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TO PREDICT LAND USE CHANGES IN GRAND BLANC
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VALIDATION OF THE LAND TRANSFORMATION MODEL (LTM) TO PREDICT LAND USE CHANGES IN GRAND BLANC TOWNSHIP, MICHIGAN

By

Matthew H. Malone

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ABSTRACT

VALIDATION OF THE LAND TRANSFORMATION MODEL (LTM)
TO PREDICT LAND USE CHANGES IN GRAND BLANC TOWNSHIP, MICHIGAN

By

Matthew H. Malone

The research examined the predicted patterns of urbanization in the Charter Township of Grand Blanc, Michigan using the Land Transformation Model (LTM). The LTM modeling engine utilizes an artificial neural network to predict urbanization trends through the input of land use data and "driving" variables shown to influence land use change. Land use data from 1978 and 2000 along with six driving variables were input to predict urbanization patterns for the year 2000 and future urbanization patterns at intervals ranging from five to one-hundred percent. These predicted urbanization patterns were compared with current land use data to evaluate the predictive accuracy of the LTM via comparisons of predicted versus actual areas transitioning to urban uses. Township officials were then interviewed to solicit their opinions and reactions regarding the accuracy of the predictions of 2000 urbanization and future urbanization patterns depicted at increasing percentages.

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1.1 URBAN SPRAWL IN SOUTHEAST MICHIGAN AND SMART GROWTH

Elected officials, planners and decision makers are constantly striving to make efficient and environmentally sound land use development decisions that positively affect their respective municipalities. The continuing spread of new suburban development continues across the United States and in Michigan as older central city cores deteriorate and decay. While city cores struggle to survive, conversion of farmland in the suburbs for other uses has increased dramatically. The Michigan Farm Bureau reports that more than 200 acres of farmland has been lost each day over the past fifteen years (The Detroit News, 1999). Additional research indicates that between 1990 and 2020 the amount of developed land in Michigan will increase from 63% to 87%, while the population will only increase by 11.8% (Rustem, 1997). The Michigan Land Resource Project (Public Sector Consultants, 2001) also indicates that between 1980 and 2040 the amount of built land in Michigan will increase by approximately 178% while an additional 17% of agricultural lands are lost

The term often used to describe this rapid rate of development is "urban sprawl", which is defined as the "rapid conversion and scattering of urban land uses away from a centralized urban core (Machemer et al., 1999)." The rapid rate of suburban development across southeast Lower Michigan makes land use decisions for local governments an increasingly important process. Many townships across this portion of the state are experiencing dramatic growth pressures as new residents and commuters in the metropolitan Detroit area populate subdivisions on the metropolitan fringe. The outward migration from the Detroit area to these fringe zones led to a population shift between

1995 and 1998 totaling 58,508 people, or 5.7% of the population of metro Detroit (The Detroit News, 1999). Southeast Lower Michigan's population is projected to increase through natural increase (births greater than deaths) by an additional 810,820 inhabitants between 1990 and 2030, when the population will reach an estimated 5.4 million residents (SEMCOG, 2001). The growth in population and migration in metro Detroit has been linked to multiple factors, including: available land, jobs within commuting distance; and increases in job growth in the suburban fringe (SEMCOG, 2001). If the population projections are correct, then approximately 251,000 acres of open land, equaling over 10 townships in size, will be converted to other uses (SEMCOG, 1995).

Growth in these rural townships extends northward from the Detroit metro area through northern Oakland County and southern Genesee County. One recent study revealed that Holly and Groveland Townships in northern Oakland County along the border with Genesee County, could experience an increase in population of 46% and 72% respectively by the year 2020 (SEMCOG, 1995). Neighboring Genesee County has also felt the impact of residential expansion. One recent land use study (Rusk, 1999) showed that Genesee County's population had increased from 198,000 people on 45 square miles of urbanized land in 1950, to 326,000 people on 164 square miles of urbanized land in 1990. The study also indicated that while Genesee County's population grew by 65% during the 1950-1990 period, the total urbanized land area had increased disproportionately by approximately 266%.

To deal with this rapid growth, elected officials and planners across the United State have utilized several tools to assist them in the planning process. These tools are often categorized under the umbrella term of "smart growth" techniques. As a basic definition, smart growth techniques are employed by municipalities to encourage efficient and environmentally sound development patterns within their municipal borders (Lee et al. 1998). Only a handful of these growth management programs are in place throughout the state of Michigan, which has allowed Michigan to rank 49th out of the 50 states in a survey measuring implementation and effectiveness of smart growth techniques (Sierra Club, 1999).

Smart growth techniques encompass numerous strategies to assist with growth management including: urban growth boundaries in Portland, Oregon and Contra Costa County, California (Staley et al. 1999); open space preservation through transfer of development rights initiatives in New Jersey (New Jersey Pinelands Commission, 2003), and purchase of development rights programs in Boulder, Colorado (County of Boulder, Colorado, 2003); regional planning in Grand Rapids, Michigan (Grand Valley Metropolitan Council, 2003) and Denver, Colorado (City of Denver, Colorado, 2000); as well as comprehensive programs and laws that are hybrids of several growth management techniques (Lee et al. 1998). Genesee County municipalities do not currently employ any of the aforementioned growth management techniques. However, two examples of urban growth boundaries are found in other regions of Michigan. The most notable cases are in the cities of Frankenmuth and Midland, Michigan (Michigan Department of Environmental Quality, 1999).

In the Frankenmuth, Michigan case, a local survey was conducted to gauge the community's interest in cooperative planning between the City of Frankenmuth and adjacent Frankenmuth Township. The survey results indicated that fifty-percent of the community residents wanted to see growth in the City restricted, and future development to take place outside of prime agricultural lands (Hamlin et al. 2000). The survey resulted in the creation of a cooperative urban growth boundary between the municipalities that designated future residential and commercial development districts over the next forty years.

The City of Midland, Michigan utilizes an urban growth boundary to dictate growth based on the availability of public water supplies. Midland has historically controlled growth on its borders through the use of a "No Annexation/No Water" policy (Hamlin et al. 2000). The City can employ this technique to control growth since its public water supply originates in nearby Lake Huron and is more palatable when compared to the brackish groundwater supply found in municipalities surrounding the City. Midland's city boundary has thus slowly crept outward via annexation of surrounding townships where water infrastructure has been extended.

1.2 LAND USE FORECASTING TOOLS, PLANNING SUPPORT SYSTEMS AND GEOGRAPHIC INFORMATION SYSTEMS

Many tools and techniques exist for planners to assist them in managing and analyzing development within their municipalities. One of these tools is called a build-out analysis, which calculates in a tabular or graphical form the maximum extent and amount of development that may occur in a region based on current zoning regulations and other land use policies (U.S. EPA, 2003; Washtenaw County, Michigan, 2002). Additional techniques include land suitability analysis, which utilizes a Geographic Information System (GIS) in order to display areas suitable for development based on factors including slope, soil composition, elevation, and other physical characteristics (Swanson, 2003). The emerging usage of GIS at all levels of government allow elected officials, planners, and decision makers to add GIS and land-use modeling as tools to assist in smart growth planning. The increasing availability of GIS data that can be made available at the local level enables these officials to more frequently utilize GIS-based land use models and software applications in their decision making process. Many land use modeling algorithms stand alone from a particular GIS package, but many have been incorporated and renamed either a Decision Support System (DSS) or a hybrid GIS known as a Planning Support System, or PSS (Harris and Batty, 1993; Hopkins, 1999; Klosterman, 1997). The DSS and PSS are additional tools in the growth management palette that are used to implement land use and growth management policies. One capability of many land use based PSS techniques incorporates the power to extrapolate and predict potential land use development patterns or regions ripe for transformation to other land uses, e.g., urban or commercial (Heikkila, 1998; Lee et al. 1998). Determining the multitude of outcome scenarios that could result from land use policy decisions had traditionally been a complex, costly, and lengthy procedure before the advent of GIS and PSS modeling.

Another advantage of using a PSS approach to simulate potential land use scenarios revolves around the inherent ability of a GIS to display visual information in the form of a map. The ability for a map to inform a layperson in a clear and accurate fashion allows a PSS to become a powerful tool to convey information. Recent PSS models also stretch beyond traditional map images and provide realistic three-dimensional visualization of the local area including existing buildings and vegetation (Brail and Klosterman, 2001). A PSS is also advantageous in its ability to expedite the creation of outcome scenarios. This timely production allows the user and the general public quick access to land use scenarios generated by altering variables in the PSS. An example would be to alter a township's minimum acreage requirements for a particular zoning class such as "residential", and then visualizing the potential impact that a change in this requirement could have on development patterns.

1.3 PERCEPTION AND INTERPRETATION OF LAND USE FORECASTING TOOLS

The increase in usage of PSS and land use forecasting tools makes it necessary for one to analyze the perception and interpretation of these potential outcomes by local officials and decision makers. The relative ease and availability of these models have made it imperative to examine the influence that maps of potential urbanization patterns have on the local officials. After all, these officials will ultimately decide the development direction for their municipalities through creation and enforcement of local ordinances pertaining to zoning and land development. Much of the power of these models lie in their ability to allow leaders to see the potential effects of policies, practices, ordinances, and plans prior to their passage and implementation. They also incite decision makers to evaluate the possibilities of future land development and to pose rational questions regarding the potential futures presented. The decision makers are then better equipped to potentially set into motion changes (e.g., zoning ordinances, local laws) to make these desired futures a reality.

1.4 PROBLEM STATEMENT

The advantages of accurate, timely, and increasingly user-friendly PSS's and land use models has not been lost on the planning community. However, despite the powerful capabilities and increased usage of these PSS's by planners and local officials, there have been few studies that examine the accuracy of the potential land use scenarios generated by these systems (Klosterman, 1999b). Even if datasets, software, and methodologies employed in the creation the predictions are of high quality, the public groups viewing the output from a PSS may accept the potential land use outcomes without much thought to the accuracy of these predicted scenarios. Often, these scenarios are demonstrated within the context of a collaborative group such as a group of citizens or officials concerned about local development (Klosterman, 1999a). These group sessions are more frequently including the demonstration of PSS software using local GIS data to provide powerful "what if" scenarios that may occur under present zoning ordinances and statues. The enhanced two and three-dimensional visualization of these potential outcomes, albeit only potential, may still be utilized by elected officials or planners to assist them in updating a master plan or altering land use and zoning ordinances to realize these scenarios. These alterations to local land use zoning laws can have enormous implications for future growth and development in a community. If they are based solely or even partially on a PSS that has not been evaluated for accuracy then they risk the potential to derail the favorable land use outcomes they had hoped to initiate.

1.5 RESEARCH QUESTIONS

The research addressed several aspects of the predictive capability of the Land Transformation Model (LTM), a neural-network based land use modeling program created at Michigan State University (MSU) (Pijanowski et al. 1997). The LTM operates through the input of GIS datasets in order to calculate the probability of an area to convert to urbanized land from other uses. In many ways, the LTM typifies the modeling “engine” used to produce alternative land use scenarios found in many PSS software packages.

Several research questions were examined regarding the LTM's predictive accuracy in producing future urbanization scenarios. First, how accurately would the LTM predict patterns of urbanization in a township? For example, which of the LTM's "driving variables", which consist of the GIS layers used in modeling these urbanization patterns, appear to have the most impact on model accuracy at a large scale? Should additional variables be considered on a township-scale project?

Secondly, how would the general public, local officials and decision makers react and interpret the results presented from the LTM? Would they take the results at face-value under the assumption that they're correct due to the complex computer techniques involved? What are their opinions on the LTM's predictions of urbanization for 2000 and beyond? Do they believe there are areas in the township that are better "handled" by the predictive algorithms of the LTM based on their local knowledge of the township?

1.6 STUDY SIGNIFICANCE AND TARGET AUDIENCE

The pervasiveness of planning support systems will continue to grow as additional municipalities begin to harness the power of GIS technology. With the advent of PSS software, it is reasonable to assume that more local governments may find the systems useful to run predictive scenarios and interact with the public on important land use issues such as master plan or zoning ordinance updates. Planners and consulting firms will also likely begin to utilize the PSS as an essential element in their planning toolbox. Focus groups, concerned citizens, and environmental organizations may also find it useful to purchase PSS software and obtain the necessary GIS datasets themselves. Many GIS datasets are available either free of charge through local government Internet sites or obtainable through the Freedom of Information Act, making this type of analysis a distinct possibility.

With these groups in mind, the importance of this study revolves around the accuracy of PSS software in general, and the LTM in particular, to predict potential land use outcomes. Modeling engines like the LTM are only as accurate as the data entry and modeling assumptions built into their mathematical algorithms. Planners and local officials who begin to use PSS output on a more frequent basis as part of their community planning processes should have a firm basis for evaluating the scenarios generated by these models. The general public tends to have a blind faith towards computer models, simulations, and their map output to the point where they do not question the model or the assumptions used to generate these future scenarios. The oft-repeated computer-related phrase "garbage in, garbage out" may not be familiar to them. Despite the fact that these systems display only potential land use scenarios, these outcomes may be seen as potential "truth" to local officials. The literature is replete with journal articles describing different PSS and land use models, but most of them describe the models rather than evaluate their accuracy or examine their impacts on their intended audiences (Harris et al. 1993; Putnam et al. 2001; Waddell, 2001). In the past, many of these models were considered far too expensive or computationally intensive to be implemented with existing computer power and finances of a local government.

The LTM could prove to be one of many powerful predictive models in the growing field of planning support systems. LTM model runs have been completed for metropolitan regions both inside the United States (Minneapolis/St. Paul, Minnesota and Detroit, Michigan) as well as an international trial in Kuala Lumpur, Malaysia

(Pijanowski et al. 2001). Hamilton County Ohio, which includes the Cincinnati area, added a PSS known as *What If?*, with predictive land use algorithms similar to the LTM to its planning toolbox in January 2000 (Klosterman, 1999c). If Cincinnati, the birthplace of the comprehensive plan, trusts in the capabilities of a PSS, then we owe it to the GIS and planning communities to begin examining the output of these models' advantages and disadvantages in their predictive capability as well as their impact on local decision makers.

