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Greater Yellowstone Rural ITS Project

Work Order II-2E: GIS Teton County

Land Use and Transportation Infrastructure Models for Application in Rural Settings:

Literature Review

Prepared For:

MONTANA DEPARTMENT OF TRANSPORTATION

and

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

In Cooperation with

IDAHO TRANSPORTATION DEPARTMENT,

WYOMING DEPARTMENT OF TRANSPORTATION,

and

U.S. DEPARTMENT OF INTERIOR, YELLOWSTONE NATIONAL PARK

Prepared by

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Bozeman, Montana

May 2003

Implementation Statement

This study is sponsored by the Montana Department of Transportation in cooperation with the U.S. Department of Transportation, Federal Highway Administration, the Wyoming Department of Transportation, the Idaho Transportation Department, and the Yellowstone National Park. The major objective of this document is to summarize the Literature Review of GYRITS Work Order II-2E, GIS Teton County.

Disclaimer

Acknowledgements

Grateful appreciation is extended to the U.S. Department of Transportation, Federal Highway Administration; Montana Department of Transportation; Idaho Transportation Department; Wyoming Department of Transportation; Yellowstone National Park, other partner agencies and the Greater Yellowstone Rural ITS Project Steering Committee members. Special thanks to those individuals who assisted with the development of this report including but not limited to the Primary Authors; Jerry Johnson, Department of Political Science and Brant Spangler, Undergraduate Research Assistant.

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Introduction

This literature review is intended to introduce the reader to modeling literature that seeks to integrate the complex interaction between land use change and changes to the local transportation infrastructure in rural settings. The term interaction is important because the direction of causality is uncertain based on the current research. Indeed, the U.S. General Accounting Office found many factors associated with the growth of low-density housing but direct causality could not be established because of the multiplicity of causes and spatial complexity of the issue (GAO 2000). Richards and Fischer (2001) have written about the history of highway improvements and population growth in Montana from a sociological and geographical perspective and we refer the reader to their publication for in-depth information on rural population trends since the 1960's and the role transportation can play in population migration and local economies.

While there is widespread agreement that a quality road infrastructure can enhance the value of adjacent land for development and that development is advanced through the provision of roads, the question of whether homes follow road improvements or do road improvements follow homes is largely unanswered in the current literature (Milller and Hoel 2000). This is primarily a question of interpretation of modeling. Consequently, the emphasis in this review is on land use change modeling and transportation models that integrate land use change into respective outputs.

There are several interconnected reasons why rural sprawl - a pattern of rural residential settlement characterized principally by low densities and scattered development – and transportation infrastructure is one of the most pressing concerns facing the rural countryside. The central concerns for the purposes of this review are to understand the connections between the influence of rural travel patterns and land use change in the rural countryside. The general outline of this review is to provide background on the issue of sprawl and its causes and consequences, modeling for land use change and modeling transportation infrastructure development. Impacts resulting from sprawl include a range of social and economic costs to rural resident populations as well as the loss of open landscapes and farmland; and ecological disturbance of sensitive lands.

The costs of sprawl have been debated largely in a theoretical sense and in some cases have been supported with factual evidence. However, the phenomena, especially as it relates to transportation has not been systematically investigated and tested for rural areas. As a result, much of the work cited below is theoretical in nature; first because most applied work is in the form of specific case study and application to a larger context is problematic. Second, most of the work is conducted using idealized models of land use change and changes in transportation. Partially as a result of these constraints, the focus of most of the literature cited is on direct impacts resulting from the interaction between land use and transportation. In addition, most transportation literature is focused on impacts typical of urban settings. This is understandable considering the much greater scale of issues in cities and interstate highway systems and the duration over which these issues have been in the forefront compared to recent rural growth issues. Given the size of the constantly emerging literature on sprawl in general and transportation modeling this review reflects two distinct biases: 1) it is focused on literature and issues related to the Rocky Mountain West and, 2) it is biased toward applications to rural areas.

Issues related to sprawl may be substantially different in the rural Rocky Mountains than in close proximity to urban centers. In the West, in general, there is less market demand for clustering of homes, we do not have the intense planning effort aimed at mitigating the effects of large numbers of people commuting into large cities, and we have a less well developed political will toward planning. As evidenced in the literature, impacts of growth that are important to focus on are the effects of growth on small communities and ecological effects to rural private and public lands.

Urban transportation planning, on the other hand, enjoys a rich and sophisticated literature, professional training infrastructure, and history. Unfortunately, much of the quality work conducted for urban centers is less applicable in micropolitan and rural areas. The focus of this review is on literature and tools that appears to be the most efficacious to a rural setting and the constraints faced by rural local governments and the political culture in which they operate. The primary model described is easily available, user friendly, relatively inexpensive to use, relatively transparent in terms of data and assumptions, and can integrate high levels of community participation.

