LINKING LAND FORM AND DEVELOPMENT LOCATION
TO MULTIMODAL TRAVEL DEMAND:
CASE STUDIES OF TRANSPORTATION AND LAND USE STUDIES
IN DELAWARE

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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 and the State Smart Transportation Initiative at the University of Wisconsin – Madison to develop a transferable process which evaluates the impacts of land form and location on travel demand and measures of effectiveness. The process produces information in a manner easily understood by the public and local officials. LUTSAM provides a bridge between GIS, travel demand modeling and 3-D microsimulation and allows traditional and advanced Traffic Analysis Zone (TAZ) based models to operate at the parcel level.

The traditional approach to transportation and land use areawide and corridor studies using existing travel demand models and microsimulation is cumbersome and time-consuming. It is difficult to produce the results needed to evaluate the direct impacts of urban form, land use, and multimodal investments on mobility. This is particularly challenging with existing models since many do not operate at the level of geographic resolution needed. Industry-wide, parcel-level modeling has been shown to overcome such shortcomings by providing the appropriate level of detail, along with measures of effectiveness that better quantify these analyses, however most parcel based models have also been developed as advanced models. This has left a gap for studies performed in areas lacking advanced models. This paper showcases the application of this tool for five case studies in Delaware.
OVERVIEW AND SUMMARY OF TRAVEL MODEL PROCESS

The Land Use and Transportation Scenario Analysis and Microsimulation (LUTSAM) process is a transferable application that takes advantage of the strengths of GIS, traditional travel demand models, and 3-D microsimulation. LUTSAM uses standard, commercially available software allowing planners and engineers to perform scenario testing on various transportation and land use alternatives. The main advantage of the process is that it uses typically available data and models to produce parcel-level analysis of the impacts of transportation and development form which has been shown to be the most effective level of aggregation for detailed transportation and land use scenario planning (1, 2, 3, 4).

Using the travel demand models commonly used for regional planning, air quality conformity, and surface transport alternatives analysis allows the process to be tailored to any region or location that maintains a travel demand model with minor modifications to the model’s workflow. Note that the case studies presented in this paper all used the suite of modeling software tools used by the Delaware Department of Transportation, Division of Planning. 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 contain updated demographics, roadways, and sidewalks, and can be input to any travel demand model to test the scenario 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.

Figure 1 presents a visual summary of the three primary steps in the LUTSAM process. The process starts with a graphical user interface developed as a GIS extension. This step includes two major features: the first is a set of screens leading the analyst through development of a tax parcel based travel demand model based on existing tax parcels.

FIGURE 1 Overview of LUTSAM modeling process.
The second GIS feature is an optional set of screens leading the analyst through development of tax parcel level detail for hypothetical or potential land developments and transportation investments reflecting a range of future land intensity, density alternatives, and connectivity. This step would typically be performed only for those studies needing detailed, parcel-level examination of residential and/or commercial land development site concepts, for both recorded development plans or potential, merely hypothetical land use options under consideration. For example, this step would typically be completed to generate model files for various build-out scenarios in a municipal or county comprehensive land use plan, access point studies across development scenarios, or detailed, multimodal studies of bike and pedestrian features in existing or future development patterns.

The second portion of the process involves importing the detailed GIS files into a four-step travel model incorporating trip generation, distribution, mode choice, and assignment components. This step combines the Traffic Analysis Zone (TAZ) based travel model used for Delaware’s regional and statewide modeling with detailed GIS files at the tax parcel level, including combining the standard TAZ-based demographic data such as aggregate population and employment with synthetically-generated, household-based data such as persons per household by employment status.

The third portion of the LUTSAM process involves transferring the detailed tax-parcel based travel demand model outputs to a microsimulation process and adding 3-D landforms from an internal library of local vernacular architecture. This is an optional process that is performed if the analyst desires the additional level of detailed Measures of Effectiveness (MOE) generated by microsimulation. This optional step would also be performed in an application where 3-D animation results were used for workshops or presentations, web review by various audiences, or visually illustrating results of multimodal studies.

