation and LUM application. PECAS is available for anyone to download, but it is difficult to anyone to install and use it. Installation instructions & code can be found at http://files.hbaspecto.com/pecasdocuments/ & http://svn.hbaspecto.com/svn/pecas/PECASSoftware/jarFiles.

Robert Johnston responded saying models need to be accessible and taken over by various consultancies, to get away from this cottage industry, dependent on too few experts.

4.8 Remarks by Mike Alexander (Atlanta Regional Commission [ARC])

Atlanta is out of conformity and is facing serious lawsuits; hence, it's critical that they have a defensible model with supporting documentation. Infill development is very important for their region, and DRAM/EMPAL has been a failure on that front.

Mike noted that they have "stolen" SANDAG's 40-year model for control totals & they are now learning to use PECAS (last 1.7 years). Their 40-year model is a 3-region REMI model, which they spent 2 years learning and which they can calibrate, but which they will never fully understand. They have also done visioning for transportation and land use futures using INDEX for small area analysis (with PB, and based on UPlan).

They are trying to get away from the "one-number" predictions for policy making & find it very important to pursue multiple runs (per scenario) & multiple scenarios. Policy makers really like to see PECAS' estimates of trade flows (in dollars), based on transportation investments. And ARC staff really appreciate the economic theory of the Input-Output models behind PECAS.

Agile development is very important, he feels. To always have a model up & running for the MPO really takes the pressure off of the modeling staff & agency. They don't want to be pioneers & are perfectly happy relying heavily on PECAS parameter estimates from SANDAG, Baltimore and Montgomery counties, as well as goods-movement parameters from Oregon.

They are applying PECAS to 78 super-districts (for the AA module), but the SD module is parcel based. It has been very hard to get TAZ-level data from PECAS, so they've been resorting to manual methods (to distribute to that level of geography). Fortunately, the local governments are happy with the super-district approach.

They won't start using PECAS for conformity analysis until 2014, but they are further along than they expected at this stage. ARC has 2 staff working on PECAS but not full time. HBA Specto is pushing them and consultant support has been good. *They have workshops where consultants come in to work on the model* at ARC, and they have learned a lot this way (e.g., how one can use PUMS data for population syntheses). They get to watch the consultant pull everything together, which is meaningful.

PECAS provides commercially-based trip generation and distribution as dollar flows at the super-district level, so they are not used yet in their TDM. As finer zones emerge, they sometimes can use those $-flow estimates more directly.

They have 20 counties & 1.9 million parcels in Atlanta. They rely on a 64-bit operating system, and can now have over 600 zones with 70 commodities. They are wondering how to manage all the details of the model outputs; it is a lot of information. Their run times are really affected by the product of the number of commodities & zones (squared). *So yearly runs & database management are real concerns.*

4.9 Remarks by Robert Johnston (UC Davis)

Robert really believe that MPOs need two types of models: a visioning tool for use in meetings (fast to run) and a large-scale computing model. Gordon Garry uses a 10-minute TDM for scenario tests while in meetings, along with a visualizing tool like UPlan to move land uses around Sacramento.

California had reviewed PECAS and UrbanSim in some detail and *decided that the state really needed economic forecasts, so they went ahead with PECAS*. Their technical advisory committee then recommended that the model be developed for the entire state. Robert wishes they had done a 200-zone run (versus just a 70-zone run) for California, with fewer household and industry sectors at first. REMI doesn't have fixed technical coefficients, so California counties will probably shift from use of IMPLAN to REMI.

Robert remarked on the very different mindset he senses in California, as compared to Texas. He feels that *California's policymakers really just want policy evaluations*, and they expect big changes with climate change policy in the works. They really don't talk much about model validation and accuracy. *They realize that models are policy evaluation tools (not crystal balls).*

4.10 Remarks by Dimitry Messen (Houston Galveston MPO)

HGAC wanted a comprehensive (including population, economy, and built environment), disaggregate and agent-based simulation model. Dmitriy believes path dependence is quite important and realistic, and they have been relying on UrbanSim since 2003. This was self-initiated by staff, without any formal review of competing models. They are now moving from a grid-based to a parcel-based approach. HGAC has had two successful implementations but without full TDM integration. They haven't received much feedback from or experienced disagreement with stakeholders, thanks, apparently, to model's seemingly scientific basis. This is a nice result.

He recommends that one explain to policy makers that *there is no guaranteed destiny – only scenarios in model development; the future is in their hands*. Challenges & opportunities include adequate feedbacks between regional models & regional investment & migration. (SCAG's Ed Shaffer feels that these do exist in reality; for example, congestion has reduced regional investments somewhat.)