The format of the review is to:

a) provide background on recent population growth in the Rocky Mountain West,
b) discuss topics of concern stemming from the impacts of population growth and transportation in high growth rural areas,
c) review the major relevant models of land use change and transportation with special emphasis on two emergent softwares that seem particularly applicable to rural settings: Land Use/Land Cover Change Prediction System and Community Viz, and
d) provide some topics of further research and directions for modeling land use and transportation in a rural settings.

Background – Population Growth in the Rocky Mountain West

Rural areas in the American West are in the midst of a period of population growth unlike any in the past. According to the recent 2000 census, the West was the fastest growing region of the U.S. over the past decade (U.S. Census 2000). While the national average population growth was 13.2%, the western region of the country grew at an average of 19.7%. During that period the population of the region grew by over 10 million and 67% of the counties in the Rocky Mountain[1] axis grew at rates faster than the national average (Beyers and Nelson 2000). Most of the growth is still in close proximity to the major urban areas of the region – Denver, Salt Lake, and Phoenix. However, significant increases in population have also taken place in mid-size cities and towns such as Boise and Coeur D' Alene, ID., Bozeman and Missoula, MT., Durango and Telluride, CO, and Jackson, WY. – so-called micropolitan centers (Vias, Mulligan and Molin 2002). But, it is the concurrent growth taking place in the small adjacent satellite communities and outlying rural areas that are the focus of this review as the unprecedented rate and nature of recent population growth in the rural countryside makes it of some concern to those interested in the maintenance of undeveloped open space and productive agricultural land, and thriving rural communities (Lassila 1999).

What is attracting these people and businesses to the region? Two views prevail (Decker and Crompton 1993). The first is the quality of life argument that states that rural location is a function of a mix of amenities acting as pull factors (see especially Bowers 1999). Examples include a move to a small town in part because of the scenic beauty of the area, low crime rate, a desirable climate, recreation opportunity, or to be close to family and friends. The demand model asserts that in-migration is a function of wages and employment - jobs first; then migration. The reasons for much of this recent growth are multifaceted and are associated with increased tourism and recreation in amenity rich rural areas and rural economies shifting from extractive economic bases to growth in the non-labor sector and service sectors of the national economy (Johnson, Maxwell and Aspinall 2003).

[1] The Rocky Mountain states include: Idaho, Montana, Wyoming, Utah, Colorado, New Mexico, and Arizona.

In fact, both models have explanatory power and both are probably simultaneously acting to change the social character of the Western states. What is clear is that the geographical features that provided natural resources in the past now act as powerful attractants to those who would live near mountains, rivers, forests, and protected public lands (Johnson, Maxwell and Aspinall 2003; Johnson and Rasker 1995; Williams, White, and Johnson 1981; Power 1996; Riebsame, Gosnell, and Theobald 1996).

Figure 1: Development of the Western Landscape
Homes are slowly moving across western landscapes. To view an animation of population growth in the Western States click here: http://www.centerwest.org/futures/development/ The site is the Western Futures Project created by David Theobald at the Natural Resource Ecology Laboratory in Fort Collins**.**

Issues Related To Sprawl, Land Use Change and Transportation

The effects of rapid in-migration to the recreation and retirement communities of the Rocky Mountains fall into two categories: social impacts and ecological impacts. The notion of rural western communities is of a close-knit social and economic structure where employment, social, and consumer functions are carried out in a self-sufficient socioeconomic system. In the Rocky Mountain West however, rural land adjacent to small towns serves primarily as residential rather than social locations so the impacts of sprawl can often be uncoupled from the place of residence and impacts are not easily assimilated (Johansen and Fuguitt 1990). For example, many people live out of town or in "bedroom communities" adjacent to micropolitan areas. They tend to work, play, and spend money in town but sleep at their place of residence. Their presence in town may impart significant impacts in terms of traffic, the flow of labor and money, demands on public infrastructure (park, trails, health care) and their home out of town may consume previously productive agriculture or impact the local viewshed. Unfortunately, the connections between these sets of impacts are poorly understood and difficult to document.

Similarly, development pressure may result in significant impacts to the ecological quality of the area but residents can be unaware of their impacts on the land. Topics of concern stemming from the impacts of population growth and transportation in rural areas include:

Impact on Rural Travel Patterns.

According to Elizabeth Humstone, the Director of the Vermont Forum on Sprawl in: The Land Use Transportation Connection, she states:

> It is critical to keep in mind the close connection between land use and transportation. Highways provide access to land, which enables the development of that land. Land uses generate vehicle, pedestrian, bicycle, and transit trips. In order to manage traffic along a highway, both land use and transportation strategies are necessary.

Accordingly, over the past decade there has been growing interest in integrating transportation and land use planning, based on a recognition that land use not only influences transportation outcomes, but that transportation investments also influence land use decisions (Waddell 2001).

