<p style="text-align:center">DOCUMENTATION FOR USE OF
THE GRAVITY-BASED LAND USE MODEL (G-LUM):
WITH AND WITHOUT IN-BUILT TRAVEL DEMAND MODEL
ASSUMPTIONS</p>

Prepared by Siva Kakaraparthi, Sumala Tirumalachetty, Dr. Kara Kockelman, Jen Duthie, Binny Paul, Varun Valsaraj and Brenda Zhou

Updated: April 2012

1. INTRODUCTION

Long-term traffic forecasts require long-term land use forecasts, which may be affected by mid and near-term transportation infrastructure decisions, as well as traveler choices and associated changes in travel times and the relative access of competing locations. A long-standing methodology (Steve Putman's ITLUP ®) for land use forecasting relies on a system of gravity-based equations, with proprietary code managed by consultants. To this end, the Gravity-based Land Use Model (G-LUM) has been coded and made accessible via freeware to facilitate greater use of land use models, under local control, with more transparency in the forecasting process.

G-LUM consists of three sub-models: EMPLOC, RESLOC, and LUDENSITY. The equations involved in each of three sub-models are presented and discussed in Appendix A of this report. Calibration provides estimates of parameter values that generate the "best fit" of forecasts for the base year based on lag year data. G-LUM's parameter estimation process is discussed in detail in the next section. Forecasts are generated in specified time increments. A time step begins with the execution of the EMPLOC model, followed by RESLOC, and then LUDENSITY. Figure 1's flowchart indicates the steps involved in G-LUM's estimation and application. The user has an option to run the program separately, or along with a travel demand model. In the later case, travel times in G-LUM are updated using the results of the travel demand model after each time step.

The GUI developed for this code enables users to run the MATLAB-based G-LUM code without a MATLAB license (which costs about $2,000). However, it requires installing the freely available compiler software, which is 100MB in size. Full version of MATLAB can be purchased at http://www.mathworks.com/store/productIndexLink.do.

MATLAB's compiler (version 4.4) was used to develop this GUI and can be obtained from a full version of MATLAB 7.2[1]. The compiler software can also be obtained via Dr. Kara Kockelman (kkockelm@mail.utexas.edu).

---

[1] MATLAB's latest version was not used, due to the absence of a full license but also to reduce the size of the compiler program required for loading the G-LUM GUI.
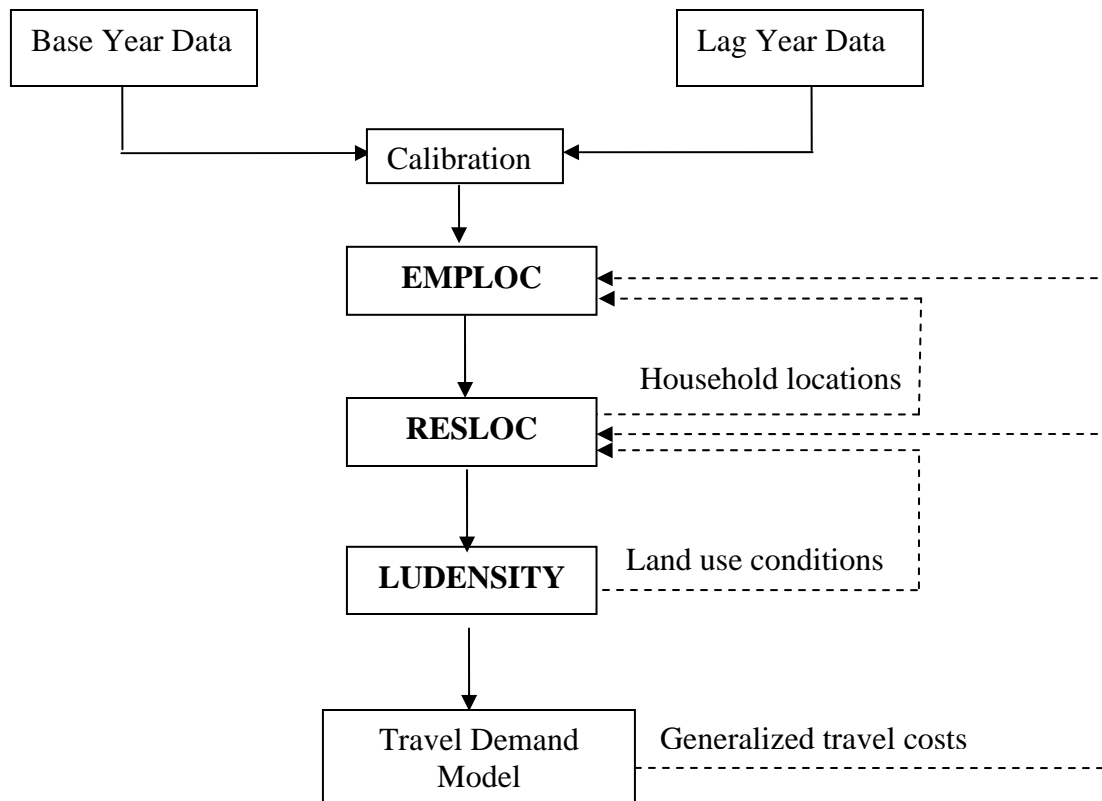
Figure 1. Flowchart for G-LUM Modules, in Concert with (external) Travel Demand Model

Note: Dashed lines represent one-period (*t*-1) lagged feedback of information.

