Using GIS to Identify Suitable Areas for Smart Growth and Transit Oriented Development (TOD) for Specific Areas within the City of Minneapolis, Minnesota.

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Abstract

Renewed interest in America's cities and investment in transit has lead to the development of new transit oriented developments (TODs) and Smart Growth developments being built all across the country (Belzer and Gerald, 2002). Identifying and assembling large tracts of land that satisfy all the conditions for successful transit oriented development can be difficult (Boarnet and Compin, 1999). Advocates claim that communities benefit from TODs that provide compact development, decrease automobile dependency, add retail opportunities, and improve quality of life (Tumlin and Millard-ball, 2003). It has also been shown that making the connection between land use and transit choices such as building light rail transit (LRT) can be used as a tool to revitalize neighborhoods, end cycles of poverty and lower crime rates (Havens, 2010). Geographic Information Systems (GIS) are a powerful tool that can be used to organize, sort, and analyze spatial data. GIS can be used to create models that reflect an area's propensity to sustain TODs and other higher density Smart Growth developments. GIS and Model Builder were used in this study to create models to identify areas within the City of Minneapolis most suitable for development of Smart Growth and TODs, and establish a set of criteria for ranking suitability: Land Use, Community Features, and Transit.

Introduction

Smart Growth is defined by the Smart Growth Network as "anti-sprawl development that is environmentally, fiscally, and economically smart and includes land-use planning, and mixed use development" (Smart Growth Network, 2009). A general consensus for transit oriented development would be mixed use developments that are pedestrian friendly with convenient transit service in a close proximity (Boarnet and Compin, 1999). New TODs and Smart Growth developments are being built all across the country due to a number of trends occurring in recent years that have increased the popularity of TODs and urban living: revival of America's downtown areas, continued growth and expanding maturity of America's suburbs, and the renewed interest and investment in transit (Belzer and Gerald, 2002).

Multimodal transportation choices are an important element of

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TODs and Smart Growth development. Light rail transit (LRT) can be one of those options and is seen as more than a way to just move people. According to Robert Cervero, it has been used as a tool to revitalize neighborhoods, end cycles of poverty and lower crime rates (Havens, 2010).

Cities and regions are developing policies to help promote this renewed interest in Smart Growth development and TODs by understanding the connection between land use and transit options in order to alleviate problems associated with rampant, unplanned development (Renne, 2005). Advocates claim that communities benefit from TODs because they provide compact development, decreasing auto dependency, adding retail opportunities and improving quality of life (Tumlin and Millard-Ball, 2003). Policies and restructured zoning ordinances can help to steer development away from dependency on automobiles and toward Smart Growth (Handy, 2005).

Purpose of Study

In 2008, the Minnesota state legislature authorized the seven core counties in the Minneapolis-St. Paul Metropolitan Area (Anoka, Carver, Dakota, Hennepin, Ramsey, Scott, Washington) to levy an additional ¼ cent sales tax to fund improvements to the transit system, including light rail, commuter rail and bus rapid transit. Five of the core seven counties authorized the new tax: Anoka, Dakota, Hennepin, Ramsey, and Washington. The additional tax in these five counties brought in $87 million in 2009 (Olson, 2010).

The renewed interest in urban living and a new funding stream for transit make this an opportune time to invest in Smart Growth and TODs. It has been shown that a connection between land use planning and transit investment can be vital to the success of a transit system (Handy, 2005). Residents of transit-based housing are as much as five times more likely to commute to work using rail than their counterparts (Boarnet and Compin, 1999). Investment in transit and TODs will assist with attracting to cities the young and educated people aged 25 to 34, who will be essential to the wellbeing of metropolitan areas in the future (Cortright and Coletta, n.d.).

It can be difficult to identify and assemble large tracts of land that satisfy all the conditions for successful transit oriented development (Boarnet and Compin, 1999). Geographic Information Systems (GIS) are a powerful tool that enables spatial data to be easily organized and analyzed, creating models that reflect an area's propensity to sustain TODs and other higher density Smart Growth developments. The study utilized GIS and Model Builder models to identify suitable locations for Smart Growth and transit oriented developments within the City of Minneapolis.

History

Minneapolis is the largest city in Minnesota and is part of the Twin Cities (Minneapolis-St. Paul-Bloomington, MN-WI Metropolitan statistical area), the 16th largest metropolitan area in the country with a population of 3,175,041 (US Census Bureau, 2007). The Metropolitan Council, Regional Planning Organization for Minneapolis-St. Paul, estimated the City's population at 390,131 in 2009 (Metropolitan Council, 2009).

Minneapolis is the primary business center between Chicago and Seattle and was once the flour milling capital of the world and a major hub for timber. Today, the city and surrounding metropolitan area house corporate headquarters for a wide variety of companies, from banking and investment firms to retailing giants to global advertising agencies (Emporis, 2010). The largest private company in the United States, Cargill, is headquartered in the Twin Cities (Ray, 2009) as well as 18 Fortune 500 companies, five of which are located in Minneapolis proper (Fortune Magazine, 2009). Minneapolis is also home to the main campus of the University of Minnesota, the fourth largest university campus in the United States, with 51,140 students in 2008–2009 (National Center for Education Statistics, U.S. Department of Education, 2008-2009).

In 2000, Minneapolis had the second highest population density for any city over 100,000 in the Midwest, below Chicago, at 6,970 people per square mile (Demographia, 2005). Participation in alternate modes of transportation is prevalent in Minneapolis where in 2007 almost 40 percent of residents traveled to work without driving alone. During the same year bicycle commuting in the City of Minneapolis was second highest in the United States with 3.8 percent of commuters using cycling as their primary mode of transportation; this was just below top-ranked Portland, which held a 3.9 percent share (Transit for Livable Communities, 2010).

City of Minneapolis Objectives

The Minneapolis Plan for Sustainable Growth (City of Minneapolis, 2009) is the visioning document for the City that guides how growth and development should occur within the City. It is a tool used to coordinate development in a sustainable manner to improve the quality of life for everyone. The plan deals with the following areas: land use, transportation, housing, economic development, public services and facilities, environmental, open space and parks, heritage preservation, arts and culture and urban design in the City. A considerable amount of public knowledge and work went into this plan that provides great insight into the future development for the City of Minneapolis. This work and knowledge about the City was valuable to the study, especially the Land Use Chapter which had significant importance in this study by identifying five designated areas for development: Commercial Corridors, Commercial Nodes, Industrial Growth Areas, Activity Centers, and Growth Areas. This provided an understanding from the City's perspective of areas most likely to incur future development as well as higher density mixed-use development.