This recognition is taking place at two scales – macro and micro. Modeling at the macro level takes into account the: (1) continued economic well being of rural communities, (2) preservation of state agricultural economy, (3) protection of important, environmentally sensitive areas of a region, and (4) reduction of capital expenditures on transportation infrastructure (Cambridge Systematics). At the micro level transportation and land use are integrated along four sets of household choices with respect to where people chose to live: residential location, job location, vehicle ownership, and daily activity and travel patterns (Waddell 2001). Without an , integrated analysis of all components of land use and transportation behavior, researchers may well overlook key system responses and/or over/under-estimate system responses to transportation investments for neighborhoods and individual decision makers and the impacts those personal decisions will have on the community. Unfortunately, little work is conducted in rural areas.

Socioeconomic Impacts Of Sprawl.

Even as the reasons for rural sprawl are understood to be complex, increased mobility through automobile usage and the infrastructure that facilitates it is clearly a contributing factor to the "livability" of rural settings (Dunn 1998) and the economic vitality many of them currently enjoy. Roads and highways can make rural living possible by shortening travel time to work thereby enabling more people to live in the small towns that typically surround larger micropolitan centers. Likewise, small towns themselves become desirable destinations for those who can make a living in a rural setting. Airports, another form of transportation infrastructure investment, may be key location factors for many growing rural communities(Rasker and Hansen 2000). Many simply find undeveloped rural land to be a desirable amenity that is part of the setting for the many small towns that dot the Western landscape (Swanson 1984; Williams and Jobes 1990). Many argue that the intact rural setting can be a significant economic asset to a community (Williams and Jobes 1990; Decker and Crompton 1993; Rasker and Hanson 2000; Power 1995; Power 1996; Johnson and Rasker 1995). However, while improved transportation connectivity makes living and working in rural areas easier the economic aspects cannot be ignored:

> In the last decade, we continue to see the erosion of rural economies despite many transportation infrastructure upgrades to state highway facilities. At the same

> time, these areas are impacted by the sustained urbanization of our metropolitan areas, which push outward and place enormous pressure on rural communities and land resources. (Espinosa 2001)

The ability then to simulate land use and travel behavior and relate this to economic impacts is important for better growth management and more efficient and cost-effective use of the transportation system (Oregon DOT 2001).

Several socioeconomic costs are typically cited in the current literature. A major economic effect of rapid land use conversion is the inflationary pressure on homes and cost of living for locals. Communities that are good places to live, work, and raise a family are increasingly unaffordable for many would-be residents working local blue collar jobs. In many communities in the Rocky Mountain region the cost of a home is well over the national average (Doyle 2002). The high cost of housing is disturbing given that some of the Rocky Mountain States rank among the highest in the nation whose populations work multiple jobs and whose pay are among the lowest in the nation (Bureau of the Census 2000).

Adjacent to the highest priced communities are service communities requiring long commutes for little pay and high housing costs. Across the West, most measures of economic well-being are on the decline as fewer workers are able to save for a home or people qualify for welfare payments (Local Government Center). For many service economy regions there is tremendous pressure to provide larger roadways to facilitate the commuter traffic and thereby unintentionally encourage sprawl even further away from the economic center (Hartman 2002).

A second important impact of rural land use conversion is the recognition of the cost of public services to area taxpayers. Very simply, the concept is that rural residential development is consistently found to not pay the full cost of development (Haggerty 1996) and that existing residents, in effect, subsidize the development of open space and agricultural lands. Some of these costs include public safety provision, increased school enrollments, public infrastructure, the road network and maintenance, and the degradation of quality of life that results from unrestricted and unplanned sprawl (Sierra Club).

Transportation, Sprawl, Downtown, and Noise.

Very simply, as quality roads help push development beyond the urban fringe, businesses and homes follow thereby spreading consumer travel patterns over a larger geographic area. This can lead to malls and shopping centers locating new operations away from the historic downtown business district and in the process, the social function of downtown erodes as a functional center for the community (Snepenger, et al. 1998). The community loses its sense of place and solidarity (Huang and Stewart 1996), and may help contribute to the high turnover of new residents as documented by Jobes (2000). On the other hand, shopping and entertainment possibilities are expanded for residents as are employment opportunities in the malls and emergent business districts.

Noise levels in high traffic areas, even in a rural setting, can be an unfortunate consequence of unplanned roadway development but it too can be complex. For example, based on surveys conducted in Bigfork, MT, a rapidly growing retirement and tourist town bisected by a major highway, it was found that compression bake noise from commercial trucks was very annoying to residents and their perceived quality of life but, “normal” traffic noise through town did not emerge as a significant issue (Johnson 2000). The effects of noise in urban areas is a rich area of study and is found to be not only a source of stress but linked to health related problems including psychological and physiological symptoms (Job 1993).

The Environmental Protection Agency (EPA) estimated that road traffic noise was the leading source of community noise (1974, 1981). Truck transportation is the major source on highways and in urban centers in addition to the motors and exhaust systems of autos, smaller trucks, buses, and motorcycles. This type of noise can be augmented by narrow streets and tall buildings, which produce a "canyon" in which traffic noise reverberates.

