Development of the State Smart Transportation Initiative's DelDOT 3-D Micro Model Process - A scenario planning tool to evaluate urban form, land use, and multimodal investment impacts on mobility

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ABSTRACT

The Land Use and Transportation Scenario Analysis and Microsimulation (LUTSAM) application is the result of collaboration between the Delaware Department of Transportation (DelDOT) and the State Smart Transportation Initiative (SSTI) at the University of Wisconsin - Madison. The traditional approach to transportation and land use areawide and corridor studies which relies on existing travel demand models and microsimulation is cumbersome and difficult to complete in a timely manner during the course of a study. It is also difficult to produce the results needed to evaluate the direct impacts of urban form, land use, and multimodal investments, especially bicycle and pedestrian investments, on mobility. This is particularly difficult with existing models since many do not operate at the level of geographic resolution needed. Industry wide, parcel-level modeling has been proven to improve such shortcomings in traditional travel demand modeling by providing the appropriate level of detail, along with measure of effectiveness (MOEs) that better quantify these analyses, however most parcel based models have also been developed as advanced models (activity based or tour based models). This has left a gap for studies performed in areas lacking these advanced models or studies that cannot be performed with the current long run times needed to take advantage of the features of advanced models.

Another current shortcoming is the need to convey the results of these studies to decision-makers and the public engagement in a manner that is easily understood. If the goal of a study is to change zoning and land use planning to help communities achieve their transportation related quality of life then this is equally important to a thorough analysis.

To this end, the LUTSAM process was developed to accurately evaluate various land use and transportation scenarios, providing a bridge between GIS, travel demand modeling and 3-D microsimulation, and quantifying meaningful results for better decision-making. This process can be easily used to improve current 4-step and advanced travel demand models to work at the parcel and building level within the study area while producing easily transferable results to industry standard microsimulation software.

LUTSAM not only accelerates scenario development but also (1) provides a platform for testing land use planning, multimodal investments such as improving bicycle and pedestrian mobility; (2) encourages public engagement in community planning and decision making; and (3) encourages interactions between planners, modelers and engineers.

This paper describes the LUTSAM GIS application, the travel demand process, microsimulation and case studies that quantify impacts to the communities, especially mobility impacts on pedestrians and bicyclists.

INTRODUCTION

The Land Use and Transportation Scenario Analysis and Microsimulation (LUTSAM) application establishes a transferable process for planners to perform scenario testing on various residential, commercial, and industrial development scenarios along with multimodal transportation investments. The application performs Smart Transportation/Smart Growth analyses by combining industry standard GIS, Travel Demand, and 3D Microsimulation tools.

The LUTSAM application requires as inputs model highway and sidewalk networks, demographics, land use layers such as buildable regions, and base map layers, such as boundaries and natural features, that aid the planner to develop various land use scenarios through a series of steps in a user-friendly Graphical User Interface Editor. The resulting output network node and link shapefiles, contains updated demographics, roadways and sidewalks, and can be input to any travel demand model to test the land use alternatives. A sub-area extraction process is then applied to export to 3-D microsimulation tools. The output network from LUTSAM can also be visualized in 3-D using 3D GIS extensions.

BACKGROUND

Existing DelDOT Model

DelDOT's Peninsula Model is a typical statewide travel demand model that covers the state of Delaware plus the 9 counties of Maryland's Eastern Shore, covering over 5,000 square miles and 1.4 million people (Figure 1). The model operates at two levels of resolution. The first, referred to as the TAZ Model, includes 2,108 traffic analysis zones (TAZ's) and 13,491 links, including most of the collector roads, arterials, expressways, and freeways within the model area. The second, referred to as the Micro Model, includes 19,640 TAZ's and 177,211 links and includes most of the local roads in addition to the TAZ Model network (1). In order to reduce processing time, the micro model allows the selection of areas to be modeled using the Micro Model resolution and run within the framework of the TAZ Model, in other words the model can be run with the enhanced resolution where necessary while still capturing regional traffic flow based upon the TAZ Model.

The Peninsula Model is a traditional four-step travel demand model with feedback between traffic assignment and trip distribution and includes a series of fully integrated supplemental modules including:

- EZ-Pass Toll/Mode Choice model
- Air Quality Post Processor
- Build/No-Build Benefit Cost Module
- Statewide Evacuation Model
- Seasonal Tourism Model

- Optional Junction Assignment Module
- TIS Trip Generation Module
- Standard reporting features

These modules have been developed as a result of DelDOT's standing policy that requires all model development and major model applications to:

1. Develop standard applications to enhance production of consistent results rather than unique model runs;
2. Integrate new modules or applications with the entire model chain; and
3. Leverage model development through existing programs such as the Delaware Travel Monitoring System (DTMS) and major studies by enforcing the first and second elements of the policy (*1*).