Methods

This study classified lands based on their suitability to support TODs and medium to high density Smart Growth development within the City of Minneapolis. The results of this analysis will be useful for city planners, policy makers, and real estate developers by providing an understanding of locations suitable for these styles of development.

Methodology

This study utilized 21 different feature classes that were each assigned a numeric value corresponding to their level of influence on TOD and Smart Growth development. For those feature classes that were not polygons, but were either point or polyline features, they had to be buffered a distance that ranged from one-eighth of a mile to one-half a mile with respect to their influence on surrounding land.

In ArcMap the feature classes were organized and separated into three unique submodels using Model Builder: Land Use, Community Features, and Transit. The models produced three separate feature classes that identified lands within the City of Minneapolis that had the highest likelihood for success with regard to their respective model. A final model was built in Model Builder to combine these three feature classes into one final feature class that identified lands most suitable for Smart Growth and TODs.

Figure 1 provides an illustration for the general process of how the layers (feature classes) were each assigned a value from 1-3 based on level of importance, 3 being the most suitable lands. The layers were then laid on top of each other and combined, using the geoprocessing task, Union, to produce a final layer (feature class). The total value was derived by adding all the values of each feature class together where they overlapped. Areas where more layers overlapped generally had a higher value than areas with fewer.

Preparation of Data

A number of steps were taken to collect, create and organize the data before any analysis could begin. Many of the datasets were obtained from MetroGIS and MnGeo, two different websites designed to help share geospatial data. The aerial imagery was provided by MnGeo through a Web Map Service (WMS), protocols for serving over the internet georeferenced map images that have been created by a map sever using GIS data (Consortium, 2010). There were other datasets that needed to be obtained from other sources and digitized manually.

The location of many of the carsharing vehicles was obtained directly from HourCar. They provided an .xls file with the lat/long coordinates that were used in ArcMap and converted to a feature class using the X, Y command. The City of Minneapolis' Community Planning and Economic Development Department (CPED) provided six shapefiles all derived from the land use chapter of the Sustainability Plan for Growth. These shapefiles were Commercial Corridors, Growth Centers, Activity Centers, Commercial Nodes, Major Retail Centers, and Industrial Growth Areas**.** These shapefiles take advantage of all the work that went into the City's Sustainabiliy Plan for Growth that determined areas with a high

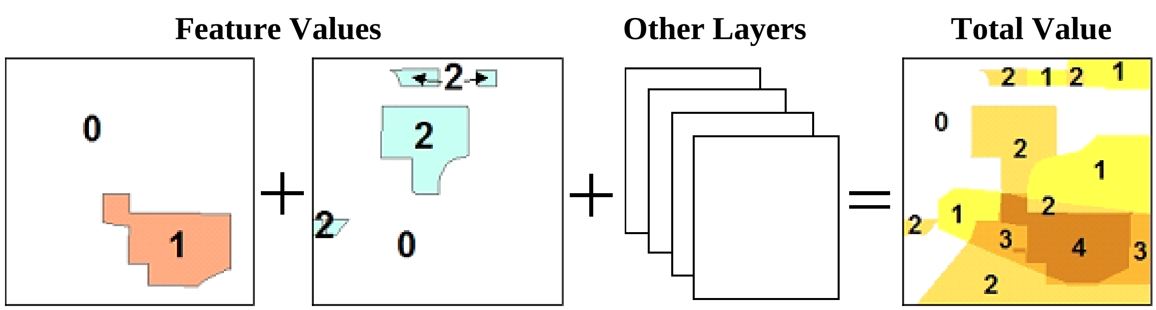

Figure 1. Process undertaken during analysis to evaluate data layers to create final suitability layer.

likelihood of where future growth will occur and where high intensity uses should develop**.**

In order to effectively use all the shapefiles provided by the City of Minneapolis in this study, two out of the six needed to be digitized. The Commercial Corridors and Growth Areas were polyline and point features, respectively. These two shapefiles were used in coordination with aerial imagery obtained from the WMS Service provided by MnGEO to manually digitize the polygon boundaries. It was decided that digitizing the polygon for these two datasets would provide a representation better suited for the study rather than creating a generic buffer around all the features. The advantage of digitizing was that items such as highways, rail yards, parks, rivers or lakes could be excluded from the polygon because these were areas that should not be identified as suitable land uses for development. The four remaining shapefiles were already polygon features and were just converted to feature classes and ready to use.

The last step in preparation was to clip any data that went beyond the boundary of the City of Minneapolis. Because the data came from numerous sources there were different extents of data: City, County, Region, and State. It was found to be easier to sort the data when it covered only the area within the City of Minneapolis.

Organization of Data

All data in this study was stored and managed in ESRI's File Geodatabase format. ESRI states that this "offers structural, performance, and data management advantages over personal geodatabases and shapefiles" (ESRI, 2009). The main advantages for use in this study were ease of data migration and storage and more optimal performance with large files. Within the File Geodatabase there were four feature datasets, one for each submodel and one for all the feature classes created during the analysis of the final model.

Evaluation of Data for Model Builder

As mentioned previously, all data layers were given a numeric value that correlated with their influence on making lands suitable for desired development. Feature classes that were either point or polyline also were buffered a specific distance corresponding to their influence on surrounding land, values ranging from one-eighth of a mile to one-half a mile. A great deal of thought and research went into devising the numeric values assigned to feature classes and the distance of buffers. Information from numerous articles were identified in the literature review (Metropolitan Council, 2006, Basile Baumann Prost and Associates, 2007, Canepa, 2007,) that provided insight into what land uses, transportation infrastructure, and community related features were catalysts for TODs and/or medium to high density Smart Growth development. HourCar, the nonprofit carsharing company in Minneapolis and St. Paul, said that most of its members were located within one-half mile from vehicles, so this buffer size was used for their vehicles as well as ZipCar's vehicles. The Minneapolis Plan for Sustainable Growth (City of Minneapolis, 2009) also provided insight and knowledge about the community and what areas would be ideal locations within the city for development.