Dmitriy believes that *data are very important to the process, especially their reproducibility, documentation and transparency.* The models' credibility depends on the underlying data sets, in part because data are one of the most familiar things to stakeholders, so they find data easiest to critique (versus, for example, trying to critique parameter values in the model).

The H-GAC modeling team has roughly four areas of expertise: the built environment, demographics, economics, and natural environment. It has been hard to hire for such positions. They must develop much of the expertise in house (e.g., GIS & data management expertise). Some firewalling of staff is great if it can be afforded. He feels it is necessary that staff members understand the code, at least 95% of it. *The keys to success are to have ambitious goals, enthusiastic staff and committed leadership.* If H-GAC can do it, so can NCTCOG! He suggested having *a Texas Modeling Consortium* including TxDoT, the 4 main regions, Texas' State Data Center and some federal support.

4.11 Tomás de la Barra (Developer of TRANUS, available at modelistica.com)

Tomás noted that there are two basic types of ITLUM: vector based (e.g., many LUMs rely on vectors of jobs and populations as key inputs & outputs) and matrix based (relying largely on OD tables [of flows & costs], as outputted by the TDM or related modules). *If a LUM is based on vectorized inputs, one can use any type of TDM. This offers the advantage of TDM flexibility, but analysts tend to lose a lot of information* via a reliance on relatively simple, summary statistics (e.g., logsums to characterize a neighborhood's accessibility). On the other hand, if the LUM is matrix-based, one can achieve a more consistent (& nuanced) representation of flows & utilities, as trip generation and distribution are handled in the LUM outputs, rather than being taken from the TDM. Such LUMs require a much tighter coordination with the TDM, for iterative feedbacks & equilibrium solutions.

NCTCOG's **Mike Eastband** thanked the workshop participants and commented that NCTCOG staff don't expect the region can build out of a lot of its transportation problems. So these LUM tools are valued for their ability to evaluate different policies and scenarios. They are beginning to convince people that higher land use intensities is not a negative thing (e.g., older people's past experiences with density). Many people can see themselves enjoying a mixed use setting. He believes the region needs some help in shaping that future.

Robert Johnston and Francísco Martínez noted that *the UT Team can help NCTCOG evaluate theoretical underpinnings, while providing a neutral perspective*.

The meeting concluded after 1.5 days of very valuable discussions.

5. POST WORKSHOP COMMENTS (VIA EMAILS TO K. KOCKELMAN)

John Gleibe feels computer modeling is a relatively recent phenomenon, and its use in public decision making has lagged behind the private sector. Public decisions have been made based on hunches, hubris, negotiations, & back-room deals for a long time. So it is not reasonable to expect analytical reasoning tools to supplant that culture and comfortable way of doing things right away. He expects the acceptance of modeling as a legitimate way to structure decision making to proliferate as the tools developed prove their worth and as the newer generations of tech-savvy public officials move up the ranks.

Michael Wegener commented that the workshop's short-list of models selected for further review seems logical. He felt it is difficult to suggest a rank order of the listed models for consideration by NCTCOG but added that a few key issues should be considered in model selection. For example, even for near-term applications with a ten-year horizon, but certainly for "long-term (&evolving) needs", policies for energy conservation and greenhouse gas reduction deserve more attention.

"Integrated urban models that do not explicitly consider household travel and housing budgets as constraints are likely to underestimate the responses of households to significant fuel price increases or carbon taxes, as demonstrated in a recent European project in which several integrated urban models were applied to similar fuel price scenarios, though in different cities." Another suggestion is to use the selected model in-house. The complex state-of-the-art models have been successfully applied without the repeated or continuous assistance by the model authors. He questioned if complex models in a fast developing scientific field and a rapidly changing policy environment require continuous improvement and adjustment to emerging policy questions and issues, in which case models and the services by their developers are a package than cannot be separated.

Robert Johnston wrote: We chose a model with an inter-industry trade table (I-O table), in order to be able to evaluate the macroeconomic impacts of state transportation policies. Such as Total Product, County Product, and Total Exports. Now, we also have the two GHG laws in California to deal with. The major bill, AB 32, requires that all State policies be evaluated for cost-effectiveness and for economic impacts. This requires a full I-O based model set.

A 2006 EC report evaluated models and recommended that I-O type models be used to capture the wider economic impacts of sustainable development plans. I think it is important to represent labor markets, to get agglomeration economies right. And to get location right, in the long run. This is the approach in the U.K., also, since the Eddington Report and the Simmonds study."