For more information on the G-LUM model, including applications to Texas's Austin and Waco regions, please see the "ForecastingPopulationAndEmploymentInTexas.pdf" report located at http://www.ce.utexas.edu/prof/kockelman/G-LUM_Website/homepage.htm.

2. DATA PREPARATION

Fourteen input files are required to estimate parameters and predict future year household and job distributions throughout a system of zones using this model. The required data for Texas regions of Austin (base year = 2005; lag year = 2000; # zones = 1074; # districts = 109), San Antonio (base year=2008; lag year=2005; # zones=1069) and Waco (base year = 2005; lag year = 2000; # zones = 283; # districts = 44) are provided in the Code + Data section of the http://www.ce.utexas.edu/prof/kockelman/G-LUM_Website/homepage.htm website at TAZ (neighborhood-zone) levels with data listed by ascending FID number. Below is a description of each required file. It is imperative that the zone-based data be listed in the same order in each file (e.g., if employment data is listed in order of ascending zone number, then all other data must be listed in ascending zone order).

1) **EMP_lag.txt** contains employment by sector in the lag year for each zone. The number of industry sectors (or the number of columns in the EMP_lag.txt file) is determined by users and can vary across regions due to data availability (between 3 and 6). A common employment classification will emphasize three categories, as follows: (1) basic jobs (often including agriculture, forestry, fishing, mining, construction, manufacturing, services of transportation, communications, electric, gas, and sanitary, and wholesale trade), (2) retail jobs (i.e., retail trade), and (3) service jobs (including finance, insurance, real estate, services, and public administration). See the Austin and Waco applications on line at:
http://www.ce.utexas.edu/prof/kockelman/G-LUM_Website/InvestigationOfTELUM.pdf.
The first column should correspond to basic employment, the second to retail and the third to service. Sector data should be separated by tabs or spaces, and the data for each zone (e.g., TAZ) should be on a new line and listed in the same order for all sectors.

2) **EMP_base.txt** contains employment by sector (equal to the number of sectors in the EMP_lag.txt file and in the same order) in the base year for each zone. As with the EMP_lag.txt file, sector data should be separated by tabs or spaces, and the data for each zone (e.g., each TAZ) should be on a new line. Also needs to have the same number and type of job categories as EMP_lag.txt.

3) **HH_lag.txt** contains the number of households by type in the lag year for each zone. The number of household types (or the number of columns in the HH_lag.txt file) is determined by users and can vary across regions (between 1 and 6). Household income is commonly used to classify households (e.g., low-income, medium-income, and high-income households). Household data should be separated by tabs or spaces, and the data for each zone (e.g., TAZ) should be on a new line and listed in the same order as in all the other household types.

4) **HH _base.txt** contains the number of households by type in the base year for each zone. As with the HH_lag.txt file, household data for each household type should be separated by tabs or spaces, and the data for each zone (e.g., TAZ) should be on a new line and listed in the same order as in the HH_lag.txt file. Also, the number of zones and types of household should match those in the HH_lag.txt file.

5) **ZoneSize.txt** contains the total size (area) of each zone. The data for each zone should be separated by tabs or spaces, and values for distinct zones should be on distinct lines. All land area across all files need to have consistent units (e.g., square miles, acres, etc).

6) **landb.txt** contains the amount of land dedicated to basic employment in the base year in each zone. The data for each zone should be separated by tabs, spaces, and data for distinct zones should be on distinct lines. As described above, basic employment generally includes jobs in the agricultural, forestry, fishing, mining, construction, manufacturing, and other sectors.

7) **landc.txt** contains the amount of land dedicated to non-basic (or "commercial") employment in the base year in each zone. The data for each zone should be separated by tabs or spaces, and data for distinct zones should be on distinct lines.

8) **landd.txt** contains the amount of undeveloped – but developable – land in the base year in each zone. (Area for streets and other undevelopable lands should not be included here.) The data for each zone should be separated by tabs or spaces, and data for distinct zones should be on distinct lines.

9) **landu.txt** contains the amount of unusable land (i.e., land preserved from any development, such as lakes or state parks) in the base year in each zone. The data for each zone should be separated by tabs or spaces, and data for distinct zones should be on distinct lines.

10) **lands.txt** contains the amount of land dedicated to streets and highways in the base year in each zone. The data for each zone should be separated by tabs or spaces, and data for distinct zones should be on distinct lines.

11) **landr.txt** contains the amount of land dedicated to residential use in the base year in each zone. The data for each zone should be separated by tabs or spaces, and data for distinct zones should be on distinct lines. As a final note, all the files on areas of land by type need to use consistent units (e.g., square miles, acres, etc.).

12) **TT.txt** contains the travel time (or travel cost) between each pair of zones in the base year. The data should be input as a matrix with one row for each origin zone and one column for each destination zone, with tabs or spaces between data entries in each row.