Radius distances varied between researchers because some provided numeric distances while others provided walking distance in time. A simple calculation was needed to compare these two methods of measurement. The average walking speed according to a study by TransSafety, Inc. states that it can vary between 2.80 miles per hour and 3.0875 miles per hour depending on age (TranSafety, Inc, 1997). The study determined that 2 miles per hour would be suitable for the formula and would provide sufficient time for waiting for traffic, signals or other obstacles.

(*2mph * Walking Time (minutes) / 60 minutes = X Miles)*

An example of determining the radius distance in miles for a 10 minute walk would be:

*2 mph * 10 minutes / 60 minutes = 1/3 Mile*

Model Builder

Model Builder is an application created by ESRI that works with ArcMap and allows a user to create, edit, and manage models. It is scalable and easily adjustable, which made it an ideal tool during this study. It works by being able to organize both feature classes and geoprocessing tasks in a diagram that is easy to follow and understand, and it provides great reference for future studies. There were a total of four models built with Model Builder in this study, one for each submodel and one for the final model.

The models used numerous geoprocessing tools from the suite of tools in ArcGIS toolbox: merge, select, intersect, buffer, delete field, add field, calculate field, union, clip, and dissolve. Most of the geoprocessing tasks preceded use of the union tool, which provided a way to sum all the values for each of the feature classes together and obtain the final suitability value for each submodel. After the union was performed in each submodel the new feature classes were dissolved based on the suitability value. This created a feature class with the number of records equal to the number of unique suitability values for each particular feature class. These new feature classes were then clipped to the City of Minneapolis, so that the extent of the feature classes would be within the boundary of the City. A similar process was performed in the final Model Builder model to combine all three submodels using the union tool in ArcToolbox to obtain a feature class that summed the suitability values from the submodels into the final feature class where a final suitability value could be determined. This feature class also went through a dissolve to minimize the number of records. After using Model Builder, the final four feature classes, three from the submodels and one from the final model, underwent further analysis so comparisons could be made between suitability values and the total land acreage and percent of land each contained within the City of Minneapolis.

Land Use

The exact layers used within the Land Use submodel as shown in Table 1. It contains the names of the five feature classes that were used in the study and information about the feature polygon, and the numeric value assigned to each feature class. The higher the assigned value the greater the level of influence that layer had on suitability. The Land Use submodel was the only model to include a feature class, Industrial Districts, which was not given a numeric value. The 'Erase' tool from ArcToolbox was used to remove all these lands from consideration in the Land Use submodel, because this area was identified by the City of Minneapolis' Plan for Sustainable Growth (City of Minneapolis, 2009) as prime Industrial Land that should stay Industrial for the foreseeable future. This study believed this warranted a hardship on that land that would be difficult to overcome for development as anything other than industrial use; however, these areas were not removed from consideration in the subsequent submodels.

Table 1. Land Use submodel layers, origin of the polygon, and suitability value of each layer.

GIS Layer	Buffer / Shape	Value
Commercial Corridors	Digitized Polygon	2
Growth Centers	Digitized Polygon	2
Industrial Growth Areas	Polygon City of Minneapolis	Erase
Commercial Node	Polygon City of Minneapolis	1
Comprehensive Plan Designation		
Medium Density	Land Type Polygon	2
High Density	Land Type Polygon	3

Four of the five feature classes used in the Land Use submodel were derived from the City of Minneapolis' Plan for Sustainable Growth. Commercial corridors were digitized using aerial imagery based on the selected roads that were identified in the Plan for Sustainable Growth. These areas were identified as meeting the following criteria: high levels of traffic, mix of intensive commercial uses, light industrial and high density residential uses. The study identified this as a suitable land use with only the suggestion of high traffic areas eliminating this feature from receiving a score higher than 2 (City of Minneapolis, 2009).

The growth centers feature class was also digitized manually using aerial imagery based on what the City's Plan identified for future growth areas within the city. These areas were considered a destination that have high levels of transit service and attract highly skilled workers and high paying jobs. They are distinguished by a concentration of business and employment activities with land uses such as residential, office, retail, entertainment and recreational uses. The value for this layer was selected as 2 because there were areas within the feature class that had land uses such as institutional and commercial that were not considered developable for residential development at this given time (City of Minneapolis, 2009).

The City of Minneapolis identifies the Industrial growth areas as vital to the long-term economic prosperity of the City by providing areas where future employment growth can occur. As mentioned previously, this feature class was used to erase areas from contention in the land use submodel, but these areas were not removed from consideration in the other two submodels.

Commercial Nodes are identified by the City of Minneapolis as areas with a mix of uses that are oriented towards pedestrians rather than automobile traffic, but are limited in service to the surrounding neighborhood. The extent is along one intersection with usually three of the corners operating retail or service oriented business. This feature was given a suitability value of 1 because of the limited influence they have outside of the immediate neighborhood. They do provide some services and generally more intense development that may be able to accommodate additional mixed use development with higher densities.

The Comprehensive Plan (Land Use) feature class was queried to form two different feature classes, medium density and high density and received values of 2 and 3 respectively. The medium densities were all areas from 10 to 30 units per acre and high density were those areas above 30 units per acre. The high suitability values were given because the City of Minneapolis has recognized these areas as appropriate for densities that may provide the critical mass to encourage transit usage and the development of retail in close proximity.

Community Features

The Community Features submodel contained five feature classes but, unlike the Land Use submodel, it combined two of the feature classes into one layer, so there were only four layers that received a suitability score. Table 2 contains the five feature classes used in the community features submodel, information about the feature polygon or the size of the buffer, and the numeric value assigned for each feature class. The two feature classes that were combined were Major Retail and Shopping Centers because they identify similar features, but contain records with different locations within the City. These feature classes were combined using the geoprocessing tool 'Merge'. The Major Retail layer was provided by the City of Minneapolis and the Shopping Centers layer was obtained from MetroGIS.

The Schools feature class was created from a shapefile that was obtained from the MnGEO website that is maintained by the Minnesota Department of Education. A buffer with

Table 2. Community Features submodel layers, the shape of polygon or extent of the buffer, and suitability value of each layer.