While the Peninsula Model meets most of Delaware's multi-modal forecasting needs, research has shown that performing analysis at the parcel level significantly improves the ability to evaluate the impacts on urban form, land use, and multi-modal infrastructure investments on pedestrian, bicycle, transit, and passenger car travel demand (*2*,*3*).

FIGURE 1 DelDOT's Peninsula model.

State of the Practice

The current emphasis of parcel based travel forecasting often combines enhanced geographic resolution with activity-based or tour-based travel demand models (*4,5,6*). On the other hand, land use modeling focusses on developing econometric models that relate the impact on development patterns based upon transportation investments. While these models are key to answering policy level questions such as induced demand or the impacts of fuel prices on regional travel, they are not necessary for area wide or corridor studies, nor do they provided the detailed measures of effectiveness needed to evaluate the direct impact of urban form, land use, and transportation investment on emissions, greenhouse gasses, or congestion. They also are not geared to evaluating multiple land use, intensity, or land form scenarios or quantifying their impacts in a manner that is easily understood by decision makers that can directly influence local land use policies.

Another shortcoming of existing practices is the level of expertise needed to develop scenarios for testing, evaluate scenarios, and convey results to other technical experts for evaluation. This is increasingly a critical shortcoming as budget restrictions limit the staff available to perform these analyses and the industry in general faces a shortage of technical experts.

The Path Forward

In order to overcome these shortcomings, SSTI and the Delaware Department of Transportation partnered to develop an application that can be used to streamline scenario development and a process that streamlines the use of a combination of travel demand and 3-D micro simulation models to evaluate, analyze, and convey results to the public and decision makers in a manner that is easily understood. In other words, the process produces improved measures of effectiveness that are easy to communicate in less time and on a smaller budget.

LUTSAM PROCESS DESCRIPTION

The LUTSAM application uses industry-standard GIS software, through a user-friendly Graphical User Interface (GUI) developed as a GIS extension. The process requires: (1) model layers, including a highway network (links and nodes) and a sidewalk network (links and nodes); (2) buildable region layers such as tax parcels, land use, environmental and topographical considerations such as wetlands and steep terrain, and TAZ boundaries that are used to define the project region; (3) base map layers such as roadways, urban boundaries and natural features that provide location and geographic reference.

The planner performs the following steps to develop scenarios for evaluation:

- Identify the project region where new development is proposed
- Subdivide the region into smaller ”areas”
- Define land use type and density for each area
- Sketch roads and sidewalks within the region
- Draw homes along each roadway by defining frontage and setback
- Connect homes and sidewalks to the roadway and sidewalk network
- Merge the new roadway/sidewalk networks with the original model networks

ArcMap Initial Processing

The LUTSAM is a GIS extension and the data required to run the program includes link and node shapefiles from the travel demand model, buildable region shapefiles such as parcel, land use, model TAZs (Figure 1) to define the subdivision. Background shapefiles such as roadways, water features, county boundaries can be loaded to understand locational features.

