DEVELOPING THE EMERGING DEVELOPMENT PRESSURE INDEX FOR WISCONSIN

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16. Abstract

Recognizing the importance of consistency in the state's corridor planning activities, the Wisconsin Department of Transportation uses a statewide, systematic process for identifying priority management corridors. As part of this prioritization process, an index is needed to reflect the likelihood of future residential and commercial development. This paper describes a methodology for creating such an index, referred to as the Development Pressure Index (DPI). A high DPI value suggests a higher likelihood of future growth around the highway segment and indicates the need for increased level of service or capacity on the highway segment. A wide range of data – from population and economic projections to land development plans and forest protection programs – are incorporated into the computation of the proposed DPI. A geographic information system is used to perform various spatial join and aggregation methods to derive a set of growth indicators. A scoring and weighing process is then applied to collapse the multiple indicators into one index. The empirical results and the subsequent assessment of the results reveal that the proposed methodology provides an effective and objective way to account for multiple influencing factors of development pressure.

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EXECUTIVE SUMMARY

Project Summary

The purpose of this project is to develop a methodology for evaluating the emerging development pressure along a state trunk highway (STH). The proposed methodology produces a development pressure index (DPI) that represents an integration of a rich set of geographical data reflecting the possibility of emergent development. The DPI is to be used in conjunction with additional indices to help planners identify priority corridors that warrants specific attention.

Background

Recognizing the importance of consistency in the state's corridor planning activities, the Wisconsin Department of Transportation (WisDOT) employs a systematic, statewide process for identifying priority management corridors. The process entails evaluating STH segments against three measures: mobility, safety, and development pressure indicies. Previously, WisDOT computes the DPI based on three factors: population growth rate, employment growth rate, and land conversion rate. All three rates are first computed at the CVT (city, town, and village) level before their values are mapped to the individual STH segments. Two issues arise from this approach. First, since CVTs are large administrative areas, the mapping of population growth, employment growth and land conversion rates from CVTs to STH segments inevitably leads to high homogeneity in DPI values across highway segments. This lack of spatial variation and accuracy prevents planning agencies from pinpointing the location of problematic corridors. Second, the inclusion of only three factors in the estimation of development pressure appears too limited. As richer and more detailed geographical data are becoming available, it is desirable to include additional, and perhaps better, indicators of development pressure in the computation of DPI. This study develops a new framework to address the two aforementioned issues related to the DPI computation.

Process

This study began with several brainstorming discussions between several WisDOT staff and the research team on what data items are good indicators of emergent development pressure. The discussions led to the identification of two types of data items: *inclusion* and *exclusion indicators* whose strengths are thought to relate *positively* and *negatively* to the level of development pressure, respectively. Collecting the necessary data for both types of indicators was a challenging process. This is because sometimes data are not readily available in the desired electronic format, or they do not cover the entire study area (state of Wisconsin). Some of the data considered were proprietarily owned by other agencies and therefore were not accessible or needed to be purchased by WisDOT. Some of the data of interest were simply unavailable from any of the agencies that the research team contacted. Among the forty-or-so indicators considered during the initial stage of this study, about 1/3 of them were eventually excluded from the DPI computation due to data quality and availability issues.

After the data cleaning and screening process, a total of 16 data items were retained for use in the DPI computation. The process by which these data items were combined to produce the final

DPI is depicted in Figure 1. The process entails first mapping each of the 16 geographic data layers onto the STH layer to provide a vector of 16 attribute values for each STH segment (Geo-processing). The attribute values are then used to derive 16 scores, one corresponding to each indicator (Score Assignment). The scores are then weighted (Weight Assignment), combined, and normalized to yield the final DPI values that take a value between 0 and 10 (DPI Calculation).

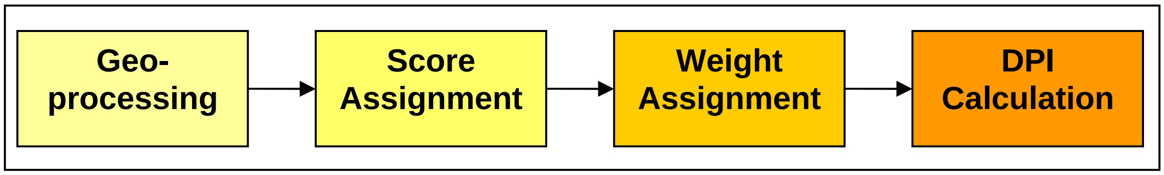

Figure 1. The proposed process for computing the Development Pressure Index

The proposed computation process was applied to compute DPI values for all STH segments in Wisconsin. The results were verified using statistical analysis and thematic mapping analysis.