APPLICATION #1: ASSESSMENT OF TRAVEL PATTERNS ACCORDING TO RESIDENTIAL DENSITY AND LOCATION

Description
A LUTSAM application was developed to examine the degree to which the tax-parcel methodology accommodated travel patterns according to two distinct subdivision forms. A LUTSAM tax-parcel base model was generated in a study area primarily comprising low-density, residential growth. The tax-parcel study included a town of about 5,500 persons; the next closest town (of 35,000 persons) was located about 15 miles north, in the regional TAZ portion of model coverage.

A copy of the LUTSAM base model was used to generate a scenario network for a hypothetical land development project using a traditional residential subdivision form (Fig. 2). The traditional form had about 35% of the residential units on cul-de-sacs, limited bike/pedestrian connectivity, and only two vehicular access points. About 40% of the hypothetical subdivision had a net density of 3 units per acre; about 60% of the development had a net density of 6 units per acre.
A second scenario was developed based on more recently developed Smart Growth residential neighborhood concepts. Under these guidelines only 5% of the residential units were on cul-de-sacs, all units had bike/pedestrian connectivity, and there were three vehicular access points (two to the external street system and one to an adjacent land use). The overall net density was also higher than the traditional form, with about 10% of the units at three units per acre, 60% of the units at eight units per acre, and about 30% of the units at 12 units per acre.

Results and Findings
The LUTSAM travel demand portion was run for each of the two scenarios noted above. Standard travel demand model outputs were obtained for each scenario, with analysis focused on comparison of results. Results included finding the smart growth concept outperformed the traditional growth form in several key areas considered to be fundamental elements of complete streets policies. For example, the higher level of pedestrian accessibility in the smart growth form resulted in an increase of over 10% higher pedestrian trips inside and outside the hypothetical subdivision. The higher level of bike connectivity resulted in a 5% increase in bike mode share. These higher non-auto mode usages in addition to the more compact development form resulted in 20% less vehicle-miles-traveled (VMT) per unit in the smart growth concept. The resulting decrease in VMT per dwelling unit had a corresponding decrease of 12% in mobile source ozone precursor emissions per unit.

How LUTSAM Supported Analysis
The LUTSAM process provided an efficient method in which to accurately and successfully represent two distinct residential land development forms in a detailed, tax-parcel based travel demand modeling platform. Model development and network coding times were substantially reduced as the GIS graphical user interface saved about 70% of the time needed otherwise for manually coding the same two dwelling unit density and form scenarios. Travel model results were significantly more detailed than typical TAZ-based models allowing examination of travel patterns for individual dwelling units in each of the two scenarios.
such as average trip length frequencies, trip frequencies by length quartiles, and mode share comparisons.

APPLICATION #2: COMMUNITY DESIGN CHARETTE, LAND USE AND TRANSPORTATION POLICY ALTERNATIVES ASSESSMENT

Description
A memorandum of agreement (MOA) was signed in July, 2012 among representatives of a municipality, county land use planners, MPO planning staffs, state planning officials, and Delaware DOT planning staff. The goal of the MOA was to collectively participate in a two-month long planning process culminating in a week-long design charrette to be attended by several hundred people who live and work in the municipality. A stated goal of the group was to transform the major north-south corridor through the town into a more pedestrian and bike-friendly environment with a distinctly improved sense of place.

In the weeks leading up to the charrette, identification of potential major development sites and key vulnerable parcels within the town’s main north-south corridor occurred, and included a consultant’s economic impact assessment and land use viability analysis for each of those key parcels. During this time a LUTSAM model application was developed to provide technical support to this community design charrette process.

A key parcel location was identified for a pilot study comparing traditional development form against one including elements of Smart Growth principles, especially those relating to land use mix and pedestrian connectivity (Fig. 3). The location was about one mile north of the existing town center, adjacent to a major north-south corridor. The results of this pilot study would be used to inform charrette participants and municipal land use decision-makers.