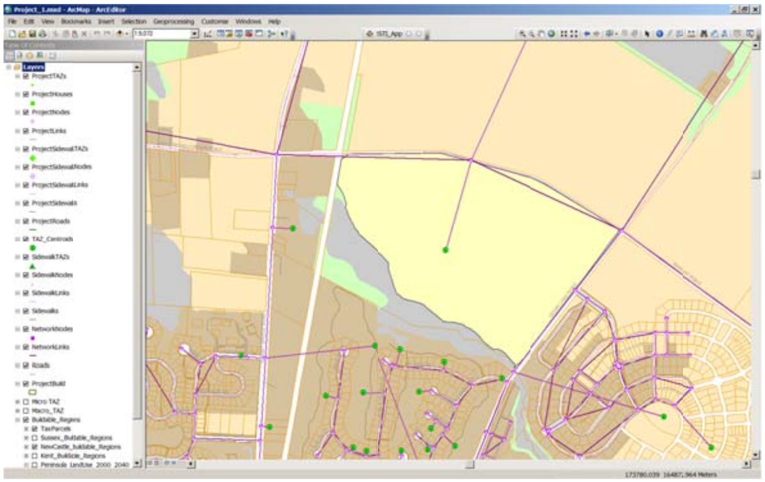
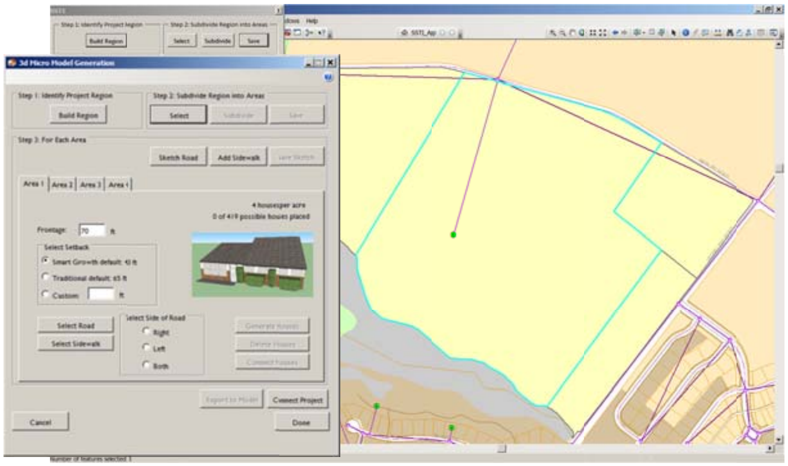


Figure 1: Initial Base Shapefiles

Building Regions and Internal Network

The subdivision region is selected from the buildable shapefiles and subdivided to define "areas" within each region. These areas can either be of residential, industrial or commercial land use. Residential areas are further defined as single-family or multi-family and vary by different densities, such as four units per acre or ten units per acres. Each home can be "traditional", with longer driveways and wider frontage or "neo-traditional" with shorter driveways, shorter frontages and garages in the rear of the homes. (Figure 2).



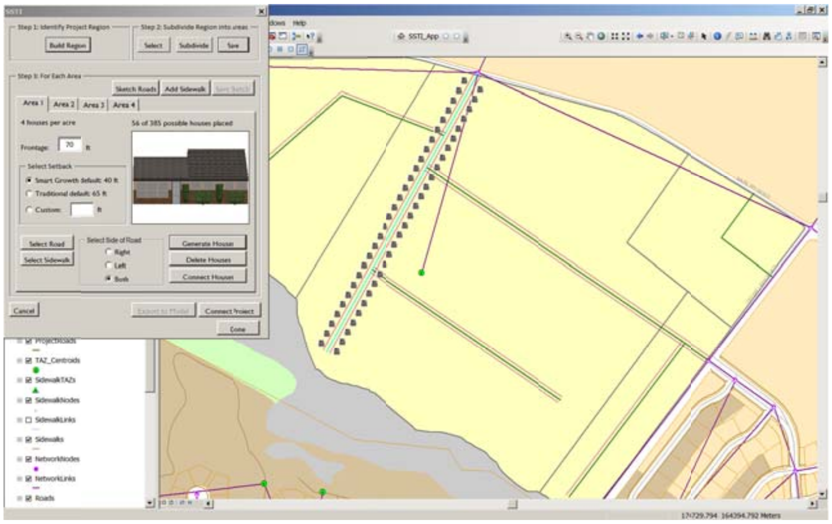
4 houses per acre
0 of 419 possible houses placed
Frontage: 70 ft
● Smart Growth default: 40 ft
○ Traditional default: 65 ft
○ Custom: ft
Number of features selected: 1

Figure 2: Building Regions and Areas

After defining the subdivision area the user can sketch the internal roadway network and sidewalks where required. Sidewalks are added by selecting the roadway section and selecting the side of the road that contains the sidewalk. User input is required for buffer strips, i.e. green space between the edge of curb and the edge of sidewalk (Figure 3).

Generating Homes and Connecting Homes to Network

New homes are placed on the side of the road selected by the user and the new homes are then connected to the subdivision roadway system as displayed in figure 4. Each home becomes a new traffic analysis zone and residential input data such as density, frontage and commercial input data such as employees and square footage is passed on to these tables.



4 houses per acre

56 of 385 possible houses placed

Frontage: 70 ft

● Smart Growth default: 40 ft
○ Traditional default: 65 ft
○ Custom: ft

○ Right
○ Left
● Both

Figure 3: Generating Homes

Finally the project roadways, sidewalks and generated homes are connected to the model network of links and nodes. Two key datasets are exported for use in the travel demand model: (1) Household level data is exported in the node database and (2) network-related data is exported as link and nodes.