GIS Layer	Buffer / Shape	Value
Schools	1/3 Mile	1
Parks	1/4 Mile	1
Major Retail / Shopping Centers	1/4 Mile	2
Activity Center	Polygon City of Minneapolis	3

a one-third mile radius was created to represent areas within a ten minute walking distance at an average speed of two miles per hour. Aside from the students who attend and teachers who work at schools they also serve as neighborhood centers and may house extracurricular events that make living near them a positive, which is why the study gave the layer a suitability value of 1.

The study made the decision that living within one quarter-mile from a park deemed a suitability value of 1. The one-quarter mile buffer created around the Parks feature class equated to a seven and one-half minute walk at an average speed of two miles per hour. The park feature class was obtained from the regional parks shapefile from MetroGIS, but also involved manual digitizing to include the City parks visible on the aerial imagery, because this layer was not able to be obtained from the City of Minneapolis.

According to Greenberg and Dittmar (2004), one of the main goals in advancing TODs benefits is location efficiency. The study identified that areas within walking distance of shopping areas create more opportunities for transit oriented development. The study gave Major Retail / Shopping Centers a value of 2 for any areas within one quarter-mile of these retail centers, approximately a seven and one-half minute walk.

Activity centers are areas within the City that have functioned as a hub of activity for decades. These are areas that attract residents, workers, and visitors throughout the city and region and support a wide range of commercial, office, and residential uses. Apart from these positives they also have a busy street life with a heavy pedestrian orientation that is well-served by transit. The study assigned a value of 3 for activity centers because it was identified as one of the key features to distinguish areas suitable for dense Smart Growth development and TODs.

Transit

The transit submodel contained the most feature classes and the highest possibility of total suitability points, making it the most important factor in determining suitable areas for TODs and dense Smart Growth development. High levels of transit service were considered an important element in creating successful opportunities for TODs and Smart Growth development by being able to use alternate modes of transportation. The proposed central light rail transit line was included in this model. Table 3 contains the ten feature classes used in the transit submodel, information about the feature polygon or the size of the buffer, and the numeric value assigned for each feature class.

Bikeways were considered an important recreational and transportation option for residents in the City of Minneapolis and were believed to warrant a value of 1. The bikeways layer was actually created from merging the bikeways and regional trails feature classes. These two feature classes had common values and if the feature classes were not combined then the areas with overlapping features would have received a value of 2 rather than the 1 the study assigned.

Table 3. Transit submodel layers, the extent of the buffer, and suitability value of each layer.

GIS Layer	Buffer / Shape	Value
Bikeways	1/8 Mile	1
High Frequency Bus Service	1/8 Mile	1
Carsharing vehicles	1/2 Mile	1
Station buffers		
LRT Stations	1/2 Mile	3
BRT Stations	1/2 Mile	2
Commuter Rail Stations	1/2 Mile	2
Bus Stops	1/8 Mile	1
Downtown Fare Boundary	Current Extend of Boundary	1
Park & Ride Station	1/8 Mile	1

High frequency bus service includes bus lines that provide service at least every 15 minutes. Basile Baumann Prost and Associates (2007) state that regular bus service has minimal impact on development, but this study believed that high frequency bus service provides opportunities over regular bus service to influence the desirability of development within a one-eighth mile radius of bus lines and was classified with a value of 1 in the study.

Carsharing is a fleet of vehicles that members share and pay for based on usage and can provide an incentive to drive less and save money (Rodier and Shaheen, 2003). Carsharing vehicles are generally found near high density neighborhoods, job centers, or universities. At the time of this study the City of Minneapolis had 20 vehicles within the city limits. This feature class was given a value of 1 because the location of vehicles had no bearing on the physical form of the community or the transportation infrastructure, but does provide a service and incentive for members to drive less making them more apt to use alternate modes of transportation.

There were three different Transit Stations included in the transit submodel: Light Rail Transit (LRT), Bus Rapid Transit (BRT), and Commuter Rail. All three of these layers received a buffer of one-half mile, but received different suitability values. LRT had a value of 3, with BRT and Commuter Rail having a value of 2. This was based on the Minneapolis Plan for Sustainable Growth and the study done by Basile Baumann Prost and Associates (2007) that concluded that influence extends up to one-half mile and LRT generally attains higher levels of development compared to commuter rail and regular bus service.

The Downtown Fare Boundary feature class received a value of 1 and was a district within the downtown area of Minneapolis that represents the decreased ($0.50) fares on all transit service. The study believed this may influence development because of the incentive to take transit within this district.

Park and ride stations provide access to multiple bus routes and access to the other transit options in the City. The study went with the understanding that multimodal transit centers generally see significant development (Basile Baumann Prost and Associates, 2007). The study determined the multiple bus routes available at these nodes warranted a value of 1 for lands within one-eighth mile from park and ride stations.

Final Model Builder Model

The final model builder model combined the three submodels, Land Use, Community Features, and Transit into a final model. The total points possible in the final model were 30, of those points 10 were land use (33.33%), 7 were community features (23.33%) and 13 were Transit (43.33%).

The intention of the study was to create a model with transit as the key feature for identifying the suitability of TODs and Smart Growth. Land use was determined to be the second highest score because of the importance of land types and densities in creating successful TOD and Smart Growth development. Community features model's objective was to identify areas that had a special appeal, a livability factor, which makes a particular location more desirable than others.

The final model builder model was the easiest to understand and follow since there were only four feature classes, one from each submodel and one for the City of Minneapolis. The following geoprocessing tasks were assigned: Union, Add Field, and Calculate Field**.** A process similar to the three submodels was used, but an additional step was undertaken to add the City of Minneapolis boundary feature class using the union task so that the final feature class would cover the entire City of Minneapolis rather than only those areas receiving a value. The areas within the City that had a value of zero were those areas that were not identified as suitable with any of the submodels.

Results

Further analysis was conducted on each submodel to better understand the total acreage for each scored value and the proportion of the city each value covered. The feature class for each submodel only contained one record for each value because of the 'dissolve' geoprocessing task that was included with each Model Builder model. To determine the acreage for each value a new field was added and then the calculate geometry command was used to find the total acreage for each value and, consequently, the percentage of the City of Minneapolis each value covered.

The submodel results provided an understanding of areas the model depicted as suitable for the three different model types. The results were depicted on a map with only those areas receiving a value shaded. The results table provided the number of points (suitability value) recorded for each model and a breakdown of acreage and percentage of the City each value covered. A bar graph provided a visual understanding of the percentage of land each value covers for the City of Minneapolis.