David Simmonds (a UK consultant & developer of the DELTA land use model) suggested that one has to start with three overall questions, about [1] the practical approach to land-use modeling, [2] model theory and [3] modeling technique. The first question in list of key questions needs to be answered by considering these three issues. The other questions can be considered if the range of models is reduced. He explained the three issues in more detail.

[1] **How much does NCTCOG want the freedom to design your own model, or to adapt someone else's ad hoc model, as opposed to the "economies of scale" that come from working in an established and supported package that imposes a more specific design?**

Even though researching and designing a model specific to the requirements and characteristics of the study area in question, might be attractive but it involves risks. A paper at ETC last year about the problems encountered in building an UrbanSim model for the Paris (France) region was fairly revealing about the fact that “if a toolkit does not give sufficient guidance on model design, there is a risk (amongst others) of calibrating very interesting and significant sub-models which cannot be used for forecasting because the independent variables cannot be forecast.” An established package may limit the choices in the design but should avoid that kind of problem and allow an operational model to be implemented more quickly and efficiently. There are also, obviously, issues of risk - the more that the model is unique to NCTCOG, the greater the risk that the departure of a few key individuals could bring use of the model to a halt.

[2] **What are the advantages of having most of the model output coming from an equilibrium process for a particular point in time (typically run every fifth year) as opposed to most of the output coming from disequilibrium processes of changes over time?**

This is a continuum of modeling possibilities which probably has PECAS and TRANUS at one end (more equilibrium results), MUSSA close to them, and UrbanSim and DELTA near the other end (excuse me for not trying to place all the others). He suggested that “more equilibrium lends itself to more elegant mathematical formulations and easier assessment of user benefits, less equilibrium/more process-oriented modeling to better representation of user responses. Equilibrium modeling also lends itself to cross-sectional calibration, which is easier - if of debatable validity. Process-oriented models are more convincing to non-modelers than equilibrium models, which can be a very important consideration”.

[3] **Are the benefits of microsimulation worth the complications it brings with it?*

The complications with microsimulation are mainly

“(a) the requirement for micro-level input data - especially if the form of microsimulation involves modeling parcels or grid cells rather than zones; and

(b) whether a single run of the model is sufficient, or whether the user will need to take the average of a large number of model runs.”

If only model-wide results are required, single runs of the microsimulation may be sufficiently stable but if local results are of interest the random variation may be a very significant problem. Based on their own work for microsimulation version of DELTA (i.e., SimDELTA), they concluded that a Monte Carlo-type land-use microsimulation model is not suitable for policy testing as it leads to unstable local effects and require more model runs which is not very practical.

Kara Kockelman wrote: TRANUS and MUSSA essentially are one-shot equilibrium models. They offer an estimate of the long-run responses, rather than a dynamic disequilibrium path.

When designing a LUM, the model’s behavioral sophistication and realism in its results are often traded off against its transparency and ease of application. The latter are generally important attributes for nearly all stakeholders (including policymakers, the public at large, and the modelers themselves). Another key tradeoff when choosing which models to pursue is ease of data acquisition. These are generally traded off against users’ desire for informative outputs relating to multiple policy objectives (including trade flows, land prices, rents, and floorspace by use type, for example).

WORKSHOP PARTICIPANTS

Attendance	First	Last	Affiliation
Users and Experts			
in-person	Kara	Kockelman	UT Austin
in-person	Sumala	Tirumalachetty	UT Austin (grad student)
in-person	Brenda	Zhou	UT Austin (grad student)
in-person	Karl	Eschbach	Texas State Demographer
in-person	Dmitry	Messen	Houston Galveston COG
in-person	John	Gleibe	Portland State University
in-person	Mark	Simonson	Puget Sound Regional Commission
in-person	Ed	Shafer	SANDAG-San Diego (PECAS contract manager)
video conference	Mike	Alexander	Atlanta Regional Commission
in-person	Rick	Donnelly	PB Consult
in-person	Brian	Morton	University of North Carolina at Chapel Hill
in-person	Michael	Clay	Auburn University
in-person	Bob	Heuer	Trust for Public Land
video conference	Gordon	Garry	Sacramento Area COG (SACOG)
video conference	Eduardo	Calvo	El Paso MPO
Developers			
in-person	Paul	Waddell	University of California - Berkeley
in-person	Francisco	Martinez	University of Santiago
in-person	Brian	Gregor	Oregon DOT
in-person	Robert	Johnston	Univeristy California - Davis
in-person	Colby	Brown	CitiLabs
in-person	Stefan	Kevin	PECAS
video conference (part)	John	Abraham	PECAS
in-person	Tomas	delaBarra	TRANUS
video conference	Sonny	Conder	Portland Metro
NCTCOG Staff			
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