3-D VIEWER AND 3-D LIBRARY

To provide a more realistic view of the subdivision, the subdivision node layer data was saved and imported into 3D viewing software. 3D landform files were created and used to display the various land uses. A qualitative assessment can be made by visualizing what the community would look like when built (Figure 4). This provides visual aid in understanding neo-traditional versus traditional housing, including driveway lengths, frontages and density of homes, sidewalk connectivity for pedestrian mobility and where aesthetics of the community can be generally improved to encourage Smart Neighborhood Planning.

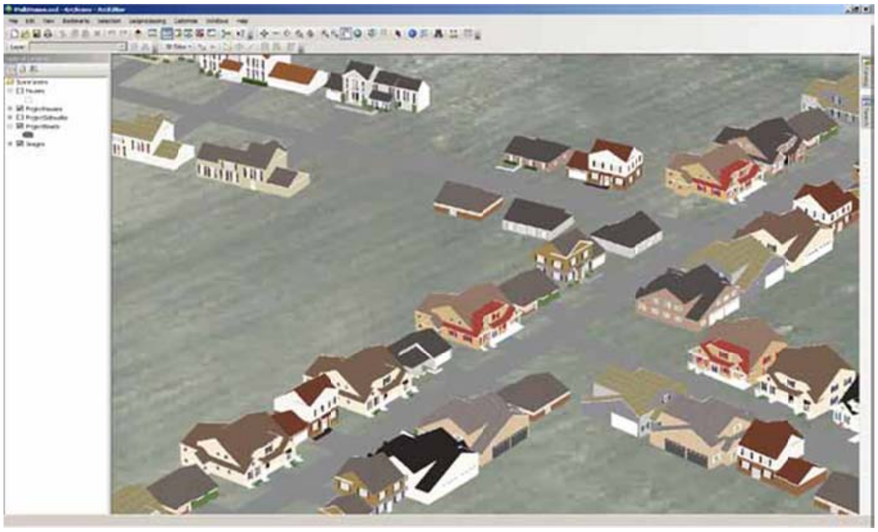


Figure 4: 3D View of Micro Model Data

TRAVEL DEMAND PROCESS

The Cube Voyager Micro Travel Demand Model (MTDM) process has been developed as an enhancement of the existing Peninsula Model (Figure 5). This includes developing the process to incorporate the land use data and network enhancements developed in the LUTSAM GUI and export the trip table and network information needed for more detailed microsimulation