Land Use Model

The land use model provided an understanding of areas within the City that have mixed use and higher density land types conducive for TODs. Figure 2 contains a map that shows the suitability values from the land use model overlaid on aerial imagery for the City of Minneapolis. All lands that received a value other than zero are shaded in a color; green indicates lower suitability values while orange and red represent areas with higher suitability values. The high and low suitability values are relative to each other because all lands that received a value are considered suitable for development with respect to land use features. The most suitable areas were those in the central portion of the City from the University of Minnesota through downtown and towards Uptown. The highest recorded values (HRV) in the Land Use submodel were in downtown and around the University of Minnesota campus. Other significant areas were the neighborhoods south of downtown that are comprised of medium to high density residential development and the main commercial corridors such as in South Minneapolis and Central Avenue in Northeast Minneapolis.

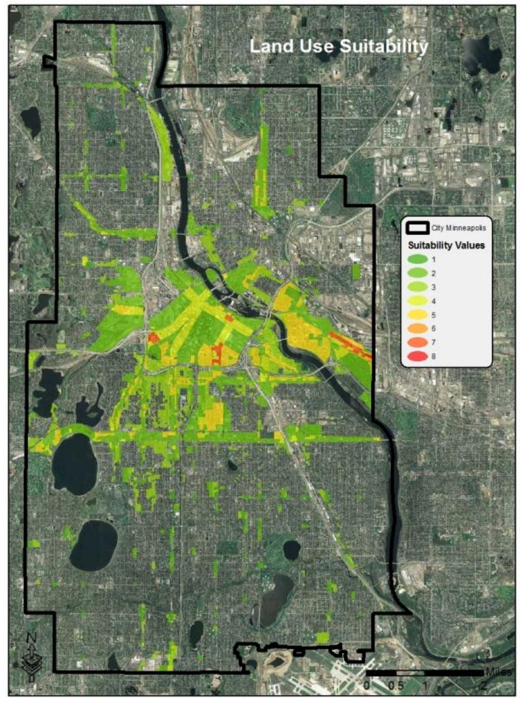

Figure 2. Land Use Suitability values calculated using models created from ESRI's Model Builder.

Table 4 provides statistics for each suitability value recorded in the land use model. The ranges of possible and actual values are indicated on the table, both of which had values from 1 to 8. The 'Total Acres' field and 'City Proportions' field provides information for the total acres and percent of land covered by each individual value. The values with the highest frequency were 2 and 3 with 3,388 and 1,426 acres respectively. The three highest recorded suitability values were 6, 7, and 8 covering approximately 102 acres or roughly 0.28 percent of the City of Minneapolis. The land use model included only18.04 percent of the City or 6,625 acres between the eight different suitability values, which is why all lands that received a value were considered suitable because over 80 percent of the City received no value. Figure 3 provides a representation of the data found in the 'City Proportions' field using a graph to better display the differences between values.

Table 4. Results for Land Use Submodel with possible and actual suitability point ranges and statistics for total acres and percentage of city coverage for each suitability value.

Land Use Submodel Results		
Possible Point Range: 1 - 8		
Actual Range Results: 1 - 8		
City of Minneapolis contains 36,726 acres		
Land Use Points	**Total Acres**	**City Proportions**
1	252	0.68%
2	3,388	9.22%
3	1,426	3.88%
4	590	1.61%
5	868	2.36%
6	8	0.02%
7	90	0.24%
8	4	0.01%
Total	6,625	18.04%

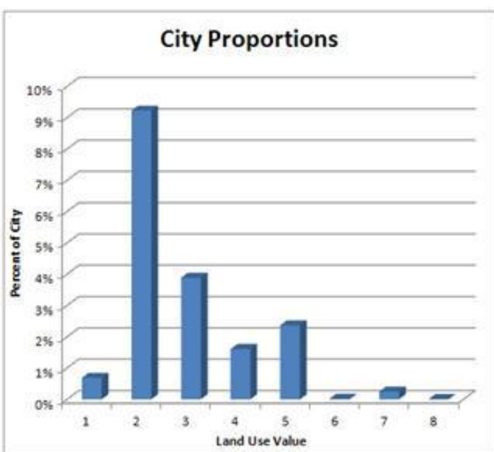

Figure 3. Land Use Suitability values and percent of Minneapolis each value includes.

Community Features Model

The Community Features model concluded that areas near an agglomeration of retail and the activity centers identified by the Minneapolis Plan for Sustainable Growth had the highest suitability. Lands with the HRV of 7 were found in the St. Anthony Main area of Northeast Minneapolis and in Uptown. Areas in downtown's warehouse district and along Hiawatha transit way received values of 6.

Figure 4 illustrates the suitability values from the community features model over aerial imagery for the City of Minneapolis. Similar to the Land Use Model all lands that received a value other than zero were considered important and were shaded with green colors for lower suitability values and orange and red for higher suitability. The orange and red areas indicated on Figure 4 correspond to areas with higher levels of shopping, services and business activity.

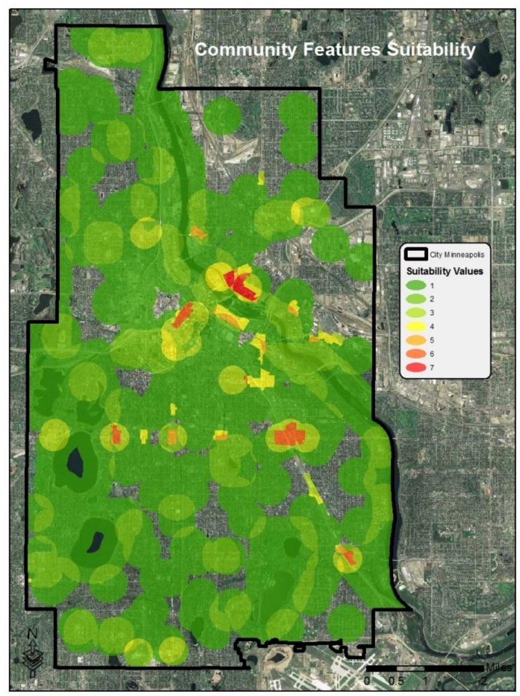

Figure 4. Community Features Suitability values calculated using models created from ESRI's Model Builder.