13) **EmpProj.txt** contains the control totals for employment over the prediction time period. The data should be input as a matrix with one row for each time period and one column for each employment type, with tabs or spaces between data entries in each row. These should be consistent with the difference in base year and lag year used while estimating the parameters.

14) **HHProj.txt** contains the control totals for the number of households over the prediction time period. The data should be input as a matrix with one row for each time period and one column for each household type, with tabs or spaces between data entries in each row. These should be consistent with the difference in base year and lag year used while estimating the parameters.

Note: EmpProj.txt and HHProj.txt are not required for calibration of parameters but are necessary for future year projections.
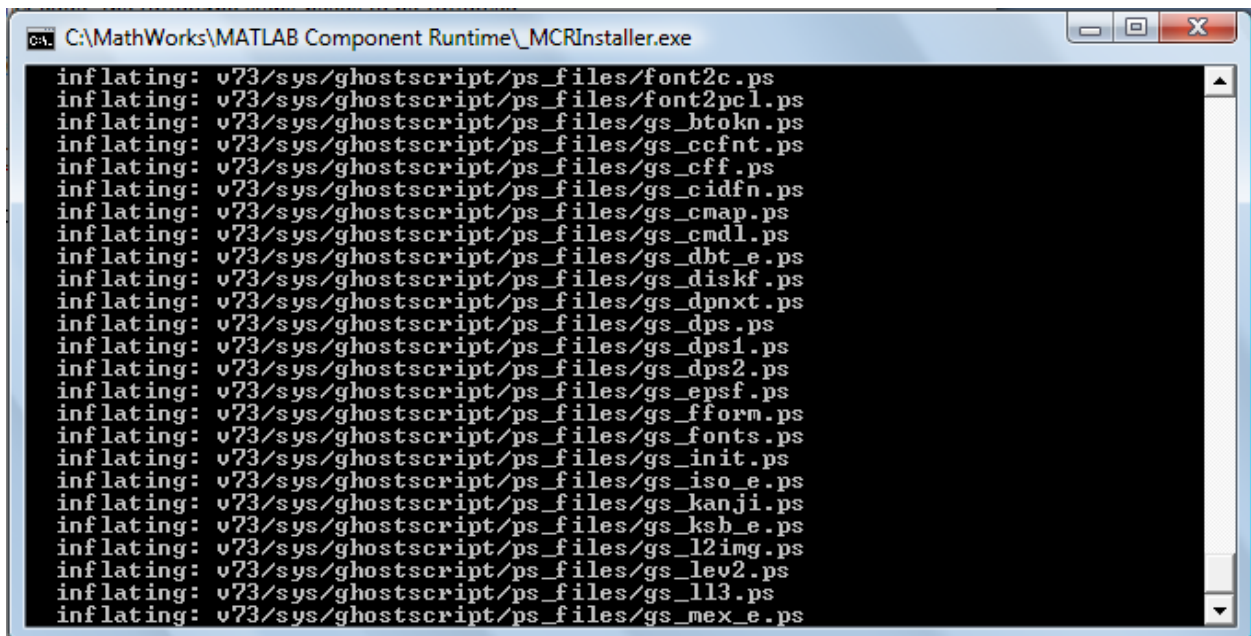
3. INSTALLING THE GUI

3.1 Installing the GUI

To run the G-LUM code, the following steps need to be followed:

Step 1: Install MCRInstaller.exe present in the unzipped folder.

Step 2: In *Windows XP*, ignore this step 2 and proceed to step 3.
    In *Windows Vista*: Navigate to the folder C:\Programfiles\ and copy the Math Works folder into C:\   (i.e., onto the C drive of your hard disk). Now, run the file _MCRInstaller.exe present in the folder C:\Math Works\ Matlab Component Runtime. You will see a command prompt window which looks like Figure 2.

Figure 2: Installing the GUI

Step 3:
 a) Click on the Start button in the task bar
b) Right click on 'My Computer' and click on properties
c) In *Windows XP*, click on the advanced settings tab.
In *Windows Vista*, click on 'Advanced System Settings' present on the left side of the window.
d) Click on the Environmental Variables button.
e) In system variables, go to the 'path' present in the list of system variables.
f) Edit the path by appending the ";C:\Program files\MathWorks\MATLAB Component Runtime\v73\bin\win32".
Note: Analysts must use a semicolon (;) before adding the path to the C:\...\win32 subdirectory, and be careful in handling this step as it can alter the system properties.

Step 4: Copy the GUI_Application.exe and GUI_Application.ctf present in the 'GUI code for G-LUM' folder of the website to the folder C:\MathWorks\MATLAB Component Runtime\v73\runtime\win32.