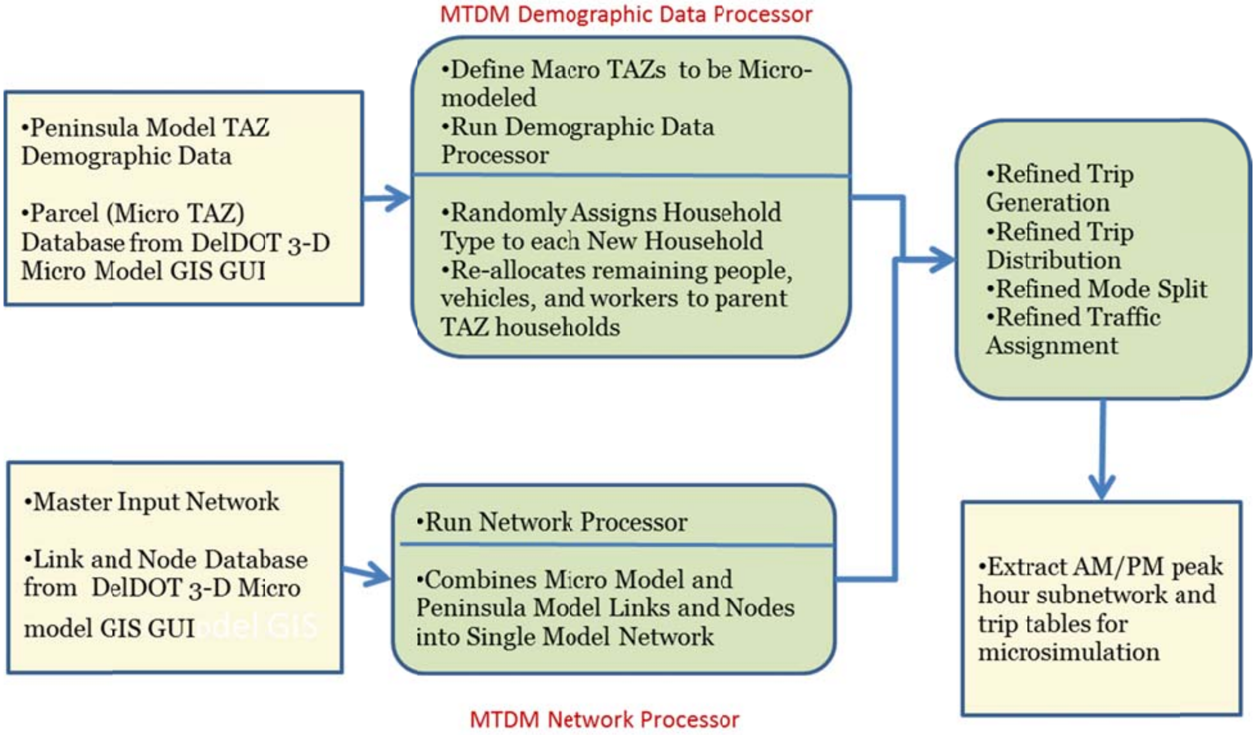


Figure 5: MTDM Flow Chart

The MTDM updates include modifications to the Peninsula Model's demographic data processing, network processing, trip generation, mode choice, and traffic assignment scripts and processes in order to assimilate the data generated with the DelDOT 3-D Micro Model GIS GUI and produce the trip table and network used as a basis for more detailed microsimulation.

Demographic Data Processing

The model enhancement combines the Peninsula Model with the Micro Model (parcel-level) demographic data and synthesizes household populations for the micro model TAZs.

Micro Model Area Selection: The Peninsula Model scripts were modified to allow the user to define which Peninsula Model TAZ(s) will be micro-modeled. The model then replaces the selected Peninsula Model TAZ(s) with the Micro TAZ's. Next, the model combines the Micro TAZ data with Peninsula TAZ's to create a single, combined, demographic data set.

Household Population Synthesizer: The Peninsula Model uses separate trip generation rates for households based upon 208 household types representing various combinations of people, vehicles, workers, and income per household using a socio-economic disaggregation sub model based upon public use microdata sample (PUMS) and the Delaware Person-Based Time Series Household Survey. The model flow and scripts were refined in order to randomly assign a household type to each Micro TAZ based on the proportion of each household type in the parent Peninsula TAZ (Figure 6). The model then removes the people, workers, and vehicles assigned to Micro TAZ's from the parent Peninsula TAZ(s) and re-synthesizes the Peninsula TAZ(s) demographic data for each remainder parent TAZ(s).

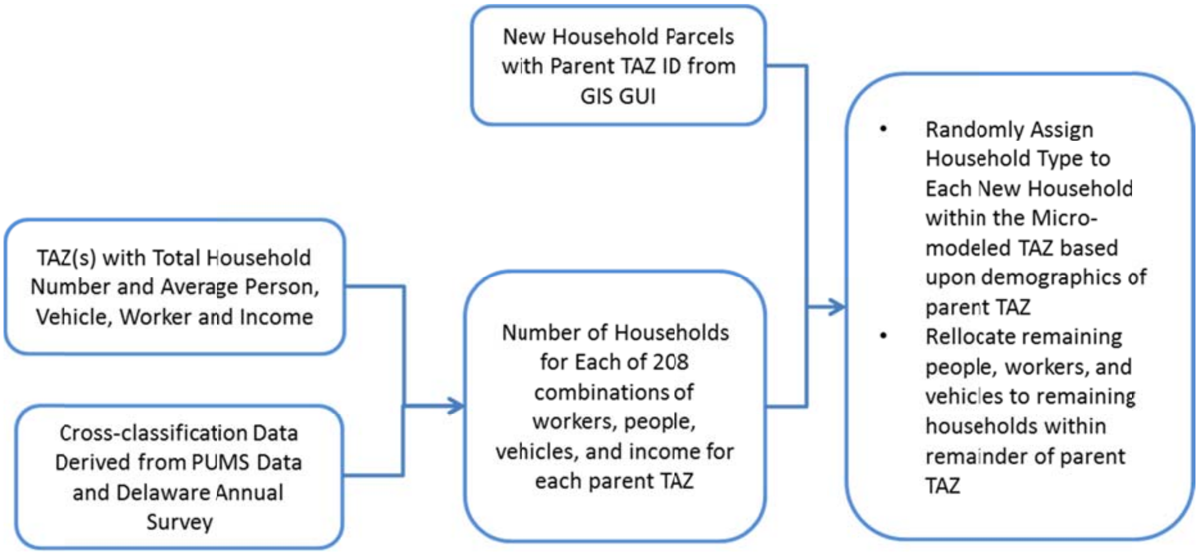


Figure 6: MTDM Household Population Synthesizer Work Flow

Network Processor

The Peninsula Model's single network processor was refined for the MTDM in order to incorporate the network refinements generated by the LUTSAM GUI. The process allows the selection of additional links and nodes based upon the definitions from the GIS link and node databases. The additional links are then automatically combined with the Peninsula Model network to create a single model network.