Table 5 provides statistics for each suitability value recorded in the community feature model. The ranges of possible and actual values are indicated in the table and both were from a value of 1 to 7. The 'Total Acres' field and 'City Proportions' field contain the total acres and percent of land covered by each individual suitability value. The most frequent suitability value was 1 with approximately 54.49 percent of the City or 20,012 acres. The three highest recorded suitability values of 5, 6, and 7 covered approximately 409 acres or 1.11 percent of the city.

Table 5. Results for Community Features Submodel with possible and actual suitability point ranges and statistics for total acres and percentage of city coverage for each suitability value.

Community Features Model Results		
Possible Point Range: 1 - 7		
Actual Range Results: 1 - 7		
City of Minneapolis contains 36,726 acres		
Community Feature Points	**Total Acres**	**City Proportions**
1	20,012	54.49%
2	6,880	18.73%
3	1,221	3.33%
4	536	1.46%
5	138	0.38%
6	195	0.53%
7	76	0.21%
Total	29,058	79.12%

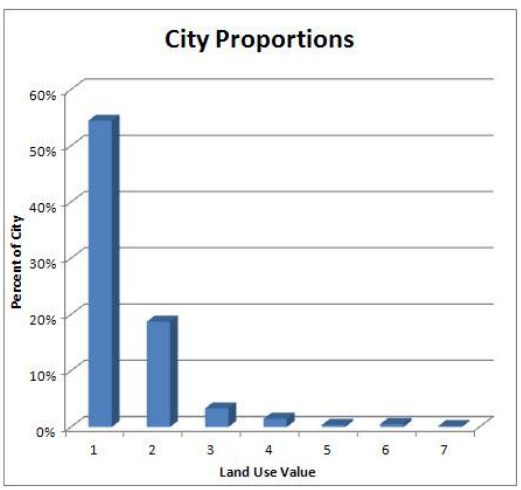

Figure 5. Community Features Suitability values and percent of Minneapolis each value included.

The community features model covered 79.12 percent of the City or 29,058 acres with the seven different suitability values all combined. Figure 5 provides a representation of the data found in the 'City Proportions' field using a graph to better display the differences between values. It is apparent by looking at the graph in figure 5 that an inverse relationship exists between percent of land covered and the suitability value, as the suitability value increases the percentage of land covered by that value decreases dramatically.

Transit Model

The transit model provided a thorough understanding of areas with high levels of transit service and multi-modal choices. Downtown was obviously the area with the highest suitability values because of it being the focal point for all transit service, the location of numerous carsharing vehicles and within the district where all fares are significantly reduced. The other areas that were deemed suitable were along the Hiawatha and Central LRT corridors, and the Lake Street and I-35W interchange area because of the newly approved BRT line that will have a station at this intersection. The model's emphasis was in rail service and BRT rather than regular bus service because bus service is not as conducive to spurring development as BRT and rail service (Basile Baumann Prost and Associates, 2007). This explains why Uptown, an area with high levels of bus service, was not given a value as high as the areas near an LRT Station.

Figure 6 contains a map that shows the suitability values from the transit model over aerial imagery for the City of Minneapolis. Similar to the first two sub models all lands that received a value other than zero were considered important with suitability values increasing from shades of green to red. The orange and red areas indicated on Figure 6 correspond to areas with service provided by LRT, BRT, and commuter rail.

Table 6 provides the statistics for each suitability value recorded in the transit model. The ranges of possible and actual values are indicated in the table and were both from a value of 1 to 9. The 'Total Acres' field and 'City Proportions' field contain the total acres and percent of land covered by each individual suitability value. The values with the highest frequency were 1 and 2 with 11,815 and 3,787 acres respectively. The suitability value of 1 covered approximately 32.17 percent of the City of Minneapolis. The three highest recorded suitability values were 7, 8 and, 9 covering approximately 1,015 acres or roughly 2.76 percent of the City of Minneapolis. The transit model

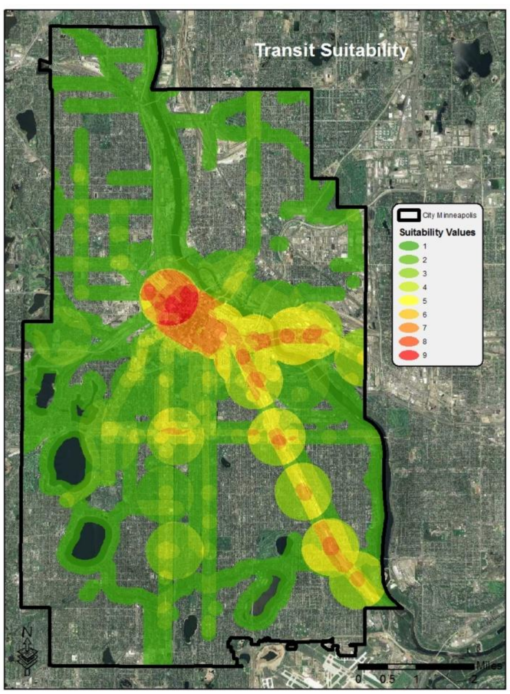

Figure 6. Transit Suitability values determined using models created from ESRI's Model Builder.

covered 60.31 percent of the City or approximately 22,151 acres. Figure 7 is a graph that represents the percentage of land each suitability value covers The suitability values for the transit model generally decrease in acreage as the values increase except for values 5 and 7 that increase slightly from the values below.

Table 6. Results for Transit Submodel with possible and actual suitability point ranges and statistics for total acres and percentage of city coverage for each suitability value.