II. LITERATURE REVIEW

2.1 OVERVIEW OF PLANNING SUPPORT SYSTEMS AND GEOGRAPHIC INFORMATION SYSTEMS

Geographic Information Systems (GIS) have become very commonplace in a myriad of professional pursuits since their genesis in 1963 with the birth of the Canada Geographic Information Systems, CGIS (University of Wisconsin, 1999). Since that time, GIS technology has advanced through the use of remote sensing technology and innovations in the design of GIS software applications (University of Wisconsin, 1999). Several definitions of GIS have been stated in the literature. Many of these definitions take what could be deemed a "software-only" approach in defining a GIS. As is the case in Aronoff (1989) who states, "A GIS is designed for the collection, storage and analysis of objects and phenomena where geographic location is an important characteristic or critical to the analysis." Or the definition that a GIS is a system that integrates hardware, software, databases, and analyses to solve geographic problems (Maquire et al. 1991), allowing map data (e.g., land use, road networks, zoning districts) to be displayed as a digital map "layer." Some practitioners however, expand the definition to include all aspects of running and staffing a GIS, including the personnel who control the system and the data that resides in the system (United States Geological Survey, 1999).

Major developments in the history of commercially available GIS packages stemmed from the creation of powerful GIS software at the Environmental Systems Research Institute (ESRI). ESRI was founded in 1969 as a private company specializing in land use analysis projects (ESRI, 2003). The company developed its flagship GIS package, *Arc/Info*, in 1981, and has since expanded their GIS products to include Internet-based and mobile, handheld GIS products. Many PSS software packages are either software extensions of existing ESRI products or were constructed using ESRI-based development tools. The datasets created for this research were produced by the LTM, but the model results and maps were created using ESRI's *ArcGIS* software. As a testimony to the widespread usage of ESRI software, the 2003 ESRI International User Conference attracted over 11,000 users from several dozen countries (ESRI, 2003).

The merging of the GIS and planning disciplines has been in existence since the first use of computers for planning desired travel routes in the Chicago Area Transportation Study back in the 1950's (CATS, 2003). The progression of planning support systems has evolved from simple spreadsheet calculations of population trends to highly complex analysis tools to visualize and extrapolate potential land use outcomes (Lee et al. 1998). The future scenarios that can be created using available GIS data can assist planners and local officials in determining the appropriate land use policies for their jurisdiction.

The works of numerous authors have bolstered the definition of a planning support system. Harris and Batty (1993) went to great lengths to define the usage and purposes of a PSS. With regards to a fully functional PSS they state:

> *"A major consideration of planning is the avoidance of unintended consequence while pursuing intended goals. Both intended and unintended consequences arise out of the propagation of effects throughout the system for which planning has been undertaken over time, space, and function. In order to assess these consequences planning needs methods for making conditional predictions based on alternative hypothetical decisions. Both the research establishing the capability to make such predictions and the mechanisms by which scores of predictions can be made and examined, call for extensive computational resources and sophisticated simulations modeling."*

Klosterman (1997) mentions that a PSS "...includes only the computer hardware, software, and related information that are used for planning, i.e., the information technologies planners use to perform their unique professional responsibilities as planners." And states further, "The heart of any PSS will undoubtedly be a GIS. The GIS will serve first as a display and communication device producing maps and charts that describe past and present conditions and model outputs that suggest alternative futures (Klosterman, 1997)." Some authors suggest that in addition to the standard points, lines, and polygons that are used in a GIS, a PSS should focus on elements of urban development such as, "actors, activities, flows, investments, facilities, regulations, rights, issues, forces, opportunities, and constraints (Hopkins, 1999)."

2.2 THE LAND TRANSFORMATION MODEL

Many of the aforementioned PSS and DSS software have at their heart a processing engine to produce alternative land use scenarios based on policy inputs as well as predictive models that use existing GIS data. The LTM program utilized in this study typifies one of these types of modeling algorithms used to run predictive analyses and trends in land use change. The LTM operates through the input of "driving variable" grids and exclusionary zones where land use transitions cannot occur. The LTM receives data inputs from the driving variable datasets in order to predict the probability (also deemed a "change likelihood value") of a grid cell to transition from other uses to urban in a region (Pijanowski et al. 2001). The LTM uses this data to train an artificial neural network (ANN) simulator known as the Stuttgart Neural Network Simulator (University of Stuttgart, 2003).

Artificial neural networks operate by simulating the brain's activity and its complex processes of transferring information between neurons (Hinton, 1992). Through simulation of neural processes acting in parallel, an ANN can achieve complex calculations through a series of inputs into the system. In essence, the system "learns" by analyzing data fed into the model through a process of repetition to train the system and reduce potential output error (Pijanowski et al. 2001). The LTM utilizes a popular ANN known as a multi-layer perceptron (MLP). The MLP contains input, hidden, and output layers to process information through the system. Driving variable datasets are fed into the system where the ANN calculates random weights for the input layers and propagates the data forward through the nodes and then backwards through a training calculation knows as back propagation (BP). These weighted inputs are then passed through the system from input nodes to hidden nodes, and finally to an output node. The BP compares the expected output with the model's calculated output, then summarizes and distributes the error across all nodes in the network. Quite often this process of error calculation requires several hundred or thousand forward and backward iterations to stabilize error throughout the network (Pijanowski et al. 2001). The LTM runs for Grand Blanc Township completed approximately one-thousand of these iterative cycles to stabilize error in the model output.

The LTM has been implemented with geographic data at varying scales in both the United States and foreign countries (Michigan State University, 2003). Applications of the LTM include studies where model output assisted in studying the spatial-temporal effects of land use change on groundwater (Wayland et al. 2002) to the impact of urbanization on multi-watershed regions along Lake Michigan (Pijanowski et al. 2002). The LTM has also been the subject of many high-profile and peer-reviewed journals within the planning and GIS profession. This proven track record of the LTM via publications and the continuous refinements and enhancements of the model indicate the

LTM's high potential to become one of the more popular and cost effective land use modeling solutions available to municipalities.

In addition, the LTM requires relatively few GIS data layers such as current and historical land use, roads and interstates, water bodies, and existing urban areas to begin processing within the ANN for forecasting and predictive purposes. The main layers that were required for the study were readily available for inclusion in the model using existing GIS resources at Grand Blanc Township.

2.3 MAP INTERPRETATION AND PERCEPTION OF ACCURACY

The primary output from any planning support system is typically in the form of a two or three-dimensional map product. Maps created by these systems are often introduced as part of a moderated forum discussing a municipality's new master plan, parks and recreation plan, open space program, etc. Maps are often presented to local officials, developers, and concerned residents as a "truthful and objective" representation of potential land use scenarios. However, the interpretation of maps produced from a PSS remains an element of the system that is far from reaching objectivity. The accuracy and interpretation of the model results are the first step towards acceptance of the model by the general public.

The terms "accuracy" and "precision" are often used to describe the output of a particular land use model. In general terms, accuracy refers to "the degree to which information on a map or in a digital database matches true or accepted values (Foote et al. 1995)." Precision refers to the consistency of that information and the level of exactness used in its measurement. In keeping with this definition of accuracy, the research attempted to evaluate the accuracy of the urbanization information presented on the LTM's predictive map with the "true and accepted values" of landuse from 2000.

Cartographic skill and mapmaking ability are vital to the accurate interpretation of any map(s) created from a PSS. The difficulty in this process is that in order to transform a three-dimensional model of the world into a two-dimensional representation of reality, the procedure will invariably introduce errors. As stated by Monmonier (1991) in his seminal cartographic work, "How to Lie with Maps," "There's no escape from the cartographic paradox: to present a useful and truthful picture, an accurate map must tell white lies."

The complexities of learning and interpreting map data compounds the difficulty of PSS-produced maps when the map readers are the general public. Maps are often taken at face value as a reflection of reality and with an inherent trust that the cartographer (and in this case, the modeler) are competent stewards of their craft. Map users tend to not question the "authority" vested in the cartographer, and operate under this assumption of competency until proven otherwise (Monmonier, 1991). Many of the maps generated by PSS software are generated by planners and consultants who thoroughly understand the model and its limitations, although the likelihood that they have had any formal training in GIS or cartography is small. Therefore, the comprehension level of these future scenario maps may be difficult if the consultant chooses to have the maps produced by an individual with little training in geography or cartographic output techniques. The predictive maps produced via a PSS model display complex patterns of information, making the appropriate color schema, line weights, etc., important to avoid misunderstanding by the general public.

The learning process employed by map readers is often a complex psychological issue, dealing with cognitive development, comprehension of graphical symbols, and even gender-based differences (Postigo and Pozo, 1998; Kirby, 1994; Harrell et al. 2000). The myriad ways that maps are interpreted remains a topic that is truly multi-disciplinary in nature, covering both the fields of geography and psychology. Studies have focused on differences in map learning as differentiated between age-based expert and novice groups (Postigo and Pozo, 1998). In Postigo and Pozo (1998) it was determined that complex tasks, such as map reading and graphical comprehension, require the formation of a detailed conceptual schematic of the region being analyzed. Verbal instructions regarding the map compositions to subjects aided significantly in the learning ability of the map reader. Adults tended to perform better on comprehension tests versus adolescents, but contrary to their hypotheses, no significant differences existed between two adult groups composed of "experts" and "novices." They further state that

> *"...in the case of graphical material, the capacity demonstrated by expert subjects cannot be explained solely by their possession of large quantities of knowledge. It is the organization of this knowledge that distinguishes the experts and determines their mental representations."*

Ironically, the "experts" in this study were geography undergraduate students.

Additional studies of map perception focus on the link between spatial representations learned via the use of computer models (Rossano and Moak, 1998). The principle of *cognitive load* is introduced as an additional hurdle for the map reader. Map readers are often confronted with questions posited by researchers that may hinder problem solving skills if the sheer amount and complexity of questions reach a critical mass. With regards to map interpretation, Rossano and Moak hypothesized that people with "direct learning" of map knowledge, e.g., real-world familiarity with the map area, would have an advantage over map readers learning the area of interest via a highly realistic computer-based model's map output. The rationale was that the cognitive load of the map reader would be reduced if their map experience was garnered from viewing a computer-based image versus "direct learning." It was hypothesized that reading the realistic computer-based map would "simulate" the direct learning experience as if the reader physically visited the location. Previous studies have suggested that even a few minutes of map experience can often lead to superior map knowledge versus subjects with 10 years of direct learning experience (Lloyd, 1989).

Map interpretation and learning also requires development of an understanding of the reason for the map's existence. This understanding stems from the three principles of cartographic maps described in Liben (2001): purpose, duality, and spatialization. It must be made clear to the map viewer what the map represents (purpose); what it stands for (duality); and its relation to the real-world (spatialization). The intended audience of the map must be able to apply these three principles in order for a sound judgment and interpretation of the map presented to them. The principle of spatialization also takes into account the three additional effects of map viewing distance, angle, and azimuth. Azimuth, the orientation of the map product, is an intriguing concept that studies the effect of map interpretation based on the top edge of the map not necessarily representing north. This representation ties itself directly to the aforementioned points concerning inherent trust between the cartographer and map user. If "up" does not always equal "north,", then map interpretation could drop substantially.

2.4 PREVALENCE OF GIS DATA AND USAGE IN LOCAL GOVERNMENTS

The usage of a PSS to determine alternative land use scenarios would not be possible without the existence of data for that system. This data collection effort has been bolstered by the GIS industry, which has expanded the creation and distribution of geographic datasets at the federal, state, and local levels. In the past decade, the advent of cheaper personal computers has allowed many local governments to harness and develop a locally based GIS (Klosterman, 1999a). These local governments have also been assisted financially by the creation of GIS based datasets by other regional and state government agencies.

In order to centralize the archiving and distribution of statewide datasets, the State of Michigan formally established the Center for Geographic Information (CGI) on April 26, 2002 (State of Michigan Center for Geographic Information, 2003). The CGI's *Geographic Data Library* currently contains over sixty (60) unique statewide GIS datasets including land use, topography, and digital orthophotography. All datasets in the GDL are free of charge and available in common GIS formats for expedited use in local GIS projects. The GDL contains enough base map information for a municipality to create their own GIS with little or no monies spent on GIS dataset development – the costliest portion of any GIS project. The GDL also contains all datasets from the defunct Michigan Resource Information System (MIRIS), which includes planimetric layers from U.S. Geological Survey 1:24,000-scale topographic maps (State of Michigan Center for Geographic Information, 2003), as well as statewide land use/land cover polygons from 1978. The invaluable MIRIS datasets have served as the primary source of GIS information for numerous state and local GIS projects over the past decade, including this research.

In addition to MIRIS data, locally generated GIS datasets exist at lower levels of government. Grand Blanc Township in Genesee County, Michigan, like many other townships, generates internal datasets within their own GIS department. They currently supplement MIRIS data with extensive datasets that include zoning, land use, sewer and water infrastructure, and parcel based information (Taylor 1999). The Charter Township of Waterford in Oakland County also has a fully-fledged GIS with the enhanced capability to display and print maps on the Internet (Charter Township of Waterford, 2003). In addition, southeast Lower Michigan is also the home to several existing countywide GIS programs, including extensive programs in Oakland, Saginaw, and Lapeer Counties (Oakland County, 2003; Saginaw County, 2003; Lapeer County, 1999), as well as startup programs in Genesee County (Gonzales, 1999). The Oakland County GIS project has also taken additional steps to ensure that the data that is created at the county level will be distributed to every governmental entity in their borders to assist in the creation of their own GIS (Oakland County, 2003). In addition to state and local governments, regional agencies in Michigan such as SEMCOG distribute numerous GIS datasets covering their seven-county region in southeast Lower Michigan (SEMCOG, 2003). The Great Lakes Information Network also distributes online GIS datasets covering the entire Great Lakes drainage basin (Great Lakes Information Network, 2003)

III. RESEARCH DESIGN AND METHODS

Note: Images in this thesis are presented in color

In order to better comprehend the validity and usage of these burgeoning land use models and PSS techniques, two aspects of PSS models were examined. First, the research attempted to validate the land use transformation scenarios produced by Michigan State University's Land Transformation Model. The LTM represents one of the components found in a traditional PSS, which is the ability to predict and visualize changes in land use patterns across a region. Secondly, the research examined the usage of the LTM's predictive output within a local municipality to gauge the reaction, impact, map interpretation skill, and understanding of the model results by local officials and decision makers.