MICROSIMULATION PROCESS

The subarea output from the Micro Model Travel Demand process was imported into the microsimulator. These inputs to the microsimulator include: (1) the roadway and sidewalk networks from the travel demand model (2) trip matrices by mode, including auto, bike and pedestrians (3) the 3D landforms that were generated for display purposes from the LUTSAM GUI.

A 3D microsimulation model resulted from this process and further refinements, such as allowing proper intersection control, were made to ensure accurate and smoother operations. Dynamic Assignment Routing (DTA) or static routing can be used to assign traffic. Standard video simulations in windows media player format were generated to make the simulations viewable for presentation purposes (Figure 7).

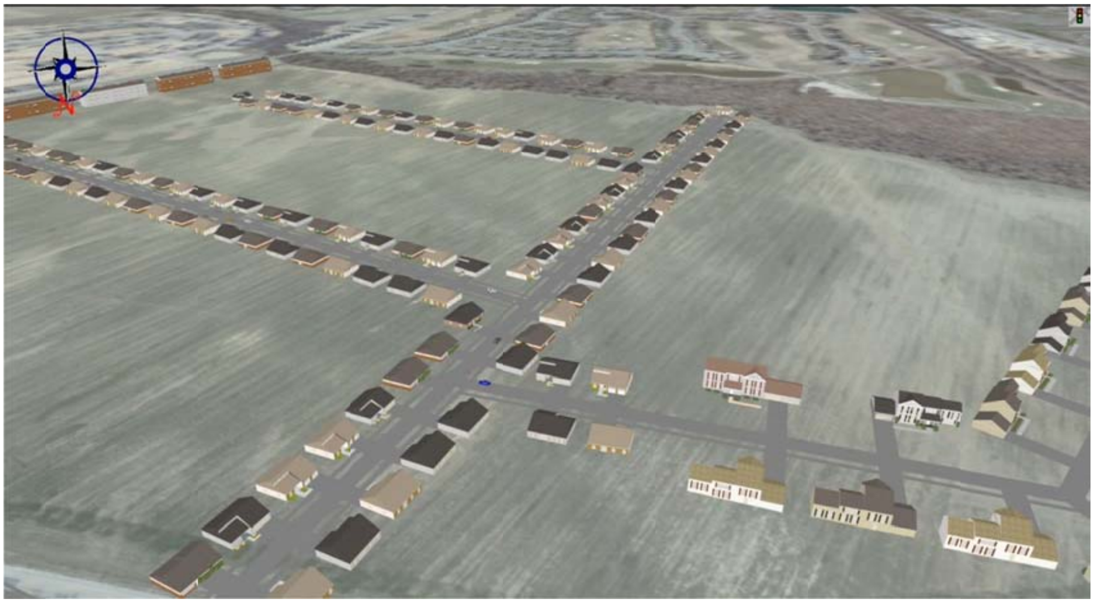


Figure 7: Microsimulation of LUTSAM Suburban Case Study

CASE STUDIES

Two case studies were tested to evaluate the sensitivity of a LUTSAM analysis. These included a traditional suburban neighborhood, and an urban neighborhood. Both studies included the same number of homes and square footage of commercial space, however the urban development had a more compact design with a more well-connected sidewalk network to promote pedestrian and bicycle usage.

The first case study was of a sub-urban auto-centric neighborhood, consisting of 190 single/multi-family homes with a big box store. This subdivision had four entrances to adjacent roadways; two from the subdivision and two from the big box store. The neighborhood had poor internal connectivity and inadequate pedestrian facilities (Figure 8).

Figure 8: Case Study 1 - Suburban Auto-Centric

Case study 2 was in an urban setting with a similar 190 single/multi-family homes and one big box store. The subdivision was more compact in design and consisted of two overall entrances. The subdivision was well connected internally and was a completely walkable/bikeable neighborhood (Figure 9).