Step 5: Double Click on the file GUI_Application.exe. You will see the command prompt window, as shown below, in Figure 3. (However, some Operating Systems might need the user to right click on the exe file and select 'Run as administrator').
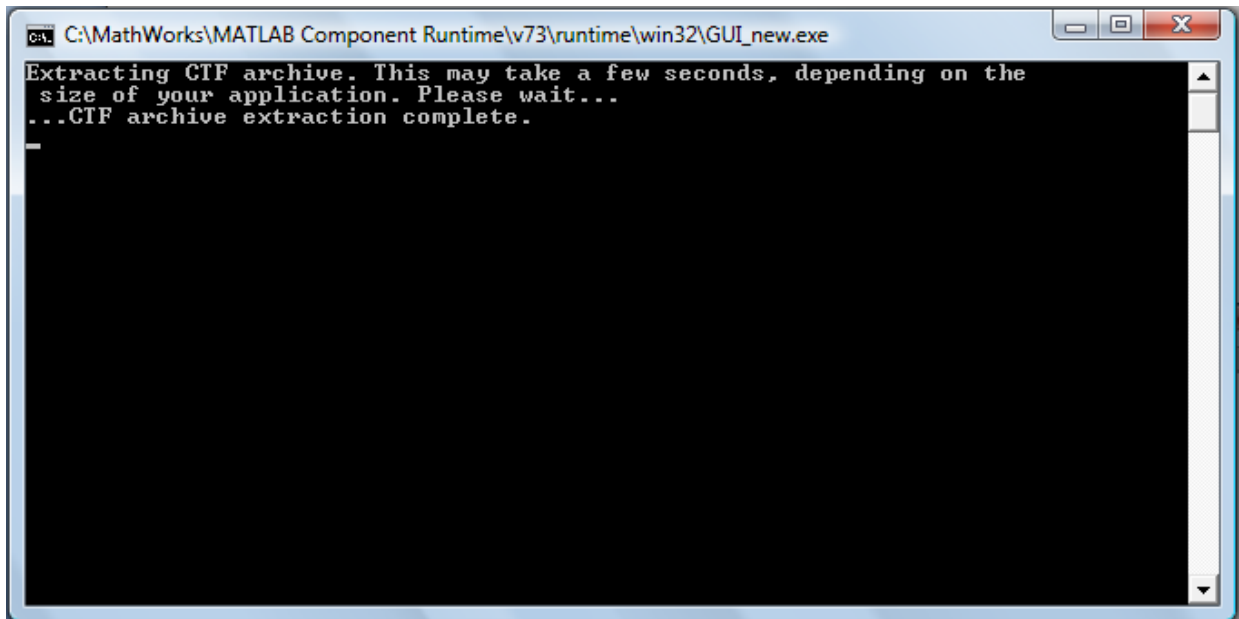

Figure 3: Running the GUI

Wait for a minute to get the GUI window.

Step 6: Unzip the G-LUM Finale folder present in the 'GUI code for G-LUM' folder of the website into the C- drive. This is sample Austin data. If you are planning to use your own data, then mimic the dataset for Austin. Data inputs needs to be provided in the input folders of calibration and prediction folders. The first twelve (12) input files listed in the data preparation section will be present in the *calibration input folder*, while the 13th and 14th input files (along with the first 12 input files) will be present in the *prediction input folder*.

3.2 Running G-LUM

G-LUM can be run either using the GUI (as specified in 3.2.1) or using MATLAB (as specified in 3.2.2). A GUI was developed at The University of Texas at Austin to allow users to run G-LUM without owning a MATLAB license.

3.2.1 Running the GUI
Step 7: The GUI has three push buttons for parameter estimation and one push buttons for model predictions. G-LUM uses the entropy-maximization principle to estimate the parameters in RESLOC and EMPLOC equations, but turns to use non-linear least-squares (NLLS) techniques

for parameter estimation in the LUDENSITY equations. (NLLS techniques were found to perform much better than entropy-maximization methods for the LUDENSITY equations, when tested for all four Texas regions, in terms of fit and reasonableness of results. Entropy maximization performed just as well as NLLS in the case of RESLOC and EMPLOC equations, and better reflects discrete count allocations in low-count zones, and so was used for those sets of equations.)

The entropy-maximization formulation used can be presented as follows (one set of these paired equations for each job type and each household type [with job and household indices omitted here for clarity]):

$$\max \sum_{i=1}^{n} N_i \ln\left(\widehat{N_\iota}\right) \qquad (9)$$

$$s.t. \sum_{i=1}^{n} N_i = \sum_{i=1}^{n} \widehat{N_\iota} \qquad (10)$$

where i is the zone index, N_i is the actual number of jobs and households zone i (depending on the sub-model being calibrated), and $\widehat{N_\iota}$ represents the predicted value in zone i. The constraint in the entropy maximization formulation (equation 10) ensures that the sum of the projected values equals the sum of the actual values. In order to implement this constraint, the predicted values are normalized by the ratio of sum of actual value to the sum of the predicted values.

The NLLS formulation can be presented as follows:

$$\min \sum_{i=1}^{n} (\widehat{L_\iota} - L_i)^2 \qquad (11)$$

$$s.t. \sum_{i=1}^{n} \widehat{L_\iota} = \sum_{i=1}^{n} L_i \qquad (12)$$

where i is the zone index, L_i is the actual area of land (in use type j – with use type indices omitted here for clarity) and $\widehat{L_\iota}$ is the predicted area of land used (of type j) in zone i. G-LUM uses MATLAB's optimization tools to solve the above maximization and minimization problem. Since the equations involved are highly non-linear and may result in sub-optimal solutions, several different starting value sets should be tested, to better ensure convergence on the best set of NLLS parameter estimates.