3.1 STUDY LOCATION

The study site for the research thesis was Grand Blanc Township in southern Genesee County, Michigan (Figure 1). Genesee County is experiencing growth pressures from the Flint and Detroit metro areas (Rusk, 1999) and Grand Blanc Township is no exception. Although not explicitly stated, the LTM implies that in a fashion similar to other PSS software such as the *What If?* PSS, that its application is most appropriate for "areas that are experiencing, or anticipating, rapid urbanization (Klosterman, 1999a)." Grand Blanc Township contains many of the key elements often considered vital to the expansion of a rapidly urbanizing area. The township's road infrastructure includes two major interstates, I-75 and I-475, which bisect the township allowing easy access for Metro Detroit area commuters. Development in the township has also been assisted by the widespread availability of public water and sewer infrastructure throughout the township. An additional incentive for development was the recent activation of a new water booster station to service the needs of residents in the rapidly developing southeast corner of the township (Riopelle, 2003). The township also led Genesee County in residential building permits issued in 2001 and 2002 (Richardson, 2003).

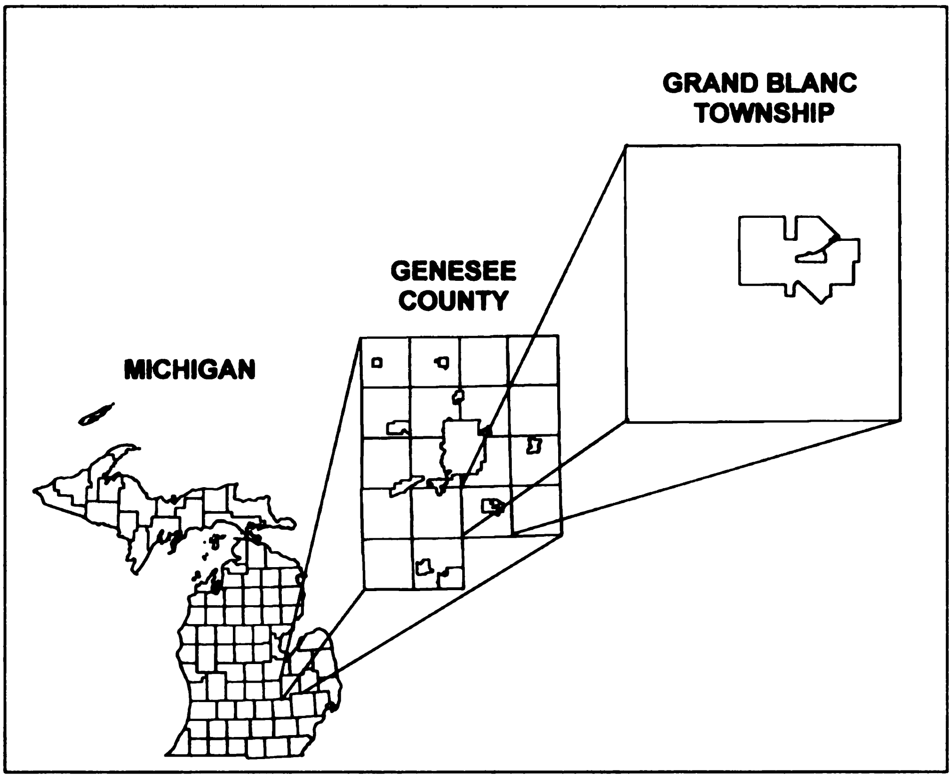

Figure 1. Grand Blanc Township study region in southeast Lower Michigan.

3.2 DATA COMPILATION AND GEOPROCESSING STRATEGY

Data access to Grand Blanc Township's historical land use and other GIS datasets were critical to the success of the project. Fortunately, my position as GIS Coordinator for Grand Blanc Township granted me unrestricted access to non-confidential materials and GIS datasets necessary to complete the research. Grand Blanc Township's GIS Department houses multiple geographic layers as part of a GIS implementation begun at the township in 1996 (Taylor, 1999).

The process of utilizing the LTM was two-fold. First, historical land use data from the DNR's 1978 MIRIS land use dataset (State of Michigan Center for Geographic Information, 2003) were entered into the LTM along with existing land use from 2000. The LTM processed the data through a back-propagation procedure in the ANN to forecast and display areas within the township that it predicted would become urbanized in 2000. The existing land use data from 2000 was then used a second time after the model run as a "truth" layer to compare the LTM's predicted urbanized areas in 2000 with the actual urban areas that existed in 2000.

Secondly, the number of cells predicted to transition to urban in the 1978-2000 model results were then utilized an additional time in the LTM to predict areas converting to urban after 2000. Using the year 2000 as the starting point, the model calculated areas where additional urbanization would occur using five percent intervals. The interval maps displayed the location of future urbanization starting at five percent and increasing to one-hundred percent change in urbanized area.

Data preparation for the LTM involved obtaining several key "driving variable" datasets that are commonly utilized within the LTM's ANN to assist in predicting changes in urbanization patterns. The original GIS layers for these driving variables were obtained from Grand Blanc Township's GIS Department in a vector-based format known as a *shapefile*, the proprietary data format used within the Environmental Systems Research Institute's (ESRI) ArcGIS 8.2 software product.

The driving variables datasets are composed of GIS layers that display the Euclidean (straight-line) distance from several natural and man-made geographic features that influence urbanization (Figure 2). Among the variables created for this study were layers that measured the distance from road features including highways, residential roads, and county roads. The distance to major roads typically influence development by allowing easier and expedited access to areas with available vacant land. Water bodies (including lakes and streams) also lead to potential development based upon the aesthetic attraction of areas surrounding these natural features. The distance to urban regions variable takes into account the outward expansion and development pressures exerted on Grand Blanc Township by neighboring urban centers.

Along with the driving variables described above, an "exclusionary zone" was integrated into the LTM. Exclusionary zones are areas within the study region where development cannot occur due to several reasons that limit further urbanization. The exclusionary zone layer was composed of three integrated GIS datasets which included existing urbanized areas (e.g., residential, commercial, and industrial development), public lands and parks, and water bodies (including wetlands). Areas in the study region that met these criteria were inserted into the model as locations where no further development could occur.

The vector data for each driving variable and the exclusionary zone was converted through a rasterization process within ArcGIS using the *Spatial Analyst* software extension to ESRI's raster GRID format. The GRID format is an image format commonly utilized in GIS software packages where images are comprised of rows and columns of individual pixels where each pixel has a distinct value. Upon conversion to the GRID format, each driving variable and the exclusionary zone were converted once again to a standard ASCII format known as a pattern file (Pijanowski et al. 2002) for input into the LTM.

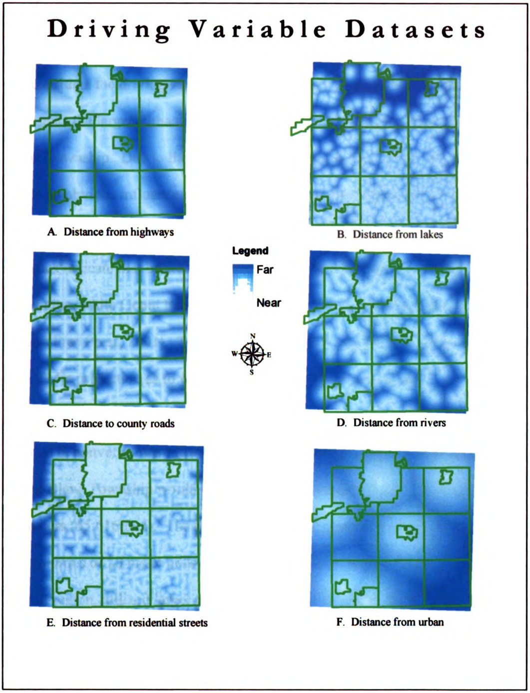

Figure 2. Driving variables for the Grand Blanc Township study region.

Driving variable grids were created for an area approximately 325 square miles surrounding Grand Blanc Township (Figure 3). Despite the fact that Grand Blanc Township only constitutes 32 square miles (with the remaining 4 square miles residing within the City of Grand Blanc), the driving variables listed above also exert development pressure from areas outside the township. This is especially relevant when one considers the driving variable for "distance to existing urban." The City of Flint represents the largest urban center in Genesee County, and lies directly north of Grand Blanc Township. Due to the proximity of this heavily populated urban center, Flint exerts an obvious influence on urbanization trends throughout the county. One possible influence is through outward migration of population from the City of Flint. Census statistics indicate that between 1990 and 2000, Flint lost approximately 11% of its population, while Grand Blanc Township led the county in population growth (The Detroit Free Press, 2001). The exclusion of Flint from the study area would likely skew the LTM's prediction as to where new urbanization would occur.

The driving variable grids and associated details are displayed in Table 1. It was decided in conversations regarding previous LTM runs, that larger scale areas such as Grand Blanc Township would likely require a correspondingly larger raster cell size of 20 meters (65.616 feet). The resulting raster GRID files were composed of 506 rows and 500 columns of 20 meter cells. LTM runs in smaller scale settings, including the Metro Detroit region, utilized larger cell sizes of 100 x 100 meters (Pijanowski et al. 2001).

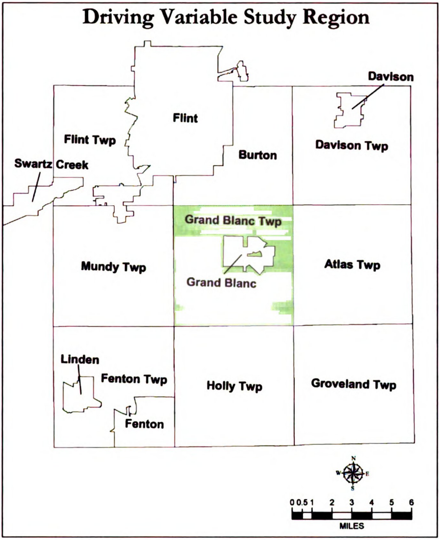

Figure 3. Driving variable study region surrounding Grand Blanc Township.

Driving variable	Description	Raster grid cell
Water bodies	Distance from lakes, rivers, and streams	65.61 feet (20 meters)
Residential roads	Distance from subdivision and minor non-arterial roads	65.61 feet (20 meters)
County roads	Distance from major arterial roads	65.61 feet (20 meters)
Highways and Interstates	Distance from major expressways	65.61 feet (20 meters)
Urban areas	Distance from existing urbanized areas surrounding the township	65.61 feet (20 meters)

Table 1. Driving variable raster grids utilized in the Land Transformation Model

3.3 LTM 1978 TO 2000 URBAN TRANSITION RUN

To gauge the overall effectiveness of the LTM's predictive algorithms, land use data from the 1978 MIRIS dataset were input into the LTM. This land use layer was then integrated with the driving variable and exclusionary zone spatial datasets to create a modeling run to predict the extent of urbanization in Grand Blanc Township in 2000. After the model was run, an output layer was created to indicate areas predicted as transitioning to urban from 1978 to 2000 (Figure 4).

The regions predicted by the LTM as transitioning to urban in 2000 were then compared to the urbanized area depicted in the 2000 existing land use layer created as part of Grand Blanc Township's 2000 master planning efforts. The 2000 land use layer contained several distinct classifications of land use found throughout the Township (Table 2). These categories were examined to determine if they were considered an urban or non-urban land use type. The land use types deemed as urban were then reclassified and grouped together in the GIS as a single layer representing the 2000 urbanized area. The reclassification allowed comparison between the LTM's predicted urbanization layer and the actual urbanized area that existed in 2000.

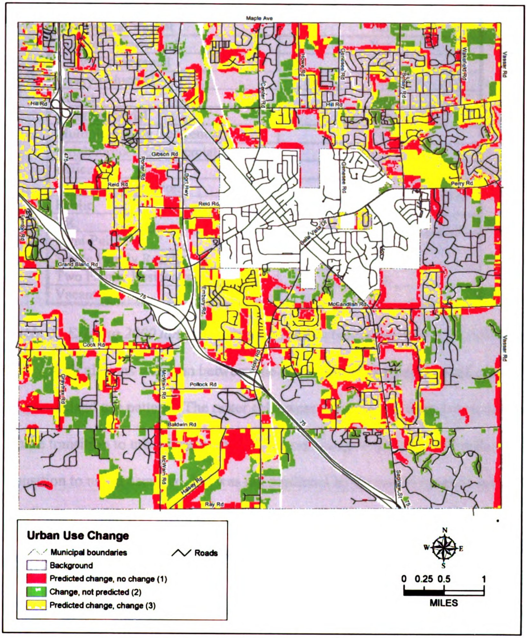

Figure 4. LTM predictions of 2000 urbanization pattern change.

Existing 2000 Land Use	Urban Land Use Type?
Agricultural Vacant	No
General Commercial	Yes
Heavy Commercial	Yes
Heavy Industrial	Yes
Hospital	Yes
Light Industrial	Yes
Multiple-Family Residential	Yes
Neighborhood Commercial	Yes
Office	Yes
Parks and Recreation	No
Public	No
RR	Yes
Semi-Public	Yes
Single Family Residential	Yes
Two Family Residential	Yes
Vacant	No

Table 2. Existing 2000 land use categories and urban/non-urban reclassification

Calculations were run between the two layers to compare several aspects of the predicted land use pattern. The raster cells were grouped into three categories: cells where transition to urban was predicted, but no change occurred (red); cells where transition to urban occurred, but was not predicted by the model (green); and cells where transition to urban was predicted where change actually occurred (yellow).

3.4 LTM PREDICTIVE RUNS WITH FIVE PERCENT INCREASES IN URBANIZATION

The second and third model runs of the LTM revolved around extrapolation of urbanization patterns as they may potentially exist with five percent increases in urbanized land with no time constraint. Initial plans were to extrapolate urbanization patterns to the years 2020 and 2040, but initial model runs indicated that by 2040 the LTM predicted all non-exclusionary cells would transition to urban. The decision was made that the research should instead focus on the incremental spread of urbanization at five percent intervals to display how this urbanization pattern would progress across

Grand Blanc Township. Creation of the five-percent increase maps were based on the results of the 1978 to 2000 modeling results. The number of raster cells predicted as having changed to urban in the 2000 run, represented by categories two and three, totaled 50,060 20-meter cells. To calculate where additional increases in urbanization may occur, these original 50,060 cells were multiplied by 5% increments and the resulting number was inserted into the LTM modeling program. The number generated represented the "threshold value" which designated the value that had to be exceeded in order for an area to transition to urban. The total numbers of cells above these threshold values were then selected in ArcGIS using the "raster calculator" included in the *Spatial Analyst* module. Maps displaying the five-percent incremental increases were then created and included as Map Series #2 (Appendix A) and (Appendix B) #3. The spreadsheet utilized to calculate the threshold values is included in Appendix C. These results were then presented to local officials to solicit their opinions, insights, and comments regarding the patterns of urbanization depicted in the scenarios.