Figure 9: Case Study 2 - Urban

Various MOEs to compare the two neighborhoods were considered such as VHT, VMT and vehicle delay. Daily bike and walking trips were quantified and compared, the results are displayed in the following figures.

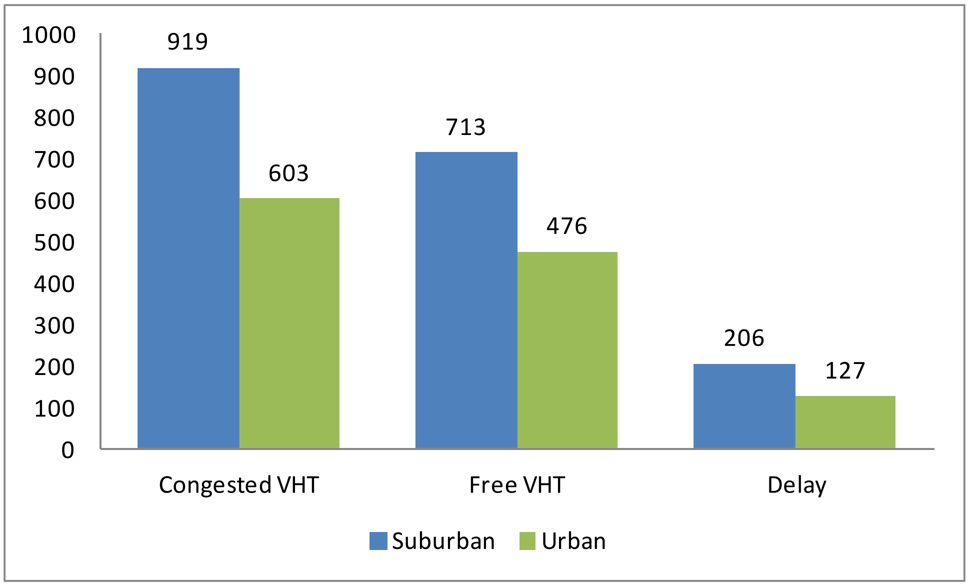


Figure 10: VHT and Delay Comparison

VHT and delay comparisons showed significantly reduced congestion for the urban case study (Figure 10). Congested VHT was reduced by 34% and delay by 39%. VMT comparisons showed a 32% reduction in miles traveled for the urban case study (Figure 11). This could imply increased use of alternative modes such as biking and walking along with proximity to other uses such as transit. This was confirmed by the increased number of bike and walk trips observed in the neighborhood (Figure 12).