Transit Submodel Results		
Possible Point Range: 1 - 13		
Actual Range Results: 1 - 9		
City of Minneapolis contains 36,726 acres		
Transit Points	**Total Acres**	**City Proportions**
1	11,815	32.17%
2	3,787	10.31%
3	1,970	5.36%
4	1,312	3.57%
5	1,565	4.26%
6	686	1.87%
7	741	2.02%
8	122	0.33%
9	152	0.41%
Total	22,151	60.31%

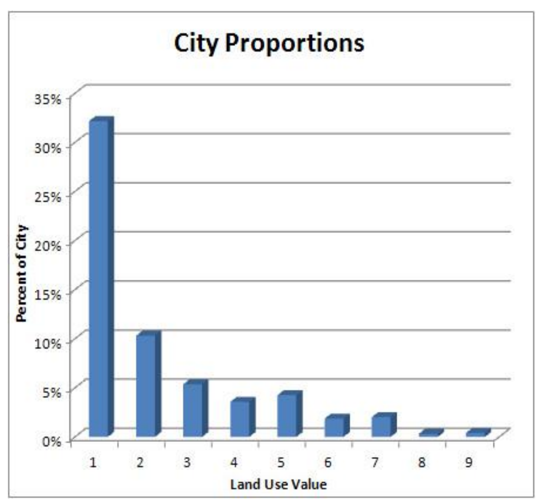

Figure 7. Transit Suitability values and percent of Minneapolis each value included.

Final Model

The suitability values from the three submodels were combined into the final model. Table 8 provides a list of all the layers that went into each submodel and ultimately the final model to create the final suitability values as shown in Figure 8. The total value possible for the final model was 30, but the highest recorded value (HRV) for any land was 19. The Land Use model's HRV of 8 could only make up 42.11% of the total model points, the Community Features HRV of 7 had the possibility of comprising 36.83% of the final model's points and Transit's HRV of 9 had the possibility of being 47.37% of the final model's total points.

The map in Figure 8 contains a map similar to those of the submodel, but contains suitability values for the entire city. The colors are the same with green shades indicating lower suitability and red being the highest. The Final Map included zero values in the shading in order to create a layer that covered the entire City. Values of 1 and 2 are similar to zero in that they received a value of zero in at least one of the sub models and should not be considered prime land for development.

The twelve highest recorded values were from 8 to 19 and covered approximately 8.9 percent of the City. These areas are shaded in yellow to red and warrant consideration for TODs and Smart Growth development. The HRV in the final model were observed near LRT stations, Downtown, and the activity centers that were identified in the Minneapolis Plan for Sustainable Growth (City of Minneapolis, 2009).

Table 7 contains the statistics for each suitability value recorded in the final model. The ranges of possible values were from 0-30, but actual recorded values were 0-19. The 'Total Acres' field and 'City Proportions' field contain the total acres and percent of land covered by each individual suitability value. The most frequent suitability value was 2 with approximately 26.11 percent of the City or 9,590 acres. The five highest recorded suitability values of 15 through 19 covered approximately 233 acres or 0.63 percent of the city.

The histogram in Figure 9 represents the percentage of land each suitability value covers. The results are similar to the submodels in that the lower suitability values cover a larger percent of land than the higher suitability values. All suitability values greater than thirteen have city proportions of less than 2 percent of the City.

Table 7. Final Model results containing possible and actual suitability point ranges and each suitability point value with corresponding acreage and percentage of coverage for Minneapolis.

Final Model Results		
Possible Point Range: 0 - 30		
Actual Range Results: 0 - 19		
City of Minneapolis contains 36,726 acres		
Land Use Points	**Total Acres**	**City Proportions**
0	4,069	11.08%
1	8,581	23.36%
2	9,590	26.11%
3	4,579	12.47%
4	2,526	6.88%
5	1,598	4.35%
6	1,403	3.82%
7	1,016	2.77%
8	793	2.16%
9	632	1.72%
10	412	1.12%
11	427	1.16%
12	469	1.28%
13	226	0.62%
14	173	0.47%
15	101	0.27%
16	63	0.17%
17	34	0.09%
18	14	0.04%
19	21	0.06%
Total	36,726	100%

Table 8. The layers of each submodel included in the Final Model Builder Model.

Land Use
Commercial Corridors
Growth Centers
Industrial Growth Areas
Commercial Node
Comprehensive Plan Designation
Medium Density
High Density
Transit
Bikeways
High Frequency Bus Service
Carsharing vehicles
LRT Stations
BRT Stations
Commuter Rail Stations
Bus Stops
Downtown Fare Boundary
Park and Ride Station
Community Features
Schools
Parks
Major Retail / Shopping Centers
Activity Center