FIGURE 3 Relative Location of LUTSAM Pilot Study Parcel to Downtown Area in Base Travel Demand Model Network.
The LUTSAM base model was used to generate a scenario network for a hypothetical land development project using a traditional residential subdivision form. The traditional form had about 40% of the residential units on cul-de-sacs, limited bike/pedestrian connectivity, and only one vehicular access point. About 80% of the hypothetical subdivision’s 800 units had a net density of 4 units per acre; about 20% of the development had a net density of six units per acre. The hypothetical development also contained about 200,000 square feet of retail and light office uses. A vehicular connection was provided between the commercial component and the dwellings; bike and pedestrian facilities were not provided on this connection but were not precluded.

A second scenario (Fig. 4) was developed using Smart Growth principles. Compared to the traditional form, about 10% of the 1600 dwelling units were on cul-de-sacs, all units had bike/pedestrian connectivity, and there were three vehicular access points (two to the external street system and one to an adjacent land use). The overall net density was also higher than the traditional form, with about 20% of the units at four units per acre, 60% of the units at eight units per acre, and about 20% of the units at 12 units per acre. The vehicular connection between the commercial component and the dwellings was enhanced to include sidewalks.

Results and Findings

The LUTSAM travel demand model was run for each scenario in the pilot study described above. Standard travel demand model outputs were obtained for each scenario, with analysis focused on comparison of results between development types.

Results indicated the smart growth concept performed better than the traditional growth form in several key measures of effectiveness. For example, the more compact and higher density form resulted in 11% less vehicle miles traveled per dwelling unit. The additional bike and pedestrian interconnectivity between the commercial component and the dwellings resulted in an increase from 45 to 341 pedestrian trips traveling between the hypothetical homes and stores. That mode shift had a corresponding 10% decrease in auto trips traveling between the hypothetical homes and stores which also resulted in a 3% decrease in auto trips on adjacent minor arterials going past the residential units and commercial areas.

These higher non-auto mode usages in addition to the more compact development form resulted in 21% less vehicle-miles-traveled (VMT) per unit in the smart growth concept. The decrease in VMT per dwelling unit had a corresponding decrease of 11% in mobile source ozone precursor emissions.

How LUTSAM Supported Analysis

The LUTSAM process provided an analytical method in which land use form, density, and multimodal interconnectivity could be effectively examined using a real-world pilot study. This application demonstrated the tool could be successfully applied within the meeting schedule and project deadlines of a community planning process, culminating in a week-long series of public charette workshops.

LUTSAM was able to quantify travel benefits associated with best practice land use policies (smart growth) including mixed-use development, bicycle, pedestrian, and transit amenities.

LUTSAM provided a data driven methodology that assisted a municipal land use agency regarding the potential transportation impacts of proposed comprehensive plan overlay (for the north-south corridor); it could be similarly applied to review zoning codes and site plans.
The 3-D simulation provided a valuable tool to help educate stakeholders through visualization of two distinct land use forms. Member of the public participating in this municipal planning process were able to understand the roles, value, and impacts of smart growth transportation planning elements.

APPLICATION #3: REGIONAL ACTIVITY CENTER A - EVALUATION OF SUB-ARTERIAL ROAD SYSTEM TO SUPPORT LAND DEVELOPMENT

Description

In the spring of 2013 a series of land development proposals arose for an existing major activity center in northern Delaware currently housing over 1.5 million square feet of retail space and about 750,000 square feet of office space. About 10 separate proposals were identified totaling another 1 million square feet of space each, for both retail and office uses. Additional hotel and support services were also proposed for this activity center. Some of these land development concepts concurrently presented local and collector roadway improvements. Approximately 12 separate roadway connections were identified based on various sources.
The need arose for a planning level assessment of cumulative system impacts of the proposed developments, separate from the individual traffic impact studies underway now or in the future. The goal of this technical effort was to understand the level of traffic demand to and from proposed land developments, to review how the roadway connections would function as a group, to estimate the extent to which each connection served general traffic and site traffic components, and to develop some understanding of the role each connection provided for project prioritization. Figure 7 illustrates the location of the development proposals as grey circles, and the general location of proposed local roadway connections as grey lines.