Impacts to Open Space and Farmland.

Of particular concern to many observers of rural growth in the Rocky Mountains is the impact on agricultural land. Based on coarse Geographic Information System (GIS) analysis the American Farmland Trust has determined that prime ranchland is at risk in all seven Rocky Mountain states and that Montana land is most at risk (http://www.farmland.org/rocky_mountain/strategic_ranchlands1.htm). They have conducted a similar study for the nation's farmland (http://www.farmland.org/farmingontheedge/index.htm). Agriculture is the dominant use of rural private lands in much of the West, with crops ranging from high value seed potatoes in eastern Idaho to sugar beets in northwest Wyoming and wheat across the high plains of Montana. Much of the cultivated acreage is devoted to livestock forage. Within the 20 counties, 57% of the private land is range, 20% is in crops, 7% is pasture, 6% is forested, and 10% is developed http://www.greateryellowstone.org/private_lands.html.

Growth pressures are affecting the one group of resident on the decline – the agricultural producer. Faced with falling agricultural prices and their childrens' inability or reluctance to remain in agriculture (Stauber, et al. 1995), owners of farms and ranches often sell the land to developers or farm and ranch brokers. In rapidly growing counties the potential wealth from selling to developers serves as a lucrative retirement. Many of the new buyers of rural land will not continue the agrarian tradition or will shift from intensive agricultural production to a less utilitarian form of land management such as "hobby ranching" or owning the land for its recreational potential. In many cases developers purchase agricultural land, subdivide it into small acreages and thereby permanently remove land from agricultural production.

As they help to define the character of the region, agricultural lands and associated open spaces are highly valued by those residents who are not involved in agriculture nor live in the countryside. At present, there is a direct conflict between efforts to maintain this character and the phenomenon of rural residential development. At once, the public is of two minds: wanting to preserve rural character, yet wanting to own rural land in small and agriculturally unproductive parcels.

Table 1 below summarizes the literature concerning the host of social and economic impacts that may be the result of rural land transformation.

Table 1: Social & Community Effects of Rural Land Use Change

Changes in landowner structure	Turner, M.G., D.N. Wear, and R.O. Flamm. 1996; Brown 1993
Changes To Community History & Culture	Williams and Jobes 1990; Jobes 1988; Rudzitis, Hintz and Watrous 1996; Beggs, Haines and Hurlbert 1996
Impact On Agriculture. Lands	Greene and Harlin. 1995; Heimlich and Vesterby 1991; Johnson and Maxwell 2001 Pauwels and Gulinck 2000.
Impact On Open Space/View	Gersh 1996
Uneven Cost Of Residential Service	Haggerty 1996; American Farmland Trust; http://www.smartgrowth.org/library/CoPGStARP.html
Changing Political/ Economic Structure	Alm and Witt 1997; Beyers, and Lindahl 1996
Quality Of Life Effects	Johnson and Rasker 1995; Jobes 1988; Decker and Crompton 1993

Adapted from: (Johnson, Maxwell and Aspinall 2003)

The Ecological Implications Of Sprawl.

Reibsame, et. al (1996), Johnson, Maxwell and Aspinall (2002), Maxwell, Johnson and Montagne (2000) and Hansen, *et al.* (2002) document the general geographical and ecological changes resulting from rural residential development in the American west. The conversion of native and agricultural lands to residential subdivisions or small ranches produces anxiety because such development will probably never revert back to undeveloped land (Riebsame *et al.*, 1996). The conversions are of concern to ecologists for a variety of reasons but most literature is focused on three areas:

1) Threats to habitat – loss of permanent habitat such as a wetland or riparian area, and fragmentation of large landscape features such as winter range for ungulates or shrublands for birds and small predators. Roads may exacerbate fragmentation if they impede the movement of migrations. These impacts, if sever, can result in loss of biodiversity for a region (Hansen and Rotella 2002).

2) Threats to geographic features – agricultural water supplies for irrigation may be compromised if aquifers are over utilized by rural homeowners, rural septic systems can pollute the quality of underground water, and homesites can be placed in geographically inappropriate locations (i.e. fault zones, poorly compacted soils).