3.5 SOLICITATION OF OPINIONS ON LTM OUTPUT MAPS BY LOCAL OFFICIALS

Upon completion of the map series run in the LTM, the second phase of the research involved asking Grand Blanc Township department heads and elected officials about their opinions, comments, and reactions on the urbanization patterns depicted in on the LTM-generated maps. The rationale for this portion of the research stemmed from the fact that many of the local officials interviewed had thirty years of experience working in Grand Blanc Township. Hence, the officials had accumulated a vast knowledge of Township growth and development via their unique personal experiences and professional perspectives over time. The interviews were meant as an avenue to "test" the pattern of urbanization depicted from the LTM modeling runs against the mental maps and development assumptions predicted by local officials.

The maps were broken up into three separate map series for interviews with the local officials. Maps depicting the 1978-2000 LTM model run and the five percent urbanization increases were formatted in an identical fashion and placed within a binder for respondents to examine. The binder included the requisite background information on the project via an abstract and the MSU University Council on Research in Human Subjects (UCRIHS) approved oral consent form (Appendix D). Respondents were given a brief introduction to the project and had the ability to ask questions concerning the map series. Their attention was then directed to the three numbered questions included on the oral consent form that corresponded to the three map series in the binder. Respondents then were left to examine the urbanization patterns depicted in the maps for approximately fifteen minutes or however long they felt was necessary to form their opinions on the maps. Upon completion, the respondents were then solicited for their opinions on the map series with their responses hand-written on a worksheet that replicated the questions included on the oral consent form.

3.6 METHODS UTILIZED FOR ASSESSING LTM ACCURACY

In order to examine differences between the predicted land use transitioned cells and cells where a land use change actually occurred, additional accuracy assessment calculations were performed. The accuracy assessment technique utilized was to determine the percent correct match (PCM), which was first described by Pijanowski et al. (2001) with the following calculation:

$$\frac{\text{\# cells correctly predicted to change} \times 100.0}{\text{\#cells actually transitioning}}$$

The second statistical measure employed was to examine how effectively the LTM deals with placement of the predicted land use types. The assessment of this accuracy was calculated using a table comparing the 2000 existing land use categories with the LTM's number of cells correctly predicted to transition to urban. The resulting percentages can then point to relative strengths or weaknesses in the model when it comes to the accuracy of predicting urbanized versus non-urbanized areas.

IV. RESEARCH RESULTS

4.1 LTM VALIDATION - 1978-2000 ANALYSIS

The validation of the 1978-2000 projection accurately predicted a conversion to urban for approximately 62% of the raster cells in the Grand Blanc Township model region. Comparison results are shown in Table 3.

Category number	LTM Cell DEscription	Number of cells
One	Predicted Change / No Change	19,083
Two	Change / Not Predicted	19,084
Three	Predicted Change / Change	30,976
	Total Cells	69,143

Table 3. Year 2000 urbanization prediction results grid.

The calculation was performed using the PCM method described in the previous section, and is shown below:

$$\frac{\text{\# cells correctly predicted to change x 100.0}}{\text{\#cells actually transitioning}}$$

$$\frac{30{,}976 \text{ X } 100}{50{,}060} = 61.8\%$$

Resulting PCM rates for the township's LTM run are significantly different from runs performed in previous studies covering larger geographic regions. The PCM results for model runs in the Metro Detroit and Minneapolis/Twin Cities region equaled 18.6% and 31.9% respectively (Pijanowski et al. 2001). Additional LTM runs in the Grand Traverse County region in Michigan yielded a 49% PCM, and in Kuala Lumpur, Malaysia a 78% PCM results was obtained. The high PCM result in Grand Blanc Township may be attributable to factors such as the smaller geographic study region, which allowed for a much smaller grid cell size of 20 x 20 meters. Another reason may stem from the inclusion of the "correct" driving variables that weigh heavily in determining urbanization patterns within the study region.

Grand Blanc Township's PCM rate of approximately 62% leads to several observations regarding the differences between the Township's LTM run and previous applications of the model. First, the model's relatively large scale analysis region allowed greater detail in terms of grid size for input into the LTM. Previous model runs have focused on regional areas utilizing raster cell sizes of 100 x 100 meters. The larger-scale approach taken in this study allowed the model's refinement and usage of cells approximately twenty-five times smaller at 20 x 20 meters. One could hypothesize that smaller cell sizes allow for the model to more easily predict areas transitioning to urban. However, when previous regional models have been tested on subsets of their regions, the PCM has been shown to increase only slightly, keeping in mind that these subsets were still many times larger than the multi-township region utilized in this study.

Comparisons with existing 2000 land use were then performed on the urbanization pattern predicted for 2000 using ArcMap's *Spatial Analyst* module to perform a "clipping" operation on the existing land use layer. The clipping process is an algorithm run within a GIS to select features from one map layer using another layer as the "clipping" layer. The analogy typically used is that of a cookie-cutter slicing out the selected geographic area(s) on the map. In this analysis, the "cookie cutter" areas were the LTM regions where change was predicted, and where it had actually occurred (value 3, yellow tone on Figure 4). This region then clipped the existing 2000 land use layer to show the percentage of cells that fell within the clipped regions. Table 4 summarizes the results.

The table shows several interesting insights into the nature of the LTM's prediction of 2000 land use in Grand Blanc Township. One interprets the table by first examining the types of land use that were predicted to become urbanized by 2000, and then seeing the actual percentage of those areas classified as urban by the model. For example, approximately 1.38% of the cells predicted to become urban in 2000 fell in areas shown to be classified as "vacant" in the 2000 existing land use layer. The second column indicates if the land use category was classified as "urban" in 2000, thus allowing comparisons of the strengths of the LTM's prediction on a categorical basis. The table output points to strengths in the model where particular land use categories were correctly predicted to transition to urban. Residential development involving single and multiple-family developments appeared as the predominant land use type predicted

Existing Land Use 2000	Number of 20-meter cells	Percent of Total
Agricultural Vacant	93.41	0.31
General Commercial	260.58	0.62
Heavy Commercial	235.21	0.77
Heavy Industrial	513.18	1.68
Hospital	549.37	1.80
Light Industrial	674.03	2.20
Multiple-Family Residential	2,292.89	7.49
Neighborhood Commercial	42.46	0.14
Office	280.61	0.92
Parks and Recreation	19.06	0.06
Public	987.34	3.23
RR	13.11	0.04
Semi-Public	1,039.90	3.40
Single Family Residential	23,025.63	75.25
Two Family Residential	149.94	0.49
Vacant	423.57	1.38
Total	**30,600.29**	**99.76**

Table 4. Existing 2000 land use categories and the number of cells correctly predicted to transition to that land use type.

correctly. The two categories constituted approximately 7.5% and 75% respectively of the total cells correctly predicted as transitioning to urban. Commercial and industrial development was also correctly predicted at a combined rate of approximately 4% of the total cells. The model only sparingly predicted a transition to urbanization in areas not classified as "urban" in this study. When combining the 2000 existing land uses not categorized as "urban," which were comprised of the agricultural vacant, parks & recreation, public, and vacant land use types, the total percentage is approximately 5%. This indicates that of the 30,060 cells correctly predicted to change to urbanized uses; only 5% were incorrectly shown as urban when they were in reality a non-urbanized use.

4.1.2 RELATIVE INFLUENCE OF DRIVING VARIABLES ON OVERALL MODEL OUTPUT

The 1978 – 2000 LTM transition run resulted in a percent correct match rate of 61.8% of the cells correctly predicted to transition to urban. The overall proportion of the number of cells that were predicted correctly can be determined by plotting a goodness of fit metric versus window size (Pijanowski et al., 2002). The window size equals the number of cells included in the width and height of the analysis, e.g., a window of 1 x 1 equals the native 20 x 20 meter cell size used in the model. Starting with this native window size and a 0.618 (61.8%) goodness of fit, the model increases to a value of 0.637 (63.7%) at 100 x 100 meters (e.g., .0.1 km, 5 cells) and quickly rises to approximately 0.84 (84%) at 1000 x 1000 meters (e.g., 1 km, 50 cells) (Figure 5). Values level off in the 0.85 to 0.86 range immediately after the 1 km window threshold. As the window size gradually increases past the calculated 100 x 100 cell window (e.g., 2 km), the values increase towards the expected value of 1.0. The increase in overall PCM rates as window size increased was expected due to comparisons with previous research. However, the high rate at which the curve flattened at approximately 85% was higher than expected

Analyses of the LTM's goodness of fit were also performed in the Grand Traverse County, Michigan region. The Grand Traverse study utilized a native grid cell size of 100 x 100 meters covering a multi-county region in northwest Lower Michigan. The number of cells correctly predicted to transition to urban in the study equaled 46% at the 100 x 100 meter cell size (Pijanowski et al., 2002). In comparison, the Grand Blanc Township percentage correct match rate equaled 63.7% at the same 100 x 100 meter resolution. The Grand Traverse study yielded a 65% match at the 1 km window size, versus an 84% match in this study. However, numerous differences exist between these two modeling analyses. In the Grand Traverse study, the analysis area covered a multi-county region consisting of dozens of townships, versus one township in Grand Blanc. In addition to study area size, driving variables considered critical to the LTM runs in Grand Traverse (e.g., lakeshore distance), were not relevant in the Grand Blanc Township area.

Another method utilized to analyze the relative performance of the LTM's output is through statistical analysis of the driving variables used in the model run. This step is performed by removing one of the model's six driving variables and running the model to calculate the difference in predictive accuracy without that variable. Upon completion of the run, the variable is added back into the LTM and the second driving variable is removed. This process continues for all driving variables to calculate a goodness of fit metric that indicates the relative influence each variable has on overall model performance. These values are calculated over an increasing window size which assists

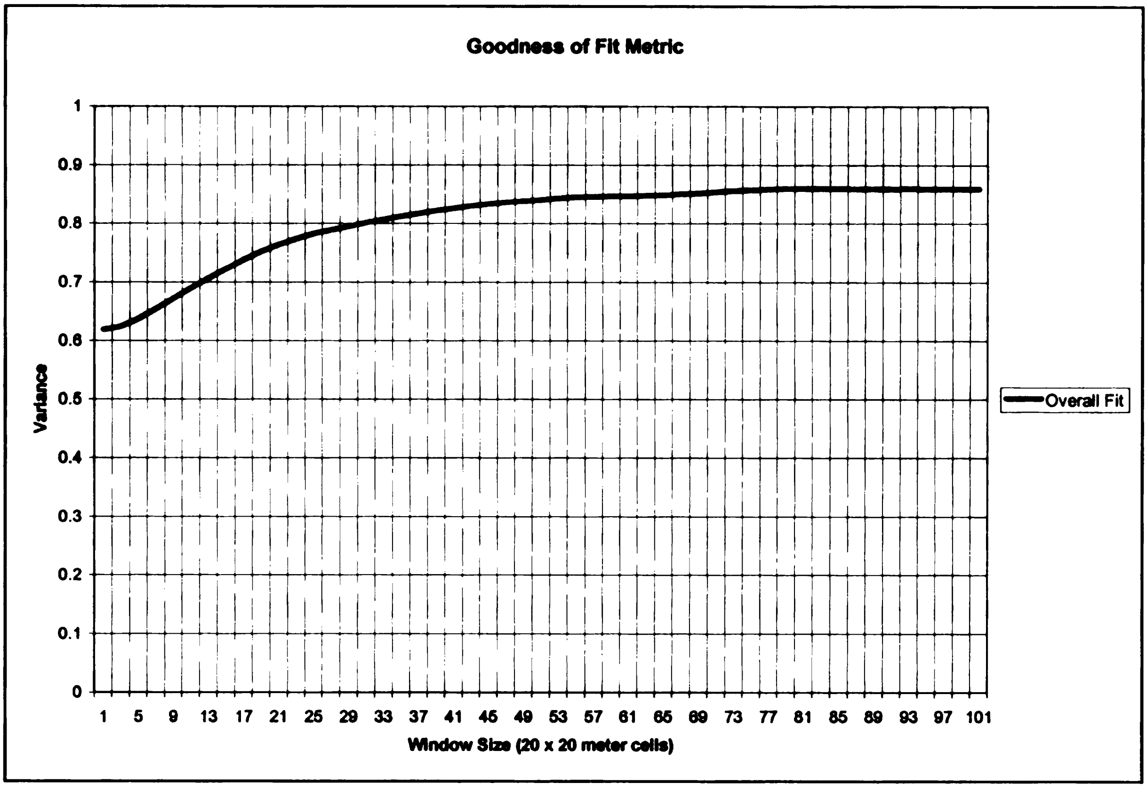

Figure 5. Grand Blanc Township goodness of fit metric versus window size.

in showing the level of influence each variable has on land use change in the region. Each variable's goodness of fit calculation is then subtracted from the full LTM model to determine the relative contribution in model performance. The calculated values can be either positive or negative in nature. Positive values indicate that the variable has a higher influence on overall model performance, and negative values indicate that the variable has a negative impact on the model's performance (Figure 6).

Driving variable influence fluctuates widely over the varying window sizes depicted in Figure 6. In small window sizes of less than 0.5 km (< 25 cell size), all six variables exert a positive influence on the model ranking from high to low as follows: distance to residential roads, distance to rivers and streams, distance to county roads, distance to lakes, distance to existing urban, and distance to highways. At this scale, the positive influence of the county roads, lakes, and existing urban variables were very similar due to the geographically small study area. The influence of the variables remains positive until the window size approaches 1 km where the distance to existing urban variable exerts a negative impact on the model performance. Interestingly, the variables tend to cluster together in their model influence at the 0.5 km window with the obvious exception of the distance to residential roads layer. The residential roads variable may exert a larger influence due to the complexity and density of the residential road network in the model. Since the driving variable region extended to the City of Flint to include the City's effect on the model, the density of residential roads also increased dramatically.