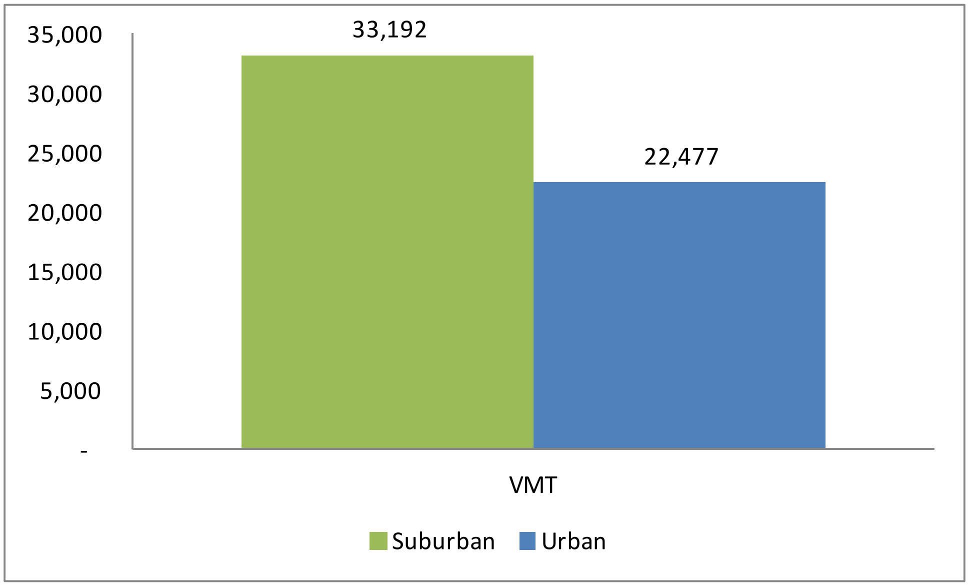


Figure 11: VMT Comparison

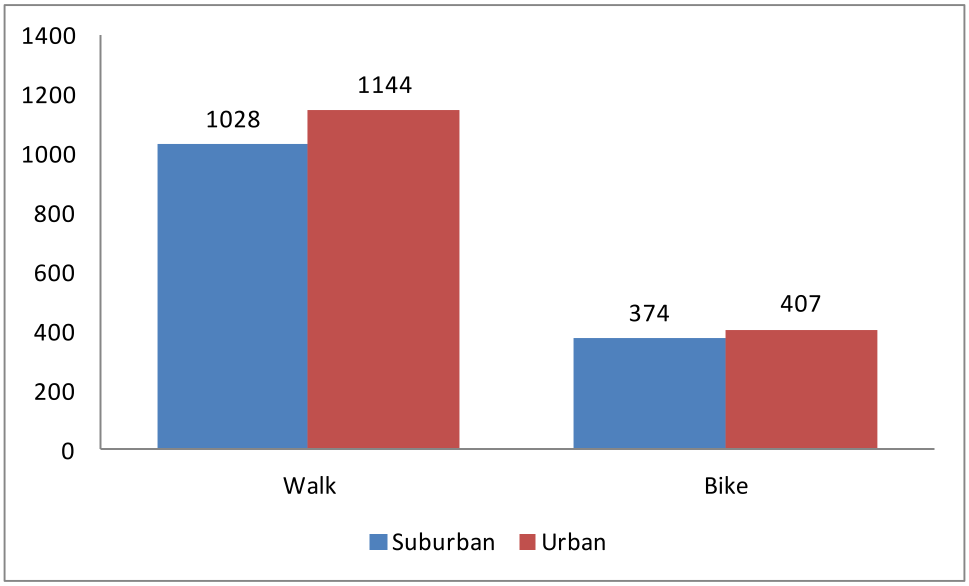


Figure 12: Walk and Bike Trips Comparison

CONCLUSIONS AND RECOMMENDATIONS

LUTSAM was developed to evaluate smart transportation/smart growth concepts in urban land form, land use, and multi-modal bicycle and pedestrian-related investments. Using parcel-based micro modeling, LUTSAM accelerates evaluation of these scenarios, and acts as a bridge between GIS, travel demand and microsimulation, quantifying easily understood MOEs for better decision-making. The time needed for scenario evaluation from GIS to microsimulation is greatly reduced (from over a month to less than a week) which allows the use of the process during the course of integrated transportation and land use areawide and corridor studies.

The results from the case studies demonstrate that LUTSAM is sensitive enough to model and quantify bicycle and pedestrian related mobility improvements. The next steps in further development of LUTSAM include collecting additional multi-modal travel data using DelDOT’s Delaware Travel Monitoring System (DTMS) and conducting additional multi-modal surveys in order to further improve bicycle and pedestrian mode choice modeling.

REFERENCES

1. Thompson-Graves, S., M. DuRoss, E. C. Ratledge, and D. P. Racca. Developing a Statewide Travel Demand Model from a Person-Based Time Series Household Survey. *In Transportation Research Record: Journal of the Transportation Research Board*, No. 1981, Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 68-75.

2. P. Waddell. Parcel-Level Microsimulation of Land Use and Transportation: The Walking Scale of Urban Sustainability. Resource Paper for the 2009 IATBR Workshop on Computational Algorithms and Procedures for Integrated Microsimulation Models.

3. Thompson-Graves, S., M. DuRoss, Li, L. Development and Application of a Parcel Based Statewide Travel Demand Model for the Assessment of the Travel Impacts of Smart Growth Strategies and Sidewalk Investments. Presented at the 92nd Annual Meeting of the Transportation Research Board, Washington, D.C., 2012.

4. P. Waddell. Microsimulating parcel-level land use and activity-based travel: Development of a prototype application in San Francisco. In *Journal of Transport and Land Use*, Vol. 3, No. 2, pp. 65-84, Minneapolis, 2010.

5. Blandford, B., T. Grossardt, J. Ripy, and K. Bailey. Integrated Transportation and Land Use scenario Modeling by Visual Evaluation of Examples. In *Transportation Research Record: Journal of the Transportation Research Board*, No. 2076, Transportation Research Board of the National Academies, Washington, D.C., 2006, pp. 192-199.

6. Griessenbeck, B. Small is Beautiful: Why You Should Get Rid of Zones and Start Using Parcels in Your Travel Demand Model. Presented at the 88th Annual Meeting of the Transportation Research Board, Washington, D.C., 2009.

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