To support internal agency decision-making, a LUTSAM model application was developed to provide technical support to this process; approximately 5,500 tax parcel TAZs were added to the regional model using the LUTSAM user interface. About 25 sub-tax-parcel TAZs were then added manually to this base network model to better represent the 35,000 parking lot spaces and internal parking lot circulation patterns.

A travel model scenario was created representing each proposed land use and its corresponding local and collector roadway improvements. This process allowed each of the land uses and roadways to be analyzed separately, with unique trip generation and travel patterns appropriate for the specific retail and/or office land uses. Several additional scenarios were developed including various combinations of land uses and roadways, representing a range of land development build-out potentials. This allowed assessment of trips generated according to both site trip impact as well as indications of when each development was likely to occur.
Results and Findings
The LUTSAM travel demand portion was run for each combination of proposed land
developments and local roadway connections. Standard travel demand model outputs were
obtained for each scenario, with analysis focused on comparison of results across the range of
individual scenarios, with additional comparisons against existing, future year no-build, and
future year full-build scenarios.

Each land development scenario had at least one tax-parcel TAZ representing the specific
land uses proposed for those developments. This detailed structure allowed analysis of very
detailed access point alternatives including driveway and parking lot locations.

Through this assessment two specific roadway connections were identified as being
significant contributors to site trip carrying capacity as well as providing enhanced regional
interconnectivity. Additional analysis of these two options focused on estimating the portion of
traffic on existing roadways that would shift to each of these new routes. An innovative
assignment and path building extraction technique was used to identify the origin-destination
patterns using the new roads, and then estimate the portion of that projected demand that would
use existing routes, assuming, the proposed route is not built. This process allowed estimation
and assessment of shifted and induced traffic that would use potential new connections.

How LUTSAM Supported Analysis
The LUTSAM process provided an analytical method in which land use locations, parking lots,
parking access points, and detailed assessment of site-oriented origin and destinations patterns
could be effectively examined. This application demonstrated the tool could be successfully
applied to look at a range of travel impacts associated with about ten proposed land uses and
twelve proposed or potential roadway connections. Further, the method provided insights to
analysts and decision-makers as to relative levels of travel impacts and benefits for various
combinations of land use and roadway network proposals.

In this application LUTSAM provided a data driven methodology that assisted review
and prioritization of group of land use proposals. It developed information that assisted scoping
traffic impact studies. Through setting up and running the travel model at this detailed level, it
was possible to estimate site trips, regional through trips, and induced trips related to each of the
proposed roadway connections. This data, in turn, assisted evaluation of project prioritization,
project funding sources, and cost sharing processes.

APPLICATION #4: REGIONAL ACTIVITY CENTER B - EVALUATION OF SUB-
ARTERIAL ROAD SYSTEM AND ACCESS POINT LOCATIONS TO SUPPORT
TRANSPORTATION INVESTMENT FUNDING SOURCE REVIEW

Description
In the summer of 2013 several land development proposals arose for an existing major activity
center in central Delaware currently housing over 800,000 square feet of retail space and about
300,000 square feet of office space. About five separate proposals were identified totaling
another 500,000 square feet of retail space. Additional hotel and support services were also
proposed for this activity center. Some of these land development concepts concurrently
presented local and collector roadway improvements which were identified previously in a
comprehensive transportation study completed in 2007.
The need arose for a planning level assessment of cumulative system impacts of the proposed developments plus the need for additional information for three of the roadway connections.

FIGURE 6 Location of Potential Local Road/Access Road Connections.

The three potential roadway connections (Fig. 6) were identified to provide system benefits supporting both additional land development (primarily expansion of existing retail and office developments) as well as facilitating improved region-wide travel.