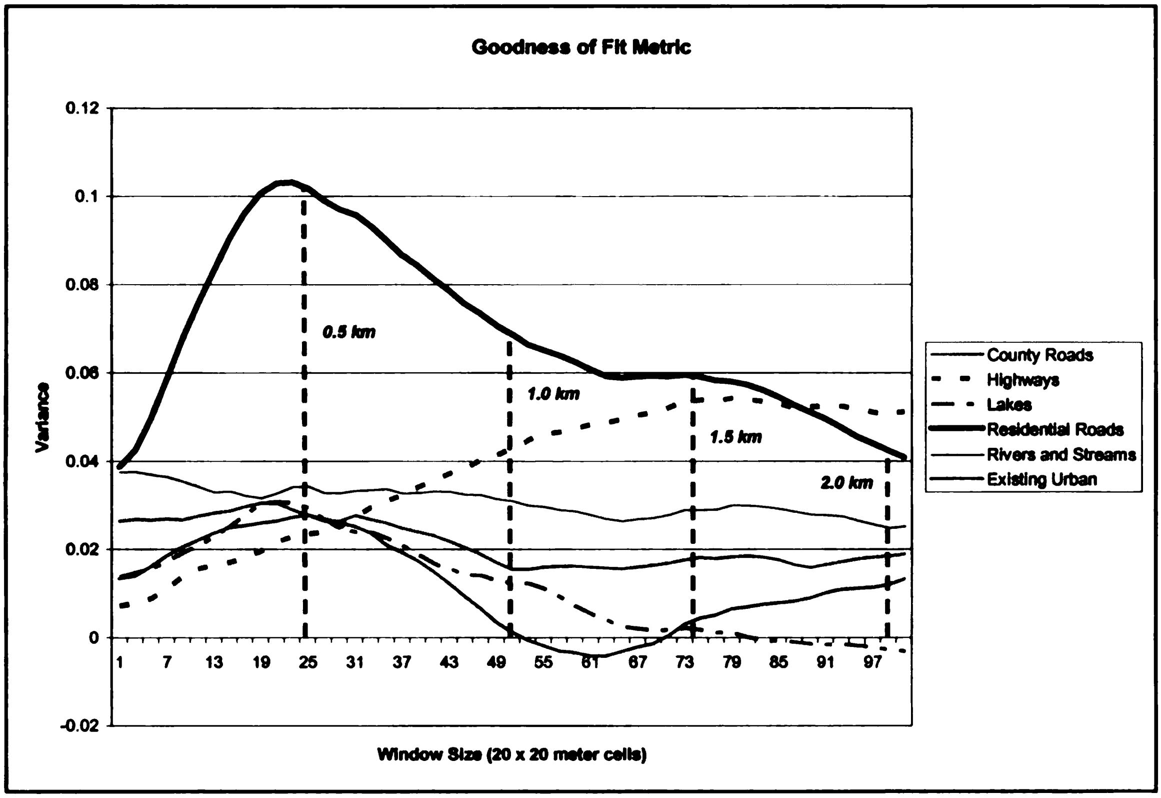

Figure 6. Grand Blanc Township goodness of fit metric versus window size showing relative influence of the six driving variables included in the LTM.

In window sizes between 0.5 km and 1 km (25 – 50 cell size), five of the variables tend to have a decreasing influence on model performance with the exception of the distance to highways variable. The highways variable increases steadily in overall model influence across all window sizes before leveling off near the 1.5 km cell size. One possible explanation could be that the larger window size incorporates a higher proportion of the three major highways that intersect the study region, including two interstates (I-75 and I-475) that bisect Grand Blanc Township. Four of the six variables increase in positive model influence after an inflection point at the window size of 1.2 km (60 cell size), where the distance to urban influence exerts a negative influence on the model before rebounding as window size increases. Once again, the inclusion of the numerous urban centers surrounding Grand Blanc Township likely exerts a larger influence as window size increases. The distance to urban influence would possibly be much higher if the driving variable study region was expanded to include the Pontiac, Michigan metropolitan area to the south.

In the Grand Traverse study, many of the same driving variables were utilized in the LTM runs. Although using a larger grid cell size, the ten driving variables' relative influence on the model was comparable to the results found in Grand Blanc Township. In particular, the distance to residential roads variable exerted the second highest influence on the model at window sizes less than 0.5 km, where in Grand Blanc Township the variable's influence ranked first overall. The distance to highways variable also exerted the third-highest positive influence on the Grand Traverse model. However, in Grand Blanc Township the distance to highways influence ranked last and nearly exerted a negative influence on the model at the original window size. Ironically, the

Grand Traverse highway variable begins with a high positive influence and decreases until reaching the 0.5 km window, where it then steadily increases across all window sizes much like the constant increase shown in Grand Blanc Township. The rationale for the increasingly positive influence of highways may be related to the enhanced accessibility that highways offer in terms of access to a region (Pijanowski et al., 2002). Highways and interstates influence also hinges on the accessibility of the highways themselves. Limited access highways typically have higher posted speed limits, thus allowing expedited access for commuters and travelers. The number of entry points onto these highways has been shown to influence commercial development through the construction of gas stations, fast-food and lodging establishments, and other businesses related to highway travel.

4.2 TOWNSHIP OFFICIALS' OPINIONS AND REACTIONS TO LTM FORECAST RESULTS

The three map series were generated and given to township officials and department heads over a two-week period in June 2003. During that period of time, interviews were conducted with seven township officials with an in-depth knowledge of Grand Blanc Township. Six department heads were interviewed including assessing, building, planning/zoning, public works, finance, police, and the township's elected treasurer. The average length of employment at Grand Blanc Township was approximately twenty years among the seven respondents, with several individuals having over thirty years experience. The interviews were set up at a time convenient for the officials since the discussions were set during business hours. Typical interviews involved 5-10 minutes of background information regarding the research and the format of the questions to be asked regarding the maps. It was made evident that the interview would serve a dual purpose. First, the interview would consist of a brief discussion concerning the map series and any questions regarding map comprehension. Secondly, the interview would serve as forum to solicit opinions and reactions based upon the official's knowledge of Grand Blanc Township.

4.2.2 OPINIONS ON LTM 1978-2000 URBANIZATION PATTERN

The first map series shown to the officials depicted the LTM's prediction of land converting to urban for the year 2000 (Figure 4). Respondents had the most difficulty interpreting this map even with several minutes of explanation regarding the modeling process. Fortunately, most respondents had some exposure to GIS via the township's GIS Department, but many were not familiar with GIS in a modeling capacity as their main exposure was simply of GIS as a "computer mapping" tool. Several were curious as to how a GIS-based model functioned in general and the LTM in particular. The respondents were provided with a figure (Figure 2) showing the inputs used in this LTM modeling run to assist in their interpretation. In order to help categorize and summarize the respondent's opinions and reactions on the pattern depicted on the map series, a map was created breaking Grand Blanc Township into four quadrants of nine one-square mile sections each (Figure 7). Results from the interviews were then categorized by the level of confidence in the maps and specific quadrants expressed by the official after examining each map series (Table 5).

OPINION RESULTS SUMMARY TABLE	Respondent's Confidence Level and Quadrants Mentioned		
	Low	Medium	High
Map Series #1: 1978-2000 Map			
Category 1-Red*	0	7 (SW, SE)	0
Category 2-Green*	2 (SW)	5 (SW)	0
Category 3-Yellow*	0	2 (SE)	5 (NE, SW)
Map Series #2: 5%-50%	0	7 (SE, SW, NW)	0
Map Series #3: 55% - 100%	0	6 (SE, SW)	1 (SE)
*Category Definitions: Category 1 = Predicted Change/No Change Category 2 = Change/No Change Predicted Category 3 = Predicted Change/Change Occurred			

Table 5. Summary table of opinions and confidence expressed regarding the three map series utilized during interviews with Grand Blanc Township officials.

As expected, the respondents' knowledge of the township and its pattern of urbanization led to mixed reactions on the map presented to them. Initial reactions to the LTM's areas where change was predicted, and change occurred (Category 3 on Figure 4) ranged from "quite amazingly accurate" to "fairly representative." Most respondents felt that the model adequately displayed areas where they knew urbanized land had existed in the 2000. Specific areas where the officials opined that the LTM predicted 2000 urban lands correctly were the NE and SW quadrants of the township. Development between Perry Road and Hill Road in the NE quadrant grew rapidly in the late 1990s, and the model correctly predicted change in those regions. The SW quadrant of the township has had many new subdivisions platted between Baldwin Road and Cook Road to the north, which were also correctly identified according to several respondents.

Criticisms of the model included the overwhelming response that the model completely overlooked the development of section 36 in the SE quadrant of the township. The development known as the Woodfield (Figure 7) Planned Unit Development (PUD) encompasses almost all of section 36 of Grand Blanc Township as well as extending into the northern half of section 1 in Holly Township to the south. Much of the Woodfield PUD, which was built in 2000 and includes several hundred single-family homes and condominiums intertwined with golf courses, was not predicted as urbanized land. It should be mentioned that despite the larger number of residences, the Woodfield PUD is classified as an "open-space development" replete with an 18-hole golf courses and walking trails. Several respondents also expressed concern over the model's prediction of urbanized land around Halsey Road in the SW quadrant. Some respondents mentioned that in their opinion the areas around Halsey Road could not be considered "changed" to urban in 2000.

The respondents then examined Category 2 (green tone on Figure 4) on the LTM map where change occurred, but was not predicted by the model. Many respondents weighed in less on the areas where the LTM did not predict change, but more on the fact that these areas had not become urbanized by 2000. The comments on the areas depicted as having changed to urban mirrored those mentioned above concerning the Halsey Road corridor. In essence, many respondents felt that the areas shown as urbanized in 2000 were not entirely correct. However, the respondents felt that these were relatively isolated and confined mainly in the SW quadrant in the Halsey Road corridor. These opinions did not detract from their overall opinions on the accuracy of the projections.

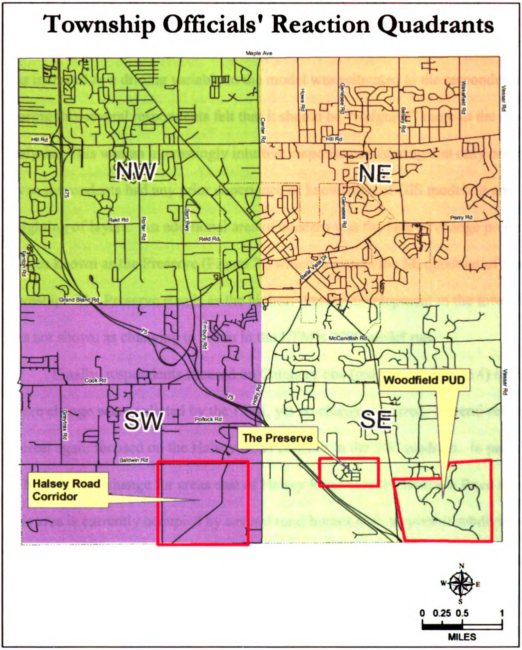

Figure 7. Grand Blanc Township quadrants used to categorize respondents opinions on LTM map series results.

Additional concerns focused on their opinions of areas where the LTM "missed the boat" (according to one observer) in not predicting urbanization. Many of the comments focused on the influence of Interstate 75 (I-75) which bisects the township in a SE-NW direction. Respondents felt that the model should have accounted more for the influence of I-75 on development in the township. The fact that distance to highways was included as a driving variable in the model was reiterated to the respondents. Upon hearing this several respondents felt that it should be "weighted" more in the model analysis. This was an interestingly intuitive response considering that only one of the seven respondents had any prior experience or knowledge of GIS modeling and weighting of layers. An additional area of concern was the lack of change prediction for an area known as the Preserve (Figure 7), which is also in the SE quadrant of the township. The Preserve stands as the highest-density development in the township, but was not shown as changing to urban in the LTM's 2000 model run.

Finally, respondents focused on Category one (red tone on Figure 4) in the model where change was predicted by the LTM, yet no change occurred. Several respondents' interest again focused on the Halsey Road corridor in the SW quadrant. In particular, the LTM predicted change for areas east of Halsey Road near the Baldwin Road intersection. This area is currently occupied by several rural homes with no platted subdivisions. The additional areas shown incorrectly according to the respondents runs north-south along Vassar Road in the SE quadrant of the Township. The area was not developed in 2000, but many pointed out that several subdivisions are currently being looked at in the region.

4.2.3 OPINIONS ON LTM EXTRAPOLATION – FIVE PERCENT PROJECTIONS

After examining the predicted urbanization pattern in 2000 depicted in Map Series #1, the respondents proceeded to Map Series #2 (Appendix A) and #3 (Appendix B), which displayed areas predicted as transitioning to urban in five-percent increments of five to one-hundred percent. The map series were broken up in two different sections. Map Series #1 displayed the result maps showing five-percent incremental increases from five to fifty percent, while Map Series #2 displayed maps showing increases from fifty-five to one-hundred percent. Although the maps portrayed identical types of data, it was decided that the respondents would be more apt to offer opinions if the maps were broken up in two distinct map series. This allowed the respondent to digest all the information presented to them in smaller amounts of ten maps per series versus twenty maps total for both series.

The respondents first examined Map Series #2, which was met with mixed results. Many respondents expressed concerns similar to those mentioned during examining the 1978-2000 predictive run. Namely, many felt that the Woodfield PUD in the SE quadrant should indicate an increase in urbanization. Respondents also felt that the rapid encroachment of urbanization around the Halsey Road corridor was unlikely based on their knowledge of the region. One respondent even categorized the Halsey Road prediction as a "total miss." However, it was pointed out by another respondent that the model may be reacting to the Genesys Hospital development which lies on the north side of Baldwin Road near I-75 and directly across from the Halsey Road region. Another opinion that was expressed regarding the Halsey Road region referenced the fact that Halsey Road is still an unpaved road, and one of only several miles of dirt or gravel roads in the township. The respondent's point was that Halsey Road's development will be inexorably linked to the inevitable paving of the road, hence leading the respondent to concede that the model may be more accurate than originally thought in the SW quadrant. The northern border of the township is defined by Maple Ave, where one respondent expected the LTM to indicate more development based on "cheaper housing and access to Grand Blanc schools." Another respondent expressed concern over the model showing development in the NW quadrant along Porter Road. The respondent mentioned that non-buildable wetland areas exist in the region were displayed as converting to urban.