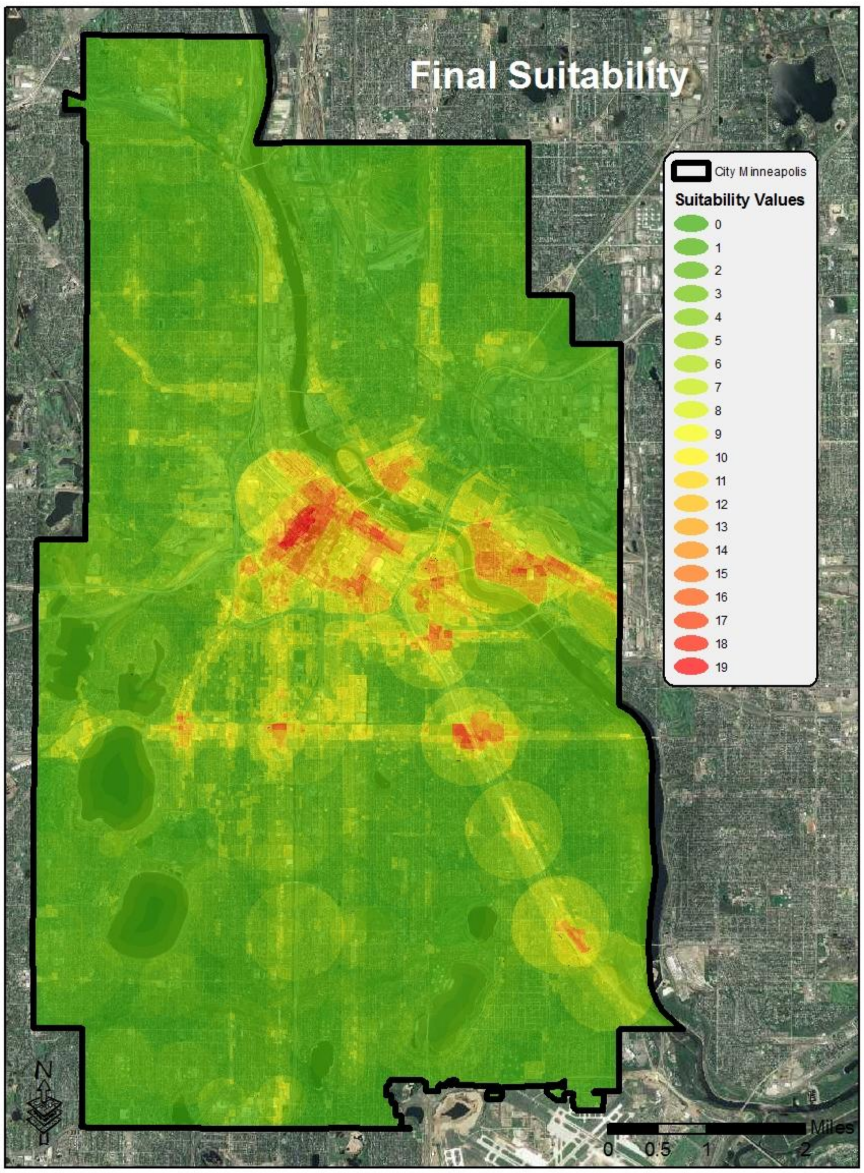

Figure 8. Final Model Suitability values determined using models created from ESRI's Model Builder.

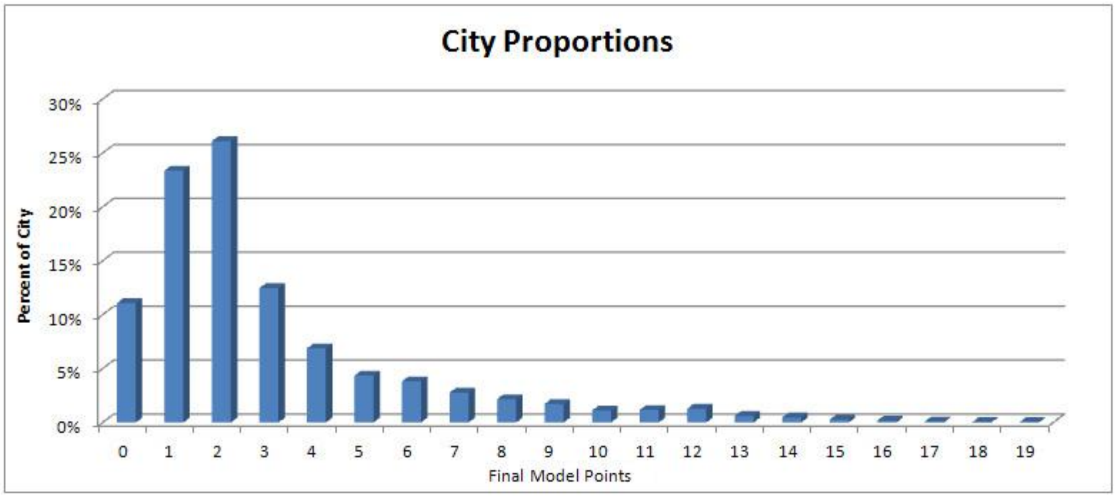

Figure 9. Final Model Suitability values and percentage of Minneapolis each value included.

Final Results

The purpose of this study was to create models to identify areas in Minneapolis suitable for TODs and Smart Growth development. The final model was a compilation of the three submodels that each, on its own identified areas suitable for their specific study area. Areas determined to have higher suitability values were found within the central part of the City of Minneapolis in sort of a triangle running from the Midtown LRT Station north towards the University of Minnesota Campus, west to Downtown and St. Anthony Main, south to Uptown and east along Lake Street back to the Midtown LRT station. Other areas with high values were around LRT stations and along main arterial roads throughout the City as observed in Figure 8.

Areas that did not measure as well in this study were found in the northern portion of the City in North and Northeast Minneapolis. Some of the main factors that contributed to the lower values were the lack of major retail and employment areas or activity centers, the smaller concentrations of higher density residential areas, and the absence of a Light Rail or Bus Rapid Transit. This does not mean this area is not suitable for future development especially with the proposed Bottineau Transitway that would travel through North Minneapolis into the northwest suburbs.

An example of an area within the City of Minneapolis suitable for TOD that scored very well in this study would be the K-Mart site in South Minneapolis along Lake Street. This store prevents Nicollet Avenue from reaching Lake Street and is in an area where redevelopment has been encroaching from the Lyn-Lake area to the west and the Chicago and Lake area to the East. The BRT station under construction at Lake Street and Interstate 35W is within one-half mile of this location.

Some areas that scored less than expected were Uptown and the Midtown Exchange area near Lake Street and Chicago Avenue. Uptown did have one of the higher scores but scored lower than expected because this study focused on LRT, BRT, or Commuter Rail instead of traditional bus service. It would be interesting to see how the results might change if the proposed Southwest Light Rail Line ran through Uptown or if streetcars were reintroduced to

Minneapolis and traveled through Uptown. The Chicago and Lake area also scored lower because of the absence of a rail or BRT station, and the Major Retail data obtained from the City of Minneapolis and MetroGIS did not have any values near this intersection.

Discussion

Sources of Error

A number of problems were encountered during the course of this study. The timeframe of this study made it difficult to gather all the data desired from the City of Minneapolis. It was also difficult to identify what data to include in the study aside from those that were easy to differentiate. There were many other factors that could have been identified, such as socioeconomic impacts, crime, perceptions of place, price of real estate, future regional transit investments and emphasis on decreasing sprawl, all of which might change the demand and suitability areas for Smart Growth and TODs in the region and in the City of Minneapolis.

Recommendations for Future Research

There were areas that were not included in this study that would be interesting areas for further research. The methods and models created in Model Builder could be easily adapted by researchers to include additional layers or submodels to predict factors such as, people's perceptions, current population densities, crime, or changes in regional policies. The methods in the study could also be used to analyze other cities in the Twin Cities Metropolitan Area or the entire Metropolitan Area. Additional research could also be conducted to determine why areas identified in this study as suitable for TODs and Smart Growth have not been developed. This type of study may help predict needed changes with current city or regional policies, zoning requirements, criminal activity, and/or market conditions.

Conclusion

Creating models and using a geographic information system was useful in determining areas suitable for TODs and Smart Growth development. Areas of land known to be candidates for development from past studies were shown to have high suitability values in this study by using a nonscientific approach of trial and error to review these known areas. The Model Builder models created in this study should have value for the City of Minneapolis and will be flexible so any changes in policy or infrastructure can be easily adjusted in the models.

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