1) **RESLOC Calibration** is used to estimate the household allocation models' parameters. The model parameters can be estimated by just clicking the push button labeled 'RESLOC Calibration' and the command prompt window shows a series of ZZ values popping up. The ZZ values report a goodness of fit for the parameter estimates, the lower the ZZ value the better the estimate. Note the final ZZ value of the run. Change the initial values in the initial_values.txt and aim for a lower ZZ value. Reasonable ranges are as follows: eta = [0,1]; alpha = [0,3]; beta = [-.01,-.1]; qq = [.01;.1]; rr = [0,1]; ss = [0,1]; bnn[i] = [-5,5]. (Note: these are simply suggested ranges and may change depending on the units used or the problem). Try different values of the parameters until it does not seem possible to achieve a lower ZZ value.

The columns of initial_values.txt file correspond to eta, alpha, beta, qq, rr, ss, bnn[1], bnn[2], bnn[3], bnn[4] (assuming four household types) in the first six rows for RESLOC.

2) **EMPLOC Calibration** is used to estimate parameters in the jobs allocation model. The procedure to run this is the same as that used for RESLOC Calibration. Reasonable ranges of initial values are lambda = [0,1]; omega = [1,5]; rho = [-0.001,-0.010]; aa = [0.01,1]; bb= [0.01,1]. Try different initial values until it does not seem possible to achieve a lower ZZ value.

The columns of initial_values.txt file correspond to lambda, omega, rho, aa, and bb in the rows 7 to 12 for EMPLOC.

3) **LUDENSITY Calibration** is used to estimate the parameters of the model's land use component. The procedure to run this is the same as shown for RESLOC. Reasonable ranges of initial values for kk, gg, and pp are [0, 1]. Try different initial values until it does not seem possible to achieve a lower ZZ value. The last row in the initial_values.txt file is for LUDENSITY and corresponds to kk, gg and pp initial values.

After calibrating the three components, copy the contents of the output folder (which is present in the calibration folder) to the input folder (which is present in the prediction folder). In other words, all files shown under C:\G-LUM\Finale\Calibration\Output should be saved in C:\G-LUM\Finale\Prediction\Input.

4) **PREDICTION:** To predict future allocations of jobs, households and land use types, the user should enter the total number of future time periods to be predicted from the base year. For example, if the base year is 2005 and one seeks to forecast land use patterns through 2015, then one should enter the number of time periods that are required to reach 2015 in the "Edit" box. The size of each time period depends upon the control totals specified (For example, if control totals are provided at intervals of 5 years, then the size of each time period is five years and two time periods are needed to reach 2015 from 2005). The user should then click on the push button labeled 'PREDICTION'.

After completion of the prediction process, users will see the words "Finished Estimation for XX time periods" in the command prompt window, signaling a successful completion of the forecasting process.

Note regarding Scaling and Residuals: After calibration each sub-model is run to predict the number of households, jobs, and land use of each type in each zone in the base year (based on lag-year data). The predicted values are then scaled proportionally, so that the sum of predicted values equals the sum of the actual values. Residuals are the difference between the actual base-year values and these scaled G-LUM's base-year predictions (stepping forward from lag-year data). Many factors influence the spatial distribution of households, jobs, and land use are not included in the model's equations, but are reflected (to some extent) by these residuals (one per zone, for each household, job and land use type). Such factors include vegetative cover, view lots, river access, and access to other amenities, as well as disamenities (such as noise and poor soil).

In each future time period, predicted counts are also scaled up by the ratio of a household or job type's total target value (for the region being modeled) versus the sum of predicted counts (for each household and job type). Land coverage estimates are scaled by the ratio of total developable land to total predicted developed land (since target values of land in use [by type] are not available for future time periods). Residuals on jobs, households, and land areas are added to these scaled estimates to match the base–year's allocations. The effects of these residuals are assumed to fall over time, with G-LUM code assuming one-quarter (25%) reduction in base-year residuals after each time-increment. Thus, after four time steps (or 20 years, in the case of five-year increments), there is no correction for residuals but simply a scaling to hit regional targets (for household and job totals, by type) and developable-land shares (by zone).

Two More Notes:
G-LUM enables users to run their own TDM externally, based on land use forecasts in each time step (or every several time steps, for example) and update travel times/travel costs as needed. This module also runs in accordance to the number of time periods entered by the user. Results are outputted to the 'output' subfolder in the prediction folder

The edit box will accept numbered values greater than zero and no letters. The exogenous control totals entered for different time periods should be consistent with the difference in base year and lag year used while estimating the parameters (as discussed above).

3.2.2 Running the MATLAB Code (G-LUM)
MATLAB code for G-LUM runs like any other MATLAB file. Running the MATLAB file will start the GUI, after this follow the steps described in section 3.2.1 to run the GUI.