The respondents then examined Map Series #3, which displayed urbanization increases from fifty-five to one-hundred percent. Respondents were much more verbose and detailed in their opinions of the maps, which allowed for interesting discussions regarding the apparent ability of the LTM. Comments on the final series' pattern of urbanization ranged from "I don't' understand why Halsey would develop" (once again referring to the Halsey Road corridor), to "Glad I'll be retiring!" expressed eloquently by one respondent after viewing the nearly total conversion to urban on the 100 percent increase map. Many of the comments centered on concerns over the model's predicted lack of urbanization in areas the respondents were certain would develop over a reasonable time frame. Once again, the Woodfield PUD was mentioned as a curious anomaly in the model results. Several respondents felt that the model didn't develop the area adequately in future extrapolations of urbanization, which was a similar concern in the 2000 prediction. The common theme was that respondents turned the map pages anticipating that the model would eventually "get it right" in accordance to their opinion. The focus on the Woodfield PUD in some ways became a litmus test for the overall accuracy of the model, as 6 of the 7 respondents independently mentioned its lack of development on the extrapolation. Several respondents also expressed their opinion that perhaps the forested areas in the Woodfield PUD were somehow preventing the LTM from increasing urbanization in that region. One respondent did point out that in some ways the LTM handled Woodfield correctly in their opinion since predicted urban didn't cover all of the Woodfield PUD, thereby "preserving the 'character' of Woodfield" with its golf courses and open space.

Additional comments on the maps referred to the lack of development in the SW quadrant's southwest corner. Specifically, three developments of over 300 homes each have been approved or are under construction in the SW quadrant. Respondents had hoped that the model would accurately show future development in that quadrant, as it will invariably happen over the next five to ten years.

4.3 CONCLUSIONS AND RECOMMENDATIONS

4.3.2 LTM 1978-2000 VALIDATION

The inclusion of additional driving variables and expansion of the study region could further refine the LTM and increase predictive accuracy. However, an increase in accuracy would require the same driving variables at an increasing level of detail as the study area grows larger in extent. It was determined early in the process that the influences of existing urban centers necessitated a larger study region surrounding Grand Blanc Township (Figure 2). Although the township was the main focus of the study with its smaller grid cell size, the township's developmental influences extend far beyond its 36-square mile border. Perhaps one of the reasons for the higher PCM rate for the township resulted from the fact that the larger study region surrounding the township was utilized for driving variable grid creation? As shown in figure 5 by the increasing PCM rate over larger cell sizes, the expansion of the study area gradually increases the PCM to a plateau after which the levels would likely decline with additional study region growth. This begs the question, "How far is too far out?" when it comes to the study region. One could ensure all urbanization influences were accounted for by pushing the study region envelope to include county, regional, or even statewide areas. Statewide projections using the LTM have shown that the model can be utilized over large geographic areas using readily available land use data from MIRIS (Public Sector Consultants, 2001). However, this would not likely be practical if highly detailed GIS data were required for such a large region.

Driving variable grids chosen for the study could be expanded to include suggestions made by township officials in their opinion interviews (many of which are described in the next section). One suggestion was to include distance to school districts as a driving variable in the model. This additional input would likely influence the model results in the township if one considers the differences in schools from region to region throughout Michigan on the basis of statistical measures such as the Michigan Educational Assessment Program (MEAP). In the case of Genesee County, the difference between school districts is very pronounced if one considers the disparities in MEAP scores for 2001 between the Flint and Grand Blanc Public School Districts. In high school MEAP tests taken in the fall of 2001, 88% of Grand Blanc high schools met or exceeded statewide standards in mathematics versus 35% in Flint high schools (Genesee County Intermediate School District, 2002). Grand Blanc schools substantially outperformed Flint schools in the additional testing categories of reading, writing, science, and social studies. Datasets of MEAP scores are readily available for school districts statewide, many of which are in database formats that are easily converted to GIS grids for usage in any future LTM runs.

The issue of parcel salability could also be a driving variable in large-scale LTM runs. During many interviews with local officials, occasional comments would be made regarding larger parcels of land that were pointed out as having "never sold" or "will never be sold." These types of observations stemmed from casual or personal knowledge of the parcel's owner and any information the respondent might have regarding the owner's intention to sell their property for future development. If GIS data were available for a municipality, a more objective driving variable could be created that takes into account the distance from these large parcels based on several factors: a "longevity factor" that examines time since last sale or parcel split; parcel size; access to infrastructure; property tax rates; and current zoning classification. Creation of these datasets could influence the model in unforeseen ways if data were obtainable. Unfortunately, even with a more objective criterion for development of the variable, access to GIS data across a study region similar in size as the one used in this study would prove difficult without a county or regional GIS authority in place. This type of analysis will hopefully be possible in the near future as more county, regional and state GIS entities such as the State of Michigan's Center for Geographic Information, and Grand Rapids' Grand Valley Metropolitan Council begin to centralize and distribute their GIS datasets.

Creation of a distance to infrastructure driving variable may also be very influential on a larger-scale model. The pattern of development across a township often follows the location of access to sewer and water infrastructure, and Grand Blanc Township is no exception. If data were available, a driving variable could be constructed using the distance to existing sanitary sewer or water mains or a combination of the two. This variable may even work on a regional context if regional water or sewer systems were taken into account. One example would be the Detroit Water System, which winds its way parallel to the I-69 corridor from Lake Huron into Flint's water distribution plant which distributes water throughout the Flint Metropolitan area. However, the ability to tap into the water line across these counties is limited, so any regional modeling with the water infrastructure variable would have to be examined closely to ensure the correct influence of the variable on model results.

4.3.3 TOWNSHIP OFFICIALS' OPINIONS AND REACTIONS ANALYSIS

Map reading and interpretation is very subjective in its very nature. People often enter into a map reading situation with preconceived notions of what constitutes "correct" and what constitutes "erroneous." These opinions are unique to each respondent since their individual life experiences and collective knowledge influence how they look at the world. The subjective nature of PSS modeling and the often volatile nature of the emotions surrounding the topics of development and urban sprawl, indicates that a high level of confidence must be demonstrated for any predictive model. The LTM provides a solid and proven foundation for land use modeling, but the critical step in testing any GIS model output or map in general is to examine its impact on the intended audience. In many cases this audience is composed of the uninitiated laymen when it comes to topics such as raster-based GIS modeling or neural networks. However, the same audience is often composed of knowledgeable community leaders, planners, and citizens who constitute the "expert panel" when it comes to local knowledge of a region and its history. These individuals come as interested observers and examiners of the end result, and their confidence is then placed into the hands of the session's facilitator, modeler, urban planner, and ultimately of the cartographer. The amount of cartographic skill that is required to properly display the model output is critical to map interpretation by the end user. Recent trends in the field of GIS have seen many educational institutions implementing GIS programs that consist less of formal geographic (and cartographic) training, than they do of "technical institute" style curricula focused on learning popular GIS software packages. Hopefully these institutions will enhance or supplement their programs with formal training in geographic principals, lest the future cadre of GIS practitioners head off to produce maps that may add to the difficulties of the map reader.

In the research, both the technological modeling aspect and the "human element" regarding the response to the model's cartographic output were analyzed. One of the human elements that were taken into consideration relates to the cognitive load on the respondent. During the interviews concerning the map series showing incremental increases, it was observed that the maps were perused very quickly by respondents as they rushed to see the "end result." Respondents were increasingly talkative when examining Map Series #3. This is likely due to the increase in reactions stemming from the spreading pattern of urbanization depicted in the third map series. The number of opinions generated runs counter to the rationale for breaking the maps up into separate map series, which was to ease the cognitive load of the respondent. The data from the respondents also display the most detailed responses and reactions expressed after viewing Map Series #3. Map Series #2 did not generate the response anticipated, as respondents appeared anxious to proceed to last map in Map Series #3 to "see what happens" to the township.

The research and opinion interviews with township officials often took the research in unforeseen directions. One intriguing new direction which evolved was that during and after many of the interviews regarding the urbanization pattern in the township, the conversation often became a forum for the official to express their opinions and rationale as to what drives suburban development. Since the opinion of each respondent on the causes of urban development exerts an obvious influence on their opinion of the LTM results, several interesting points were raised which could lead to future refinement of the model. Many of the additional driving variables suggested for future LTM research such as distance to quality schools, existing infrastructure, and parcel salability, were all "discovered" during these interview sessions.

Several respondents pointed to the fact that the model tended to show development in areas near the fringe of the township, and speculated that access to Grand Blanc Schools were the influencing factor. It was pointed out that the model inputs did not include distance to particular schools or school district regions, but acknowledged that the addition of a school distance driving variable might exert influence on the model. One way this factor could be included would be through the addition of a weighted distance to school district driving variable that could be based upon statistical measures such as retention rates and MEAP scores, which are readily available from the State of Michigan website (State of Michigan Department of Education, 2003). Grand Blanc Community Schools would undoubtedly influence the model as its schools are highly regarded with some of the highest MEAP scores in the State of Michigan

Many respondents also stated that in the case of Grand Blanc Township, development trends point to an influx of population and spreading of development in a south to north fashion. Grand Blanc Township fits the definition of a "bedroom community" with little commercial development but rapid development of residential subdivisions along the southern border with Oakland County. Respondents felt that the model inaccurately displayed heavier concentrations of urbanization heading south from the Flint metropolitan area. Ironically, much of the development on the northern border of the township has cropped up in recent years due to the aforementioned proximity to the Grand Blanc School District. Respondents were informed that the model included distance to urban centers in the nine-square township study region including local cities. One observation is that perhaps the scale of the study area needs to be larger to account for this driving variable. Especially if one tries to extrapolate urbanization trends in a large-scale area such as Grand Blanc Township.

The factor would also depend on the proximity to larger urban centers. In the case of this research, it was decided to include the Flint metropolitan region, but not the Pontiac metropolitan region due to Flint's sharing of a portion of the township's northern border. The results of the LTM's urbanization pattern on the southern fringe may have been much different if the study area included the Metro Detroit region where much of the outward migration to suburban areas originates. However, individual model runs will have to be evaluated on a case-by-case basis to determine the geographic extent necessary to include all relevant factors in the model, which will evolve with future studies of the LTM and its predictive outputs.

4.4 FUTURE RESEARCH AND THE LTM

The research results presented in this study indicate the power and ease of use inherent in the LTM. The small number of required datasets consisting of physical driving variables such as water bodies and roads, and the common GIS functions employed to create these datasets, has led to several applications of the LTM worldwide. One of the goals in this research was to determine the opinions and reactions of local officials on the output presented by the LTM. Although the research employed my own cartographic techniques to display the model results, the intention was to examine the reactions of officials when exposed to the output from technologies as advanced as an artificial neural network. Research has been relatively sparse when examining how end users utilize the maps produced by any PSS or modeling algorithm. Future applications of the LTM should attempt a more dichotomous approach focusing on model refinement and research, as well as the "human element" involving interpretation and mapping of the model output.

When compared to other planning support systems, it's apparent that the LTM exists simply as artificial neural network "engine." Many PSS applications include an advanced graphical user interface (GUI) from which to perform a variety of planning and GIS-based routines. The LTM exists in a "raw" form only, using a command-line interface without the GUI familiarity expected by most computer users. Although the researcher may be familiar with the GIS inputs necessary for the system, the lack of an interface or input "wizard" to feed data into the LTM could create difficulty for users unfamiliar with the system.

The future of the PSS in the opinion of this researcher should be to invest in an effort to transform the LTM from a stand-alone modeling package to a fully-functioning PSS on par with other software in this burgeoning field. It is recognized that it might not be the goal of the developers to take the package beyond a purely theoretical research tool. However, the relative ease of use and power of the model engine could be a valuable addition to the suite of tools available in other PSS packages. Integration of the model into an existing PSS could complement tools such as policy analyzers and three-dimensional visualization routines to assist the decision-making capabilities of the end user. The result may be beneficial to both the developers of the LTM to receive wider usage of their model to assist in sensible planning, as well as to planners and officials seeking tools to visualize the impact of planning decisions on their local communities.

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APPENDIX A
Map Series #2
Five Percent Increment Maps
Five through Fifty Percent

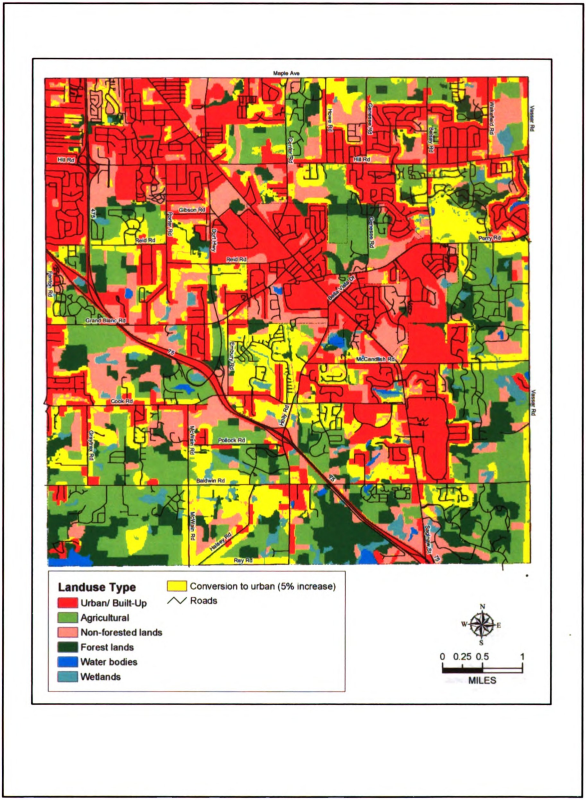

Figure 8. Five percent increase in conversion to urban.