3) Native species and ecosystem processes – one of the most common observations of critics of rural sprawl is that the land too often becomes a weed garden. Disturbances to agricultural lands can result in the uncontrolled spread of noxious weeds; sometimes to the detriment of native species. An emerging concern in wooded areas is disturbance of natural fire regimes necessary to forest health. While this research is in its infancy, the fear is that in order to protect homes in private forest lands, fuel loads will be allowed to build up and catastrophic wild fire will be the result. Additionally, scare public resources are spent to control fires for very few private landowners (http://www.fs.fed.us/land/wdfire7c.htm; http://www.fs.fed.us/foresthealth/fh_update/update96/issue2.html) . Table 2 below provides sources of more background reading:

Table 2: Ecological Effects of Rural Land Use Change	
Fragmented Habitat	Theobald 1998, Hansen, et al. 2001; Knight, et al. 2000
Threats To Biodiversity	Pimental, et. al 1992; Farrier 1995; White, et. al 1997; Forester and Machlis. 1996
Land Use Conversion	Riesame, Gosnell and Theobald 1996; Bean and Wilcove. 1997
Water Pollution & Sewage	Gersh 1996; LaGro 1997

Adapted from: (Johnson, Maxwell and Aspinall 2003)

Research Efforts to Model Land Use Change

Research efforts aimed at modeling social, economic, and ecological changes taking place on rural land is an active area of research whose overall objective is to assess and predict the rate, nature, and impact of land use change in rural areas at multiple scales (Johnson, Maxwell, and Aspinall 2003) Hansen, *et al.* (2002) (see also: http://lcluc.gsfc.nasa.gov/products/index.asp). Predicting land use change in areas with a mosaic of private ownership requires combination of a wide range of driving variables. Land capability can be determined by soil, climate and land cover variables that are often available in geo-referenced form (Berry *et al*., 1996; Turner *et al*., 1996). Other variables such as those related to social and economic drivers have not been well-represented in the literature (Wear and Flamm 1993) due in some part to the difficulty of data acquisition via electronic or remote sensed means and relatively fewer researcher in the area of study. However, various models have been designed to describe the host of driving variables responsible for land use change. The models fall into three primary categories: multiple regression models, those based on cellular automata theory, and agent based models (Theobald and Hobbs 1998; Hill and Aspinall 2000).

Multiple Regression Models.

Multiple regression is a procedure that analyzes the relationship between several independent variables (IV) and a dependent variable (DV). This form of analysis assumes development patterns (DV) respond to a relatively few locational factors (IV) such as proximity to towns and highways, and that the likelihood that development decreases with increasing distance from urban areas (Wear, Turner and Flamm 1996). This reflects traditional urban and rural development models that are based on the assumption of accessibility – usually through a well-developed transportation corridor (Chen 2000) and the importance of a few predictor variables (Turner *et al*., 1996). Multiple regression analysis has the benefit of being low cost in terms of time, data and resources but is limited by dependence on the most powerful drivers or predictors of change to the independent variable; variables that may not emerge in regression as statistically robust but may important predictors at a smaller scale will tend to fall out of the equation. As such, it use in larger spatial scales may tend to miss important subscale predictors.

Cellular Automata (CA) Models.

These models assume that future development patterns respond to local patterns of existing development, and the likelihood of development is higher in areas of higher neighboring change in the variable being measured. Further, these models assume that local processes can influence global patterns; that is, there can be a "ripple effect" through and beyond system boundaries. Briefly, cellular automata models can be thought of as a dynamic system where the state of one cell depends on the previous state of surrounding cells where the transition takes place according to a set of transition rules (White, Engelen and Uljee 2000). These rules are typically expressed in terms of probability functions. CA models benefit from computational efficiency because the "cell neighborhood" can be limited to only adjacent cells to conduct the transition analysis but can also be expanded to include cells across the probability space if needed. Further, the set of transition rules can be very broad to include "weak" drivers that may be present in only one location of the probability space and permit fine spatial detail (i.e. the influence of a single road). Finally, because the analysis is spatial in nature, findings are easily compatible with GIS applications and are typically written as program extensions.

The CA method assumes that future land use patterns are driven by local patterns of land use change and that local changes strongly influence nearby change. This method differs from a regression approach in several ways. First, the model makes the prediction of future land use change based on the probability of change from surrounding cells. Second, whereas regression approaches tend to drop variables that do not contribute significantly to prediction on a large portion of the map, a probability approach allows a full compliment of the independent driving variables to reflect the potential land use change (Berry et al. 1996). Finally, regression approaches tend to model change based on proximity to geographical features (roads, water) and predict a gradient of change that decreased with distance from these features (Theobald 1998). Thus, the likelihood of development decreases with increasing distance from urban areas. Yet, observation of rural growth suggests that accessibility is perhaps not the driving factor of homes in the rural countryside. Rather, future development patterns are more likely a function of the near or distant views available to potential homeowners, characteristics of the community, or geographical isolation from others (Maxwell, Johnson and Montagne 2000). With respect to transportation, people do not necessarily follow roads (the regression approach) but roads will invariably follow where people live (rules based approach).

The forecasted patterns produced by these two models were compared (Theobald and Hobbs 1998) against historical observed development patterns using both a spatial (aggregate) and spatial measures. Overall, the cellular autonoma model outperformed the regression models with respect to observed land use patterns.

Agent based models.