The goal of the assessment was to understand the level of traffic demand to and from proposed land developments and to update the 2007 study by reviewing how the roadway connections function individually and as a group. Another goal was to extend the 2007 study analysis by assessing the level of site trip impact based on benefits of the number of jobs created, considering the role of an economic development program as a funding source.

To support internal agency decision-making, a LUTSAM model application was developed to provide technical support to this process. Approximately 1,100 tax parcel TAZs were added to the regional model using the LUTSAM user interface. About 15 sub-tax-parcel TAZs were then added manually to this base network model to better represent the 15,000 parking lot spaces and internal parking lot circulation patterns.

A travel model scenario was then created representing each of the three proposed local and collector roadway improvements. This process allowed each roadway to be analyzed separately, with unique traffic characteristics depending upon the trip generation and travel patterns derived from specific retail and/or office land use sizes. An additional scenario was developed including all of the three proposed connections, representing full build-out potential of the study area according to current zoning.
Results and Findings

The travel demand portion of LUTSAM was run for each roadway connection scenario. Travel demand model outputs were obtained for each, with analysis focused on comparison of incremental differences across the range of individual scenarios, and with additional comparisons against existing, future year no-build, and future year full-build scenarios.

Each land development scenario had at least one tax-parcel TAZ representing the specific land uses proposed for those developments. This detailed structure allowed analysis of very detailed access point alternatives including driveway and parking lot locations.

Through this application, review of traffic data indicated two of the three roadway connections had greater potential for significantly supporting site trip carrying capacity as well as enhancing arterial and collector road interconnectivity in the study area. Tax-parcel travel model results were presented using Google Earth (Fig. 12). Additional analysis of these two options focused on estimating the portion of site traffic on existing access route roadways that would shift to each of these new access points.

FIGURE 7 Example of LUTSAM Results, Showing Select Link Output for Site Trip Origin and Destination Patterns in Google Earth.

How LUTSAM Supported Analysis

The LUTSAM process provided an analytical method in which expansions of existing retail and office uses, associated parking lots, existing and proposed parking access points, and detailed assessment of site-oriented origin and destination patterns could be effectively examined. This application demonstrated the tool could be successfully applied to look at a range of travel impacts associated with proposed land uses and proposed or potential roadway connections. Further, the method provided a significant increase in output data upon which a previous analysis
done in 2007 could be not only updated, but improved based on the newer method LUTSAM provides.

In this application LUTSAM provided a data driven methodology that supported review and prioritization of three local roadway connection proposals. It developed information that will be used in the future for scoping traffic impact studies. Through setting up and running the travel model at this detailed level, it was proven again that it was possible to estimate site trips, regional through trips, and induced trips related to each of the proposed roadway connections through the LUTSAM user interface process. Results and output data directed evaluation of the three connections, their prioritization, and potential project funding sources including economic development sources.

APPLICATION #5: COMPLETE STREETS: A METHODOLOGY FOR DETERMINING THE TRADE-OFFS ASSOCIATED WITH STREET DESIGN WITH RESPECT TO DELAY AND EMISSIONS WITHIN THE TRANSPORTATION NETWORK

Description
In analytical support of a doctoral dissertation (5), the LUTSAM tax-parcel based model was used to examine impacts on delay and emissions of providing varying levels of accommodations for cyclists and pedestrians as part of a complete streets program in a typical, small community (population 6,000) in Delaware.

Two sets of scenarios were developed as part of this research. One set of scenarios was based on a connected network of complete streets that connected residential areas with a number of points of interest: downtown, schools, shopping areas, religious institutions, hospitals, parks, and large employers. The other set of scenarios developed a complete streets network where any street that could accommodate bikes and pedestrians was included.

While impacts on vehicle delay are difficult to quantify, a 2030 transportation study by Douglas County, CO (6) presented a set of friction factors that could be used to estimate impacts on capacity. Before any modifications were introduced, a base case was run using the tax parcel model. Using this concept, several cases were run. The first case used the smaller network of complete streets described earlier and introduced a 10% reduction in capacity, representing the side friction introduced by cars moving with cyclists in the traffic stream or in bike lanes immediately adjacent to the traffic stream.