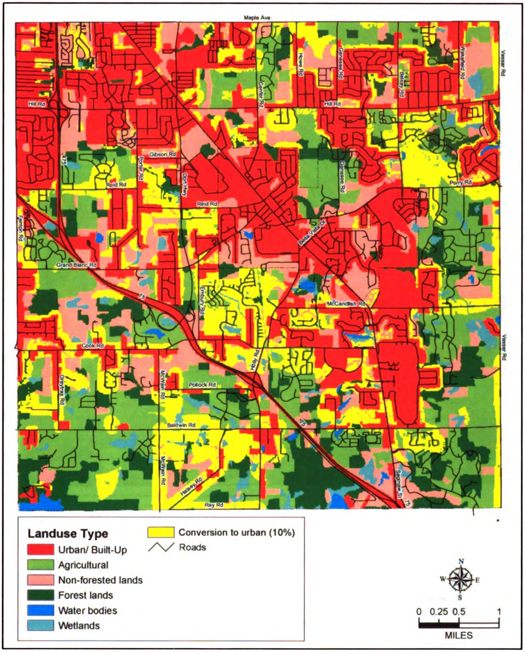

Figure 9. Ten percent increase in conversion to urban.

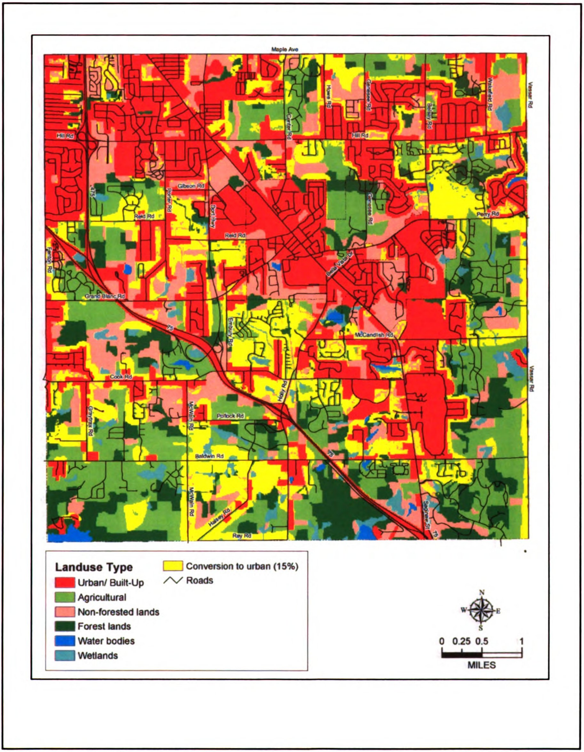

Figure 10. Fifteen percent increase in conversion to urban.

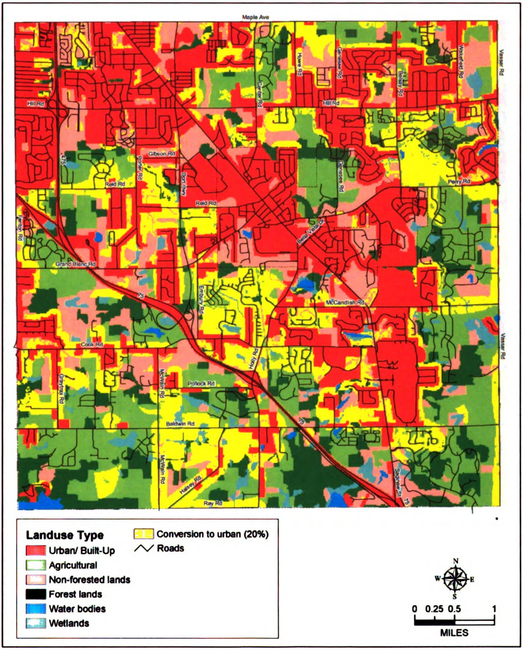

Figure 11. Twenty percent increase in conversion to urban.

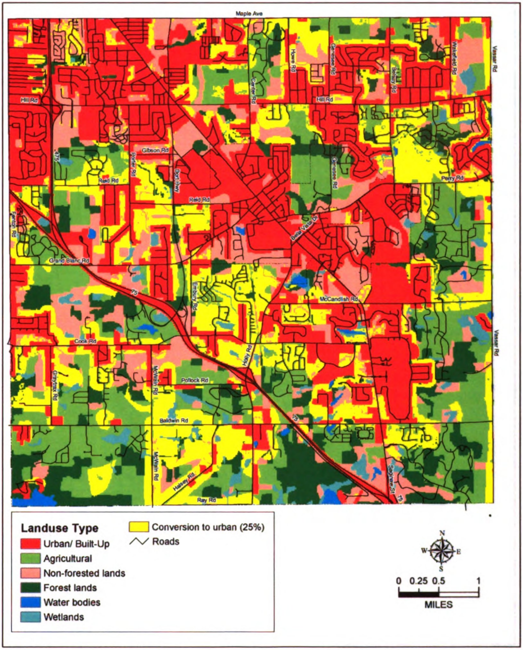

Figure 12. Twenty-five percent increase in conversion to urban.

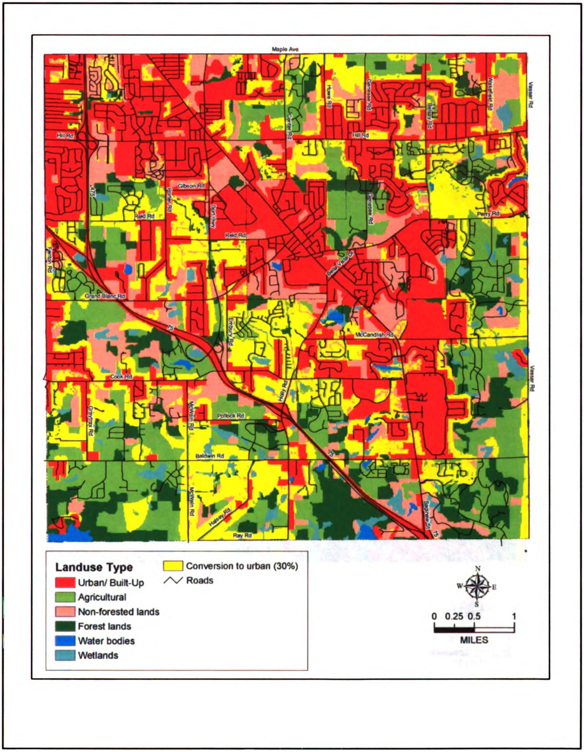

Figure 13. Thirty percent increase in conversion to urban.

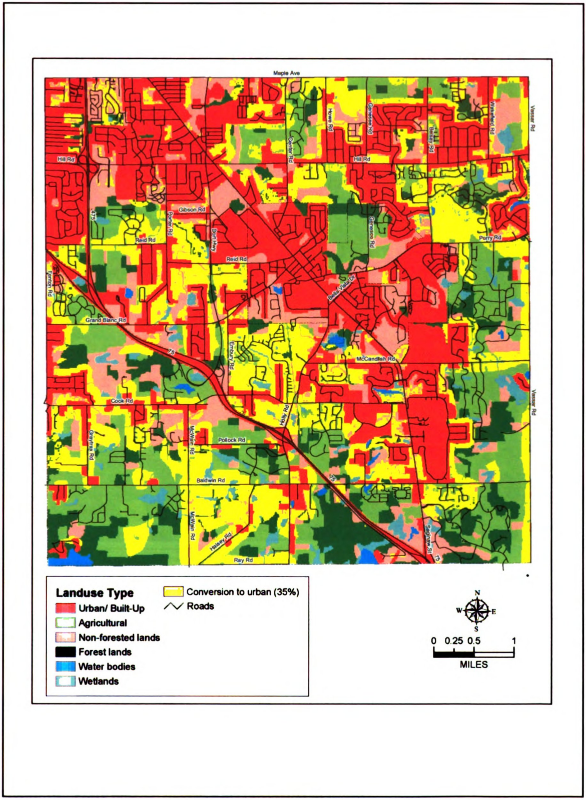

Figure 14. Thirty-five percent increase in conversion to urban.

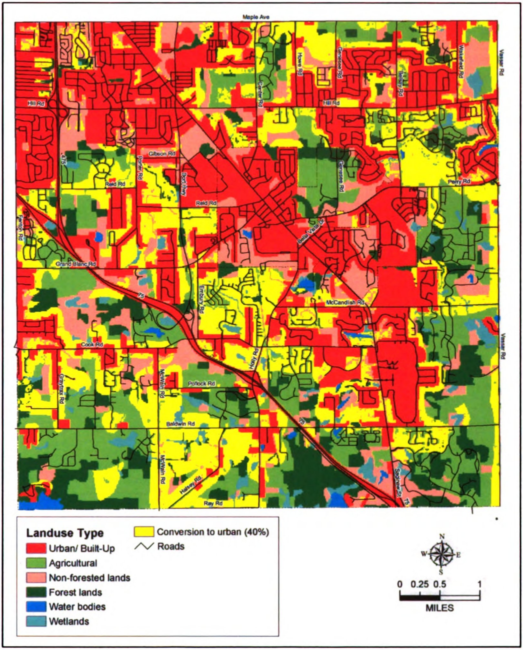

Figure 15. Forty percent increase in conversion to urban.

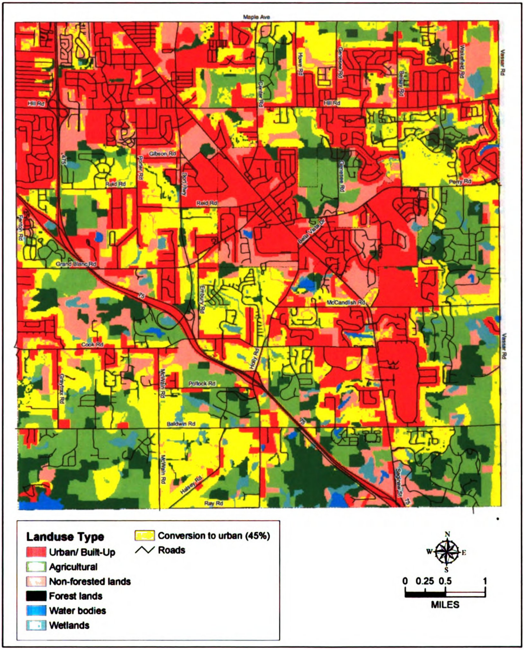

Figure 16. Forty-five percent increase in conversion to urban.

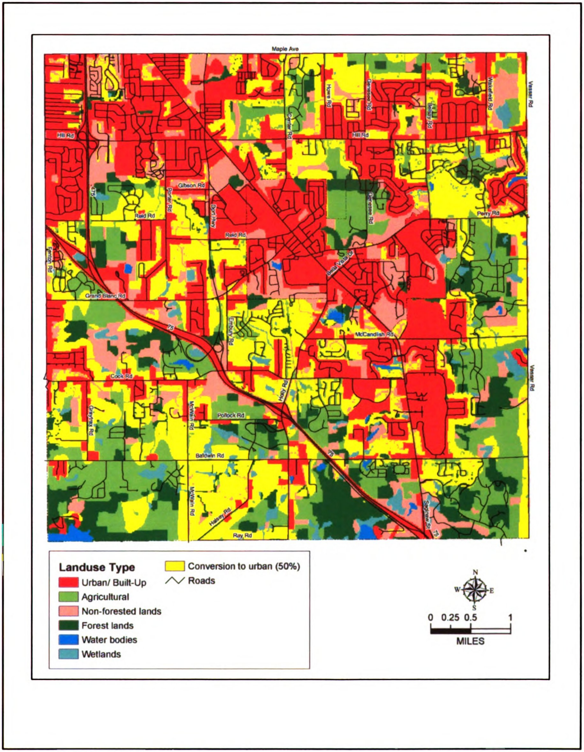

Figure 17. Fifty percent increase in conversion to urban.

APPENDIX B
Map Series #3
Five Percent Increment Maps
Fifty-five through One Hundred Percent

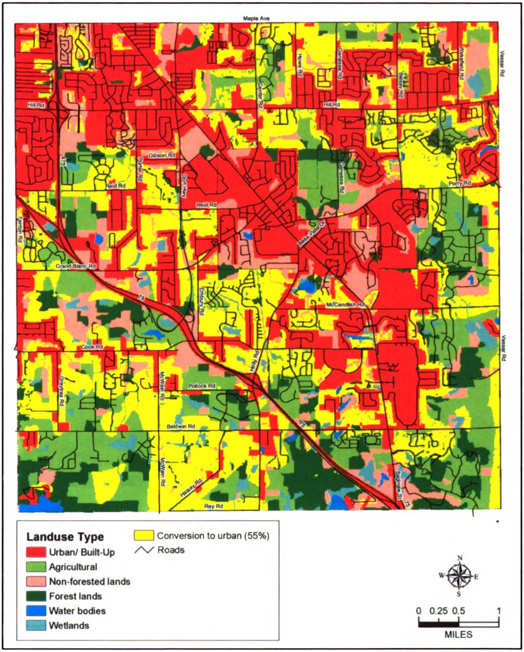

Figure 18. Fifty-five percent increase in conversion to urban.

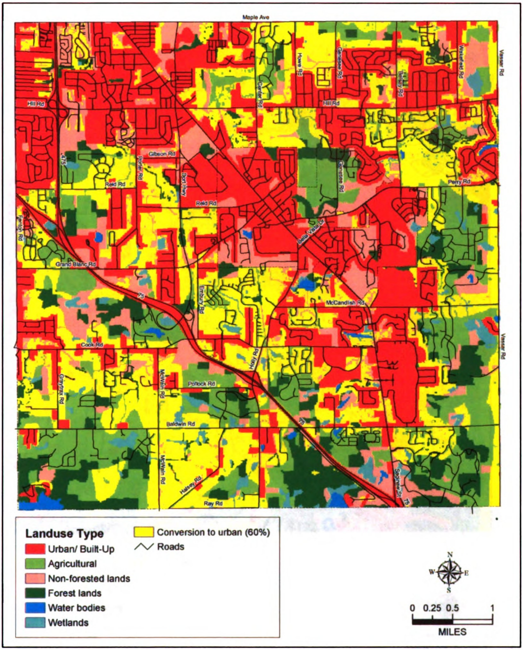

Figure 19. Sixty percent increase in conversion to urban.