4. VIEWING RESULTS

Output data can be viewed in ArcGIS or any GIS mapping software by mapping the output data with a spatial layer. To map within MATLAB, visit http://www.spatial-econometrics.com/ and navigate to download the MATLAB Arc Map Toolbox file (courtesy of James P. Le Sage of Texas State University – San Marcos). Also, several open-source GIS options are available for download at http://opensourcegis.org/.

REFERENCES

Caliper (2000) Travel Demand Modeling with TransCAD4.7. *TransCAD Manual*.

Coalition on Sustainable Transportation (COST) (2010). Austin: Decentralization, Suburbanization Accellerates. Accessed from http://www.costaustin.org/jskaggs/?p=59 on 24th January 2010.

Kneebone, E. (2009) Job Sprawl Revisited: The Changing Geography of Metropolitan Employment, Metropolitan Policy Program at Brookings Institution, pp. 11-13. Accessed from http://www.brooking.edu/~/media/Files/rc/reports/2009/0406_job_sprawl_kneebone/20090406_jobsprawl_kneebome.pdf on 24th January 2010.

Kockelman, K. (2008) Gravity-based Land Use Model Website. University of Texas at Austin. Available at http://www.ce.utexas.edu/prof/kockelman/G-LUM_Website/homepage.htm.

Valsaraj V., Kockelman K., Duthie J. and Zhou B. (2007) Forecasting Employment & Population in Texas: An Investigation on TELUM Requirements, Assumptions, and Results, Including a Study of Zone Size Effects, for Austin and Waco Regions. Available at: http://www.ce.utexas.edu/prof/kockelman/G-LUM_Website/InvestigationOfTELUM.pdf

APPENDIX A

Model Description

ITG-LUM consists of a land use model (G-LUM) with three sub-components, RESLOC, EMPLOC, and LUDENSITY and a four-step travel demand model. A description of the sub-models of G-LUM can be found in Kockelman (2008). The only change to G-LUM is that LUDENSITY has been replaced by simple rules for how much land each type of use requires. The rules selected for the test application will be presented along with the section on 'Sample Network and Input Data.'

RESLOC

The equations obtained from calibrating RESLOC, the residential land use allocation module, are shown below for each household type n. Here, i and j are used as zone indices, k is an index for employment type, n indexes household type, and t indexes time period. The number of households of type n residing in zone i at time t $N_{i,t}^{n}$ is given by

$$N_i^n = \eta^n \sum_j Q_j^n B_j^n W_i^n c_{i,j,t}^{\alpha^n} \exp(\beta^n c_{i,j,t}) + (1-\eta^n) N_{i,t-1}^n \tag{1}$$

where

$$Q_j^n = \sum_k a_{k,n} E_{j,t}^k \qquad B_j^n = \left[\sum_i W_i^n c_{i,j,t}^{\alpha^n} \exp(\beta^n c_{i,j,t}) \right]^{-1} \tag{2}$$

$$W_{i,t-1}^n = (L_{i,t}^v)^{q^n} (x_{i,t})^{r^n} (L_{i,t}^r)^{s^n} \prod_{n'} \left[\left(1 + \frac{N_{i,t-1}^{n'}}{\sum_n N_{i,t-1}^n} \right)^{b_{n'}^n} \right] \tag{3}$$

and $c_{i,j,t}$ is impedance (travel time and/or cost) between zones i and j at time t; $a_{k,n}$ is the number of type n households per type k employee in the study region; $E_{j,t}^k$ is employment (number of jobs) of type k in zone j at time t; L_i^v is vacant developable land in zone i at time t-1; x_i is the proportion of developable land already developed in zone i at time t; L_i^r is residential land in zone i at time t-1; and $\eta^n, \alpha^n, \beta^n, q^n, r^n, s^n$ and $b_{n'}^n$ are parameters estimated in model calibration. In addition, $Q_{j,t}^n$ converts employment to households, and W_i^n represents the attractiveness of zone i for household type n at time t-1.

EMPLOC

The equations obtained from calibrating EMPLOC, the employment land use allocation module, are shown below for employment type k (basic, retail, service).

$$E_{j,t}^k = \lambda^k \sum_i N_{T,i,t-1} A_{i,t-1}^k M_{j,t-1}^k c_{i,j,t}^{\omega^k} \exp(\rho^k c_{i,j,t}) + (1-\lambda^k) E_{j,t-1}^k \tag{4}$$

where

$$A_{i,t-1}^k = \left[\sum_l (E_{l,t-1}^k)^{a^k} (L_l)^{b^k} c_{i,l,t}^{\omega^k} \exp(\beta^k c_{i,l,t}) \right]^{-1} \tag{5}$$

$$M_{j,t-1}^k = (E_{j,t-1}^k)^{a^k} (L_j)^{b^k}$$

and $N_{T,i,t-1}$ is total households in zone i at time t-1; L_j is the total area of zone j; $\lambda^k, \omega^k, \rho^k, a^k$ and b^k are estimated in model calibration; and $M_{j,t-1}^k$ represents the attractiveness of zone j for employment type k at time t-1.