An emergent model in the study of land use change, agent models are analogous to cellular automata models by assigning attributes that describe condition and characteristics of agents or actors in a system (Ferber 1999). Like CA models, agents exist in some “space”. In the context of land use change, that space may be an area of discrete geographical space or behavior constrained by an artificial environment as in the behavior of grazing herds with respect to simulated drought conditions. As in CA models, agent behavior is driven by transition rules. Any number of rules can be devised to govern the activities of agents: goals that agents seek to satisfy (e.g., minimizing travel distance between points, desire to live away from others). However, a unique attribute of agent models is that "preferences" that agents might regard as desirable can be defined (e.g., "likes" and "dislikes" for certain spaces, neighbors, or solutions) http://www.casa.ucl.ac.uk/geosimulation/abms.htm). These preferences can inform new and emergent relationships on the land. These models may be especially useful for understanding and modeling different groups of rural residents based on demographic typologies or psychographic motivates. In other words, if the rules are written specifically, agent based models allow researchers to treat people as discrete individuals rather than over generalized groups.

Case Study Models for Land Use Change

Large Scale Land Use Change Model

Aspinall (2002) utilizes existing spatial data to assess overall growth and to model large scale (i.e.multi county) land use change and residential development. The model is able to predict >90% of rural residential development in the GYE using two data layers: distance from roads and distance from major regional micropolitan centers as measured by travel time. The methodology relies on a Bayesian probability logic that is relatively simple to apply to a large regional setting. These inputs were also found to be important in a study of growth in 5 counties in the Appalachians between 1950 and 1990 (Wear, Turner and Flamm 1996). Such a simple but effective model demonstrates that a straightforward prediction and interpretation is possible with little investment in time and data. It also demonstrates that at the aggregate scale, transportation infrastructure is an important driver of regional development.

Small Scale Model: Land Use/Land Cover Change Prediction System (LUCCPS)

The Land Use/Land Cover Change Prediction System (LUCCPS) (Maxwell, Johnson, and Montagne 2000) was designed as a cellular automata model that can also be utilized as an agent based model. The design criteria were to be able to assess and predict the rate, nature, and impact of land use change in rural areas and to use the best available technology to do so. A second objective was to develop modeling tools that meet the criteria of being user-friendly, relatively low cost, and applicable to rural communities. The third criteria was that it be designed to be compatible with existing GIS software thereby making multidisciplinary investigation and policy analysis feasible as well as high quality visualization possible. The model is based on the history of past land use change, natural features, man-made infrastructure, and land use decisions. Each layer of information is used as an independent driving variable to calculate the transition probabilities for landscapes in private ownership (For a complete description of the model and output examples see: (Maxwell, Johnson, and Montagne 2000). The LUCCPS model can also be used as an agent based model through manipulation of existing data layers. Likes and dislikes for certain types of spaces or infrastructure, neighborhood density, or various planning solutions such as clustering or open space preservation can be expressed as driving layers thereby allowing artificial conditions to be imposed on the model output.

Transportation Modeling and Land Use Change

The standard model used by urban planners and economists to represent household decision-making assumes that households will determine where they live based on a combination of the costs of commuting distance to work and the cost of land (Chen 2000). This suggests that both existing land use (i.e. developed vs. undeveloped) and existing transportation patterns strongly influence residential choice. Chen (2000) suggests that this underlying belief is the basis for most policy analysis on land use and transportation and that it is also empirically weak. He cites several studies in urban settings that refute the basic premise (See the following cited in Chen 2000: *Hamilton 1982; White 1988; Small and Song 1992; Giuliano and Small 1993; Song 1992*). Rather, he suggests, residential location choice is the result of an amalgamation of economic and noneconomic values. For example, rural areas enjoy lower crime rates and (some) require a lower cost of living.

It is likely that these noneconomic factors are even more important in rural settings and that travel distance and road quality has little to do with the choice of residence location (Johnson and Rasker 1995; Decker and Crompton 1993). In rural areas where the automobile may be an even greater necessity for everyday life, rural residents must travel more frequently and substantially further to acquire the full range of goods and services desired by most households. A recent analysis of land use and transportation in and around Portland, Oregon, for example, found that households in low-density car-reliant suburbs make roughly 7.7 vehicle trips per day, substantially more trips than households in denser, transit oriented areas (Chen 2000). Yet, it is these suburbs that are the fastest growing locations adjacent to most metro and micropolitan areas. Traffic volumes and choices of mode of travel are influenced by the location, density and mixture of land uses. Low-density land uses encourage driving and require longer travel times (Humstone and Campoi 1998). As a result of these findings, models that can accurately depict the role and impact of transportation infrastructure on land use emerge as very useful planning tools.