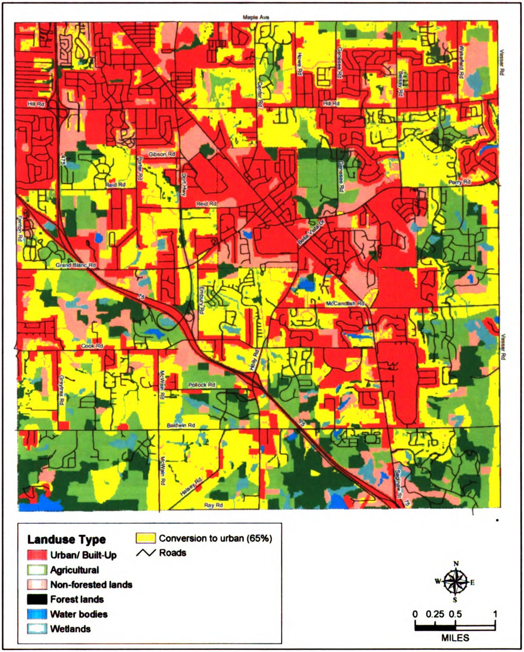

Figure 20. Sixty-five percent increase in conversion to urban.

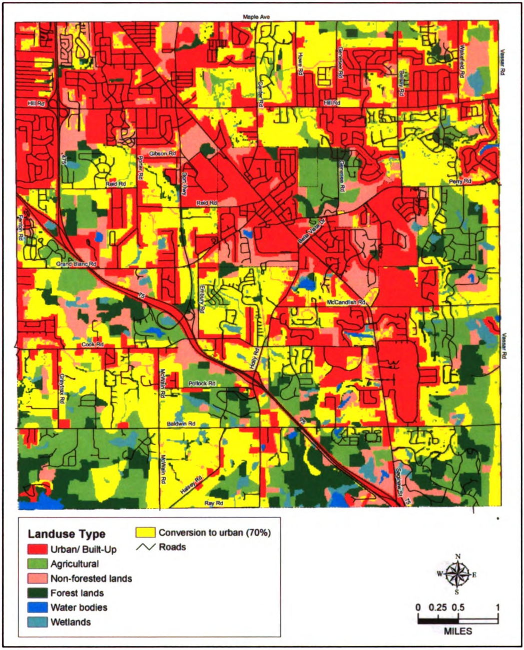

Figure 21. Seventy percent increase in conversion to urban.

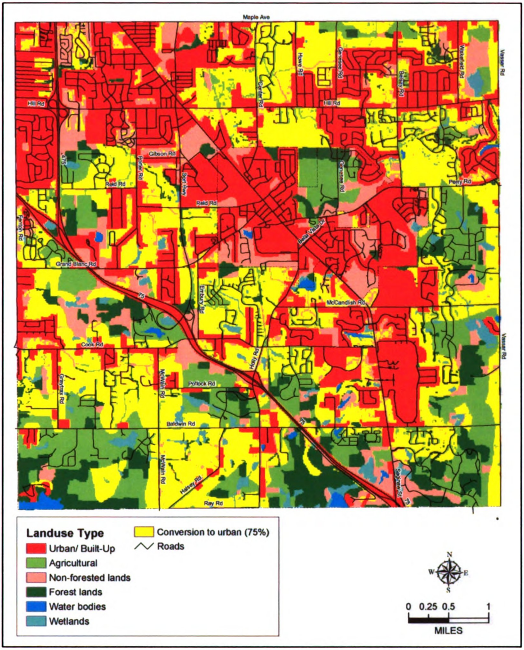

Figure 22. Seventy-five percent increase in conversion to urban.

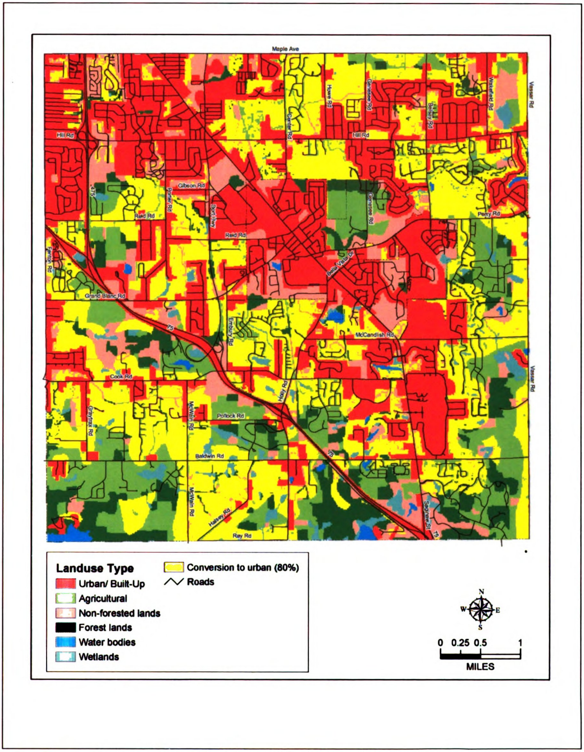

Figure 23. Eighty percent increase in conversion to urban.

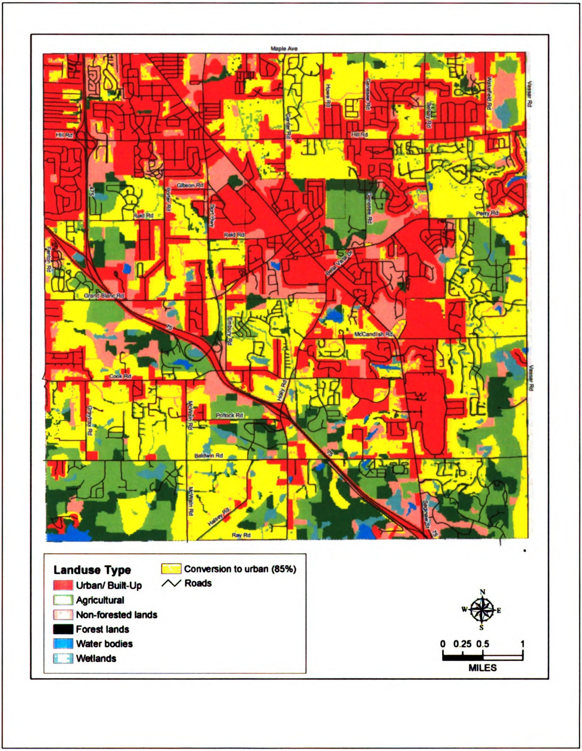

Figure 24. Eighty-five percent increase in conversion to urban.

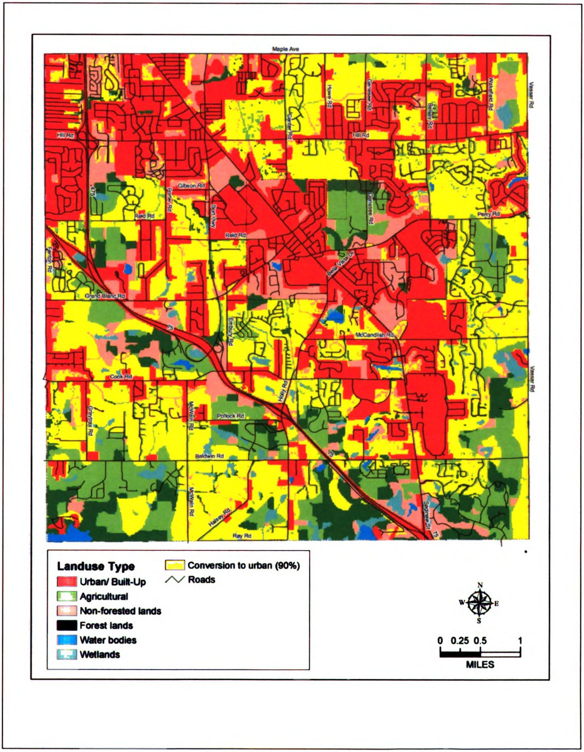

Figure 25. Ninety percent increase in conversion to urban.

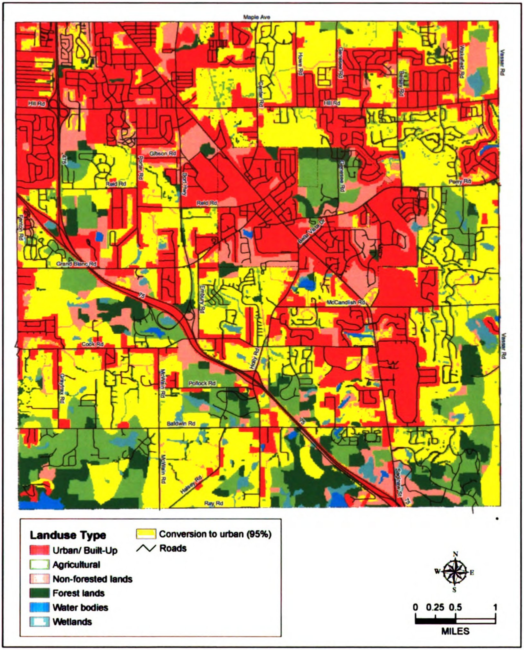

Figure 26. Ninety-five percent increase in conversion to urban.

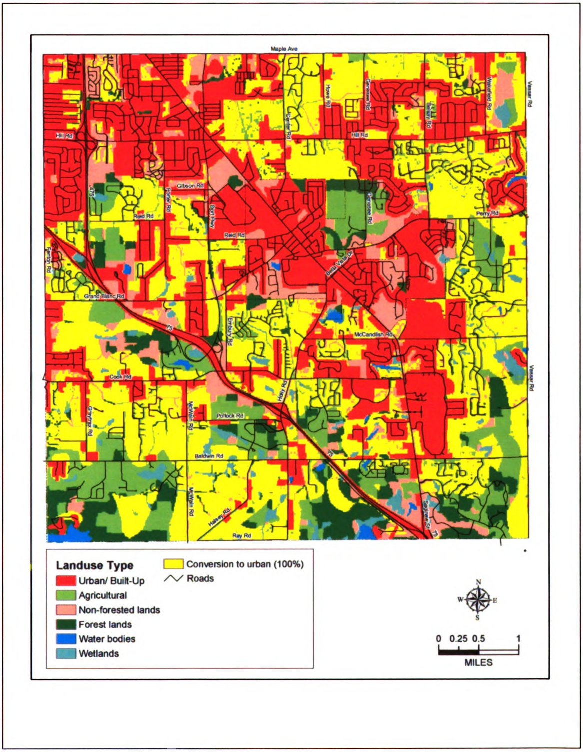

Figure 27. One-hundred percent increase in conversion to urban.

APPENDIX C. FIVE PERCENT INCREMENT SPREADSHEET CALCULATIONS

Urbanization Increase Percentage	Number of Cells (out of 50,060)	Change Threshold Value
0	50,060	43,698
5	52,563	42,076
10	55,066	40,501
15	57,569	38,894
20	60,072	37,514
25	62,575	36,239
30	65,078	34,962
35	67,581	33,862
40	70,084	32,787
45	72,587	31,834
50	75,090	30,937
55	77,593	30,145
60	80,096	29,429
65	82,599	28,769
70	85,102	28,060
75	87,605	27,428
80	90,108	26,782
85	92,611	25,951
90	95,114	24,651
95	97,617	22,922
100	100,120	20,994

APPENDIX D. UCRIHS ORAL CONSENT FORM

ORAL CONSENT FORM
FOR MASTERS THESIS RESEARCH

Study Title: Validation of the Land Transformation Model (LTM) to Predict Land Use Changes in Grand Blanc Township, Michigan

Abstract: The issues of sprawl and suburban development have focused attention on the necessity of sound land use planning practices through the use of growth management techniques. One of these techniques involves the use computer modeling through the usage of Geographic Information Systems (GIS). GIS allows communities to utilize existing geographic data to aid collaborative planning efforts through the extrapolation, prediction, and allocation of potential land use scenarios for a municipality. These scenarios may then assist in amending or implementing changes in zoning ordinances in order to realize these hypothetical futures. However, no empirical analyses have taken into account the predictive accuracy of these models in determining future land use patterns. In this study, Grand Blanc Township, Michigan was analyzed using the Land Transformation Model (LTM) created by Michigan State University. Historical land use data, circa 1980, was entered into the LTM and used to simulate land use patterns for the year 2000, as well as projections simulating urbanization patterns at increasing percentages across the township.

Confidentiality and Anonymity: Your privacy regarding this study will be protected to the maximum extent allowable by law. Participation in this research project is voluntary. You may refuse to answer specific questions or withdraw from this study at any time without penalty. No direct quotations will be used in the aggregate data collected in this study. All data and observations will be destroyed after study completion.

Contact Information: If you have any questions about this study, please contact the investigator at the following:

Project Investigator:	Matthew H Malone
Address:	PO Box 190, Grand Blanc, MI 48439
Phone:	810-513-0282
Email:	malone@twp.grand-blanc.mi.us

If you have questions or concerns regarding your rights as a study participant, or are dissatisfied at any time with any aspect of this study, you may contact – anonymously, if you wish – Ashir Kumar, M. D., Chair of the University Committee on Research Involving Human Subjects (UCRIHS) by phone: (517) 355-2180, fax: (517) 432-4503, email: ucrihs@msu.edu, or regular mail: 202 Olds Hall, East Lansing, MI 48824.

RESEARCH QUESTIONAIRRE
FOR MASTERS THESIS RESEARCH

Estimated Time of Completion: Thirty (30) minutes.

Oral Instructions for Subjects: Please examine the three maps presented to you as output from the Land Transformation Model (LTM).

1. The first map represents the LTM's prediction of urbanized areas in Grand Blanc Township in the year 2000. These predictions were made utilizing GIS data representing 1978 land use patterns. What is your opinion on the accuracy of the pattern of urbanization depicted on the map based upon your knowledge of Grand Blanc Township?

2. The second map series represents the LTM's prediction of urbanized areas as projected using five (5) percent intervals in urbanization in Grand Blanc Township. These predictions were made by extrapolation of urbanization patterns from the year 2000 and depict future urbanization patterns at five (5) percent intervals ranging from five (5) percent to fifty (50) percent. What are your opinions, insights, or comments on the pattern of urbanization depicted on this map series for Grand Blanc Township?

3. The third map series represents the LTM's prediction of urbanized areas as projected using five (5) percent intervals in urbanization in Grand Blanc Township. These predictions were made by extrapolation of urbanization patterns from the year 2000 and depict future urbanization patterns at five (5) percent intervals ranging from fifty-five (55) percent to one hundred (100) percent. What are your opinions, insights, or comments on the pattern of urbanization depicted on this map series for Grand Blanc Township?