Of the three employment types, service employment is least dependent on existing service employment, and retail employment is most dependent on existing retail employment.

LUDENSITY

The equations obtained from calibrating LUDENSITY, the land allocation module, are shown below for each land type. Other notation needed is L_b – amount of land devoted to basic employment, L_c – amount of land devoted to commercial (retail + service) employment, L_D – amount of developable land, L_d – amount of developed land.

Residential land use:

$$\frac{L_{r,i,t}}{N_{T,i,t}} = k_0 L_{D,i,t}^{k_1} \left(\frac{L_{d,i,t}}{L_{D,i,t}} \right)^{k_2} \left(\frac{E_{b,i,t}}{E_{T,i,t}} \right)^{k_3} \left(\frac{E_{c,i,t}}{E_{T,i,t}} \right)^{k_4} \left(\frac{N_{1,i,t}}{N_{T,i,t}} \right)^{k_5} \left(\frac{N_{2,i,t}}{N_{T,i,t}} \right)^{k_6} \left(\frac{N_{3,i,t}}{N_{T,i,t}} \right)^{k_7} \left(\frac{N_{4,i,t}}{N_{T,i,t}} \right)^{k_8} \left(\frac{N_{5,i,t}}{N_{T,i,t}} \right)^{k_9} \left(\frac{N_{6,i,t}}{N_{T,i,t}} \right)^{k_{10}} \tag{6}$$

Basic Land Use:

$$\frac{L_{b,i,t}}{E_{b,i,t}} = g_0 \left(\frac{L_{d,i,t}}{L_{D,i,t}} \right)^{g_1} \left(\frac{E_{b,i,t}}{E_{T,i,t}} \right)^{g_3} \left(\frac{E_{c,i,t}}{E_{T,i,t}} \right)^{g_4} \left(\frac{N_{1,i,t}}{N_{T,i,t}} \right)^{g_5} \left(\frac{N_{2,i,t}}{N_{T,i,t}} \right)^{g_6} \left(\frac{N_{3,i,t}}{N_{T,i,t}} \right)^{g_7} \left(\frac{N_{4,i,t}}{N_{T,i,t}} \right)^{g_8} \left(\frac{N_{5,i,t}}{N_{T,i,t}} \right)^{g_9} \left(\frac{N_{6,i,t}}{N_{T,i,t}} \right)^{g_{10}} \tag{7}$$

Commercial Land Use:

$$\frac{L_{c,i,t}}{E_{c,i,t}} = p_0 \left(\frac{L_{d,i,t}}{L_{D,i,t}} \right)^{p_1} \left(\frac{E_{b,i,t}}{E_{T,i,t}} \right)^{p_3} \left(\frac{E_{c,i,t}}{E_{T,i,t}} \right)^{p_4} \left(\frac{N_{1,i,t}}{N_{T,i,t}} \right)^{p_5} \left(\frac{N_{2,i,t}}{N_{T,i,t}} \right)^{p_6} \left(\frac{N_{3,i,t}}{N_{T,i,t}} \right)^{p_7} \left(\frac{N_{4,i,t}}{N_{T,i,t}} \right)^{p_8} \left(\frac{N_{5,i,t}}{N_{T,i,t}} \right)^{p_9} \left(\frac{N_{6,i,t}}{N_{T,i,t}} \right)^{p_{10}} \tag{8}$$

E stands for employment by type, as defined above (b = basic, c = commercial, including both retail and service jobs); N represents households by type; and the k's, g's and p's are estimated parameters.

To summarize: This documentation explains the data requirements and procedure for installing and running the ITG-LUM and G-LUM using both GUI and MATLAB. The document's appendix provides further details of the land use model and the travel demand model. The purpose of this software is to provide a friendly user interface while allowing various users to run the model (which was coded in MATLAB) without specialized software installed.

Common Errors in Using GUI

While installing the GUI, care should be taken in choosing correct paths. For example, C:\Program files\MathWorks\MATLAB Component Runtime\v73**bin**\win32 is different from C:\Program files\MathWorks\MATLAB Component Runtime\v73**runtime**\win32.

Application to Austin Region

Data Preparation

The data for Austin region was provided by the Austin's Capital Area Metropolitan Organization (CAMPO) for the 1074 TAZs. Year 2000 and 2005 were taken as lag and base year, based on data availability. The data were checked for any errors (negative number, large numbers, etc,) and were remedied accordingly. After this the data was assembled in the required formats in each of the input files.

Results

The runtimes for the three components of the model (RESLOC, EMPLOS and LUDENSITY) were approximately 60 minutes, 70 minutes and 5 minutes, respectively. It took just another 5 minutes to predict land use patterns from 2005 to 2030 in five time periods. The results were viewed using TransCAD in forms of 2-D and 3-D maps. Figures 1 and 2 illustrates the employment density in the base year (2005) and the final forecast year (2030), based on a series of five 5-year forecasts (for years 2010, 2015, 2020, 2025, and 2030). Images are shown in two-dimensional (2D) and three-dimensional (3D) formats. In the final forecast year 2030, employment density peaked at around 400 jobs per acre (from 250 jobs per acre in 2005), in Austin's downtown (in TAZ #379).