This realization applies at two levels of analysis simultaneously: the local or household level and the macro or community level. At the local level the focus of transportation modeling is on neighborhoods and individual homeowners. Typical of these commonly used models would be to integrate trips per day, destination, and noise for a newly developed subdivision. The purpose of the traffic impact study (TIS) itself is to help solve a localized problem and deal with project-related traffic within a limited area. Usually, this is the street system immediately adjacent to the site. As the size of the development grows, so too does the area of analysis. The TIS must answer the question: "Does the traffic generated by the proposed development cause a decrease in service or safety?" If the answer is "yes," then the TIS should go on to assess how improvements can be made to mitigate the impact of the new traffic. These assessments are based on observation, surveys, experiments, and simulations. They are very well developed and understood by traffic planers.

Good traffic analysis depends upon good site design. The two are inseparable. The site planning and design process inherent in the TIS usually begins with decisions relative to the micro level household analysis (trips per day, shopping habits, school bus routes) and building(s) size and shape, and its placement on the site; the analysis is not qualitatively different for subdivisions or business developments, only the nature of the data collected will vary. Parking and on-site or neighborhood circulation are then designed around the project. Finally, the intersections of the access drives with the adjacent street are established, sometimes with little or no consideration being given to the impact on the street. This is particularly an emergent issue in rural subdivisions that must interface the traffic originating in a new residential development with main transportation corridors that are probably already near capacity.

When inadequate attention is given to the location and design of access, and feedback does not occur between site design and traffic engineering, the following problems may result:

- Inadequate access capacity – more trips per day than anticipated
- On-site congestion – unanticipated flow periods
- Congestion on the public street system – turn lanes or controls are inadequately planned
- High accident experience – due to the above
- Limited flexibility to adjust the design or operation to future changed conditions – either because of existing infrastructure or lack of political will

  (Cambridge Systematics)

Currently there are many models available to planners that take these points into consideration. The best are compilations of several modules that include traffic impact studies, economic and demographic feedbacks, and a land use change model. Few are relevant to rural settings however. All are aimed at reducing traffic congestion and sprawl while encouraging preservation of open space and undeveloped land. One problem with a review of these products, as opposed to most land use change models, is that they tend to be proprietary and offer little in the way of information for comparative purposes. As such, little to no scientific peer-reviewed literature exists for these planning tools; much of the information is derived from conference papers, reports and web pages. On the other hand, the profit motive is driving the modeling sophistication faster than the land use change models. The three models described below do not in any way represent an exhaustive list of all those available to planners, rather, they represent an evolution of modeling approaches. Typical of these models are TELUS, UrbanSim, and Community Viz. All three share similar attributes and appear to be similar in methodology using a cellular automata and/or agent based approach. They differ in the quality of output and ease of use for disparate applications in rural settings.

TELUS (Transportation, Economic, and Land-Use System).

TELUS (http://www.transportation.njit.edu/TELUS/overview.html delineates transportation projects into four categories: (1) road capacity, (2) road accessibility, (3) transit capacity, and (4) transit accessibility. TELUS is predicated on the assumption of a strong and positive correlation between transportation improvements and positive residential property values. The assumption is that transportation infrastructure should not detract from private property values.

The TELUS system has four major components. The Automated Transportation Improvement Program (TIP) component uses a large data base containing key information about key aspects of a transportation project (project number, description, location, cost, schedule, functional class, etc). The Economic Component is an “Input-Output” model that calculates the projected outcome (jobs created, income generated, and tax implications) of an investment on a single project (including Cost of Services data in the case of residential growth). The Land-Use Component uses a computer generated model that predicts the location of new residential and nonresidential development taking into account factors such as population, employment, and travel time. The fourth and final component is the Mapping Component. Using GIS analysis technology, TELUS is supplied with quick, accurate maps and data reflecting geographical content. This component allows for the strengthening of decision making in regards to transportation planning by providing a visual feedback to project outcomes.

TELUS is quite complicated and operates in a data rich environment. It is also quite expensive in terms of time and financial outlay. However, in return it offers a complete and comprehensive set of outputs that are useful for urban to suburban planning. It can readily be scaled up to encompass larger geographical districts. Based on review of the company's literature (it is a proprietary product) intensive planning is possible with TELUS outputs. One major component missing is a readily integrated public input part of the package. It is a program designed by planners for planners.

UrbanSim

UrbanSim (http://www.urbansim.org/). simulates the development of primarily urban areas at larger geographic scale. It seeks to integrate land use, transportation, and environmental impacts, over periods of twenty or more years (Noth, Borning, and Waddell 2001). Its purpose is to aid urban planners, residents, and elected officials in evaluating the long-term results of alternate plans, particularly as they relate to such issues as housing, business and economic development, sprawl, open space, traffic congestion, and resource consumption:

> The design of UrbanSim differs significantly from many of the existing operational modeling approaches by explicitly representing the demand for real estate at each individual location, and the actors and choice process that influence patterns of urban development and real estate prices . (Waddell 2000)

The input data used to construct the model database, called the data store, include parcel files from tax assessor's offices, business establishment files from the state unemployment insurance database or from commercial sources census data, GIS overlays representing environmental, political and planning boundaries, and a locational grid. A set of software tools, collectively referred to as the data integration tools, read these input files, diagnoses problems in them such as missing or miscoded data, and applies decision rules to synthesize missing or erroneous data and construct the model data store. (Waddell 2001). In fact, UrbanSim is several models in one. Components include an economic impact model, demographics, individual agent behavior model, and a developer model (i.e. market information driven).