The next case used the same network of complete streets, the 10% reductions in capacity along road sections and added a 20% reduction along approaches to intersections to account for delays to drivers caused by accommodating pedestrians with crosswalks at all intersections and modified signal timings at signalized intersections.

The third case used the larger complete streets network and repeated the capacity reductions of the second case; 10% along roadways and 20% at intersections. The final case assumed that predictions of usage and impact were significantly low due to driver behavior, popularity of the new bike lanes, etc., so a capacity reduction of 30% along road sections was used with 20% at intersections.

Results and Findings
The LUTSAM travel demand portion was run for each of the four network-oriented scenarios noted above, plus a base scenario with no changes. Travel demand model outputs were obtained for each scenario, with analysis focused on comparison of results.
The changes were considered to be insignificant based on detailed review of cumulative results for the town as a whole and for specific corridors of between one and four miles long. Along one of the major east-west roads (Glenwood Avenue), the worst case scenario only generated a twelve second change in travel time, from 426 to 438 seconds along the 3.55 miles of this road or a change of .8 mph. Again for the worst case in the downtown area, (Commerce Street) showed a nine second increase in delay along its 3.08 miles (.6 mph change).

Nearly all of the 14,000 road sections, for which these delay analyses were conducted, had AM peak volume to capacity ratios of .2 or less. This low starting volume explains why so little delay was induced in the network by complete streets.

How LUTSAM Supported Analysis

Three regional TAZ’s were expanded to over 5,500 tax-parcel TAZ’s through the LUTSAM process. Most of the trips that were the focus of this research originate and end within the town and simply would not be part of the analysis if simulations were done at the regional TAZ level. The detail of the tax parcel model allowed the research to focus on short vehicle trips within the entire community (to/from each dwelling), as well as all of the longer trips that originate or end in the community.

The findings suggest that, in areas where the road network is not currently over-taxed, there should be no significant impact on the network for a wide range of complete streets impacts. The methodology used in the research could be used for communities of any size.

CONCLUSIONS AND RECOMMENDATIONS

LUTSAM greatly facilitates evaluation of a wider range of land use and transportation scenarios than those that can typically be evaluated using traditional travel demand models.

The goal of LUTSAM is to easily generate data-driven, quantifiable results that are easily understood by the public citizen and agency staff. The ultimate goal of the process is to produce MOEs toward better decision-making, as well as improved understanding of the relationships between proposed land uses, their forms, and transportation alternatives.

In theory, the steps included in the LUTSAM process could be done manually, with a relatively long series of user-directed imports and exports to transfer data among the various software programs. However, with the LUTSAM process, analyst time needed for scenario development and evaluation is greatly reduced (possibly from well over a month to less than a week) and the overall process is standardized.

Results from the case studies demonstrate that LUTSAM is sensitive enough to model and quantify local and collector road connections, parking lot driveways and access point locations, and bicycle and pedestrian system enhancements. These types of projects are increasingly relevant to transportation planners and engineers, and in some agencies increasingly comprise a greater portion of overall construction funds. LUTSAM provides a technical process supporting analysis, evaluation, and prioritization of these types of projects.

The next steps in developing LUTSAM include continuing to collect additional multimodal travel data, especially focused on bike and pedestrian trips and travel patterns, using the Delaware Travel Monitoring System (DTMS) and conducting additional multimodal surveys in order to further improve bicycle and pedestrian mode choice modeling. Analysis is already underway using GIS to estimate tax-parcel based accessibilities for auto, transit, bike, and pedestrian modes. Further, that analysis will correlate those GIS-based access levels (primarily based on route path building) with address-matched (and therefore, tax-parcel based) DTMS...
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travel survey results allowing projections and forecasts in the near future to include those elements in appropriate steps in the travel model and microsimulation processes.
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