Figure 1: Employment Density (Jobs per Acre) in Base & Forecasted Year (2005 & 2030)

The inter-zonal travel time was not changed between different time steps which actually changes with change in household and employment densities. Ideally the users can run their own travel demand model after each time step using previous period's forecasts as a direct input for travel demand model.

Figures 3 and 4 summarizes household densities in the base and forecast years. A peak household density of 163 households per acre was observed in TAZ #358 in the final forecast year (increased from 47 households per acre in 2005). Since simple regional density numbers

(gross and averaged across zones) obscure variations in density, as experienced by Austin's residents and workers, count-weighted averages of household and employment densities were calculated. Also, accessibility indices were calculated as measures of accessibility of jobs and households from CBD zones. Table 1 lists the count-weighted densities and accessibility indices for base year (2005) and forecasted year (2030).

Figure 2: Employment Density (Jobs per Acre) in Base & Forecasted Year (2005 & 2030)

Figure 3: Household Density (HHS per Acre) in Base & Forecasted Year (2005 & 2030)
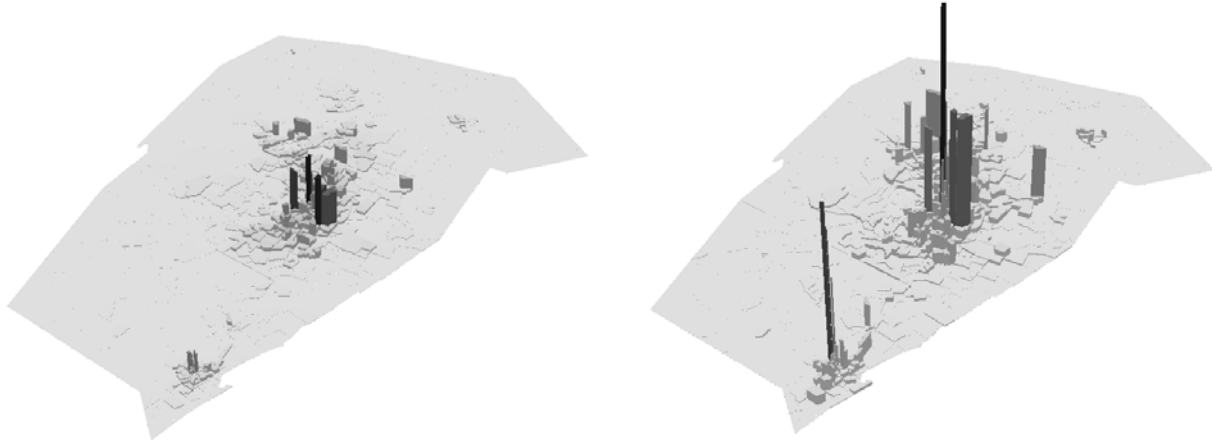
Figure 4: Household Density (HHS per Acre) in Base & Forecasted Year (2005 & 2030)

As shown in Table 1, even though total jobs rises over time, the count-weighted job density falls, suggesting continuing suburbanization or greater sprawl. A look at the lag and base year data reveals that between 2000 and 2005 Austin's job total increased from 602,399 to 699,447 but count-weighted density fell from 28.81 to 26.49 jobs/acre. Such decentralization of jobs from lag to base year is captured by the G-LUM parameters, resulting in a similar behavior under the TREND (business-as-usual) scenario.

Table 1: Numerical results in base and forecast year for Austin

	Total Jobs	Job Density* (count-weighted)	Total HHs	HH Density* (count-weighted)	Job AI (to CBD)	HH AI (to CBD)
Lag (2000)	602,399	28.81	444,953	4.59	202,351	142,161
Base (2005)	699,447	26.49	546,692	4.84	223,620	172,332
Trend (2030)	1,388,330	21.05	1,095,198	13.84	360,224	299,783

$$AI = \sum_i \frac{count}{(distance\ to\ CBD)} \quad Count\ weighted\ density = \sum \frac{HH_i \times HHDens_i}{TotalHouseholds}$$

Kneebone (2009) reported Austin to be among the metropolitan areas which experienced rapid decentralization between 1998 and 2006. Many other organizations, like the Coalition on Sustainable Transport (COST) have also reported acceleration in employment decentralization in Austin between 2000 and 2006. The centralization or decentralization behavior might result from a lot of temporary factors (rapid construction, etc.) which may not be present in the future years. Utmost care must be taken while assembling the data for lag and base years. The household density increased in the forecasted year as expected. The increase in household density indicates densification of households. Also, the accessibility indices corresponding to both jobs and household increases as a result of increase in number of households and densification.

Common Errors
- Storing input files in wrong folders.
- Error in setting the paths for input files.

- Entering wrong information in different input files.
- Having negative or non-compatible values in the input files (e.g., negative area).
- Running the prediction without copying the parameters files from the calibration folder to the prediction folder.
- Sometimes the counts for each type of HHs or jobs are printed without a separator. This oversight can lead to high densities in certain zones.