In the UrbanSim model, transportation is assumed to interact strongly with land use. For example, automobile-oriented development may induce demand for more roads and parking (which in turn induces more automobile-oriented development), while compact urban environments may induce more walking and demand for transit. (Noth, Borning, and Waddell 2001). The model has the capability to run and compare scenarios based on differing assumptions or data inputs. These scenarios can be evaluated using feedback query.

UrbanSim is an example of a very effective modeling package that uses a comprehensive set of data available to the urban planner. It has been used successfully in the Eugene-Springfield Oregon area of Lane County, OR and demonstrates significant progress toward the development of models that inform land use and transportation decisions. The system works well for urban where market data and infrastructure outputs are known; output is GIS based and readily visualized. In rural settings some of the critical data to using UrbanSim is lacking due to outmoded data gathering or simply missing data. It lacks environmental components such as land use change, water demand feedbacks, and ecological monitoring capability but does have the capability of integrating a community input component.

Community Viz

The next generation of land use and transportation modeling is Community Viz (CV) (http://www.communityviz.com/). It is also a model that integrates several submodels to produce a comprehensive package of particular use for rural applications. The CV approach is to build the modeling capability around three "products": *Scenario Constructor* – the programmable framework for the modeling project in a spatial spreadsheet format, *Policy Simulator* – an agent based module that simulates future impacts as a result of community planning proposals providing economic, demographic and other stipulated outcomes, and

Sitebuilder 3D – a module that provides photo-realistic models of land use proposals; this module allows for virtual 3D "flythroughs" to visualize that land use and infrastructure changes.

Unique to CV is an explicit public input component. Using a concept called "active response GIS" (Faber 1997) the program allows citizens to design their own criteria and alternative to almost any proposed changes to city planning, land use change scenario or transportation policy – or all three at once. The proposals can be submitted to the program and then Scenario Constructor is used to examine the accounting output with respect to criteria specified in the project design. Several proposed alternative can be compared at any one time. Integrated into Scenario Constructor is a land use change model and account, a cost of service provision, and an ecological accounting model that provides feedback on, for example, water quality and quantity, soils, land cover, etc. Any of the assumptions for these components can be changed by members of the public at any time.

CV is particularly useful to rural settings at several levels. First, the program itself was designed as an application for rural planning. The program was funded as a nonprofit by the Orton Family Foundation whose mission, in part, is to preserve the rural community and way of life. Second, because it has rural communities as a priority, CV is organized to provide user support at relatively low cost. Finally, the program is designed with rural data needs and availability in mind.

The models presented here and others share several characteristics in common. First, virtually all quality transportation and land use models utilize GIS technology as either the operating platform or is integrated as a GIS add-in program. Most utilize GIS visualization capabilities but only a few are truly interactive in nature, that is; they are not easily manipulated through a public input process. Further, they all require trained personnel to interact with the model. All the models are very data intensive and as a result, cost of data acquisition must be a budget priority. All the models except Community Viz suffer the disadvantage that they appear to the public as a "black box" where assumptions and manipulations are invisible. Public trust in such models is lower as a result.

Conclusion

The integration of land use change and transportation modeling is making rapid and continued progress. As the marginal cost of computing power continues to decrease and modeling software is more sophisticated, the models are increasingly more accessible to planners and members of the public. Integrated planning specific to rural settings that meets the criteria of accuracy, relative ease of use, and has a public input component is limited however. One high quality product – Community Viz – is an example of where rural land use planning models will move if they are going to be politically and economically successful. CV is of particularly high quality and appears to be easily assimilated by non technical participants in the planning process. Other product will undoubtedly follow.

Rural based modeling possesses some unique characteristics not found in urban settings and these too will need to be addressed. Landscape planning by cities and counties in the rural west is a fragile process that is often plagued by lack of public and political support. Rural communities are not perceived to suffer from ineffective land resource allocation – they give the impression of ample land left for homes, roadways, and business expansion. However, agricultural lands, whether in active crop production or under conservation protection, play an increasingly important role as a viewshed feature in many high growth communities. Open land is, in effect, the present and future wealth of many rural communities and as such, is an asset that will require wise and effective management.

Further, there is a lack of funding for local governments to engage in comprehensive visualization as it relates to planning. While expertise resides within many micropolitan planning departments, there is a consistent lack of data, time, resources, and political will to engage in computer aided planning and modeling. In many cases local public services are simply trying to keep up with current demand for services and cannot move ahead with anticipated growth management issues beyond what the law requires. Because these structural problems exist within local governments, the integration of growth management policy and transportation planning will continue to lag behind urban centers.

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