Findings and Conclusions

Normalized DPI values were obtained for the 14912 segments on the Wisconsin STH by applying the proposed methodology. The DPI values range from 0 to 10, with 0 indicating the least likelihood for emerging development and 10 indicating the highest level of development pressure. The average across all segments was 4.85 and the standard deviation was 1.60. The distribution of these values resembles a normal distribution.

The distribution and variation of the DPI values across the STH network were examined using thematic mapping of the normalized DPI values. Spatial concentrations of high development pressure segments were found in the City of Appleton, outskirts of Milwaukee, urban fringe of Madison, and City of Eau Claire. Discussions with WisDOT staff suggested that these areas are indeed among those witnessing significant growth and expecting increased traffic volumes in the near-term future. The assessment of the results indicated that the proposed process provides an effective and objective methodology to account for multiple influencing factors of development pressure. The method is particularly effective in assigning the highest DPI values to urban fringes where spill-over growth and development is deemed imminent.

Recommendations for Further Actions

The analysis of development pressure is a data intensive exercise. The analysis calls for data produced by many different agencies that often differ in format and nature, making the task of acquiring and integrating these various datasets laborious and difficult. Moreover, as the data are updated by the different agencies over time, tracking down the latest data and keeping the DPI values up-to-date presents yet another challenge. The lessons learnt from this study points to the need for improving the data inter-operability and data accessibility within WisDOT and across various state departments in order to support the planning process in Wisconsin.

It is envisaged that, as geographic data of higher quality becomes available in the future, the DPI computational methodology proposed in this study can be further refined in at least a couple of ways. First, the DPI is currently computed for highway segments with a priori defined start and end nodes. The definitions of these segments are often too coarse and too inflexible to support the accurate identification of localities with emerging development. A computational method that is not bound by the STH segment definitions and that allows the DPI to be computed at a higher spatial resolution is desired. Yet, such a refined methodology would be effective only if data of high spatial resolution were available. Second, the DPI is currently computed based on variables and weights that have been selected in an ad hoc fashion. If historic data were available about the traffic volumes (endogenous variable) and the various development pressure indicators (exogenous variables) being considered, one can develop a time-series model to determine the statistical significance, and the relative explanatory power, of the exogenous variables. The model estimation results can then be used to inform the selection of input variables and the associated weights.

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1. INTRODUCTION

State highways represent billions of dollars of transportation capital investment. As with any other transportation assets, a highway system needs continual investment to maintain, update, and expand. Due to the limited availability of public funds and resources, it is important to make these investment decisions in an objective and equitable manner. In Wisconsin, these decisions are made based on the corridor management philosophy and approach, with considerations of the highway facility in the context of surrounding land uses, access management, condition of adjacent facilities, etc. The corridor management process begins with identifying priority corridors that warrant specific attention due to existing mobility problems, safety concerns, and/or emerging development pressure. Once these priority corridors are identified, a management vision is then developed and implemented for each corridor through the coordinated application of various planning activities, strategies and tools.

Recognizing the importance of consistency in the state's corridor planning activities, the Wisconsin Department of Transportation (WisDOT) employs a systematic, statewide process for identifying priority management corridors. The process includes two analysis stages – a quantitative analysis conducted at the state level and a qualitative analysis conducted at the district level. In the first, quantitative analysis stage, WisDOT staff evaluates the State Trunk Highway (STH) segments (approximately 15,000 in total) along three dimensions: mobility, safety, and development pressure. The evaluation along each dimension involves assessing each STH segment against a number of factors that are considered to reflect that dimension. The process begins with assigning to each STH segment a score for each factor being considered. The scores are then weighted and summed across all factors. This weighted sum of the scores becomes the priority score for each STH segment. The list of factors and their corresponding weights used by WisDOT are listed in Appendix 1. In the second, qualitative analysis stage of the priority corridor identification process, the District planning staff reviews the priority scores in conjunction with local knowledge and qualitative considerations to determine the corridors of high priority for their respective Districts.

This study is concerned with WisDOT's approach for evaluating the development pressure along STH segments during the first stage of their corridor prioritization process. For the purpose of corridor prioritization, *development pressure* is defined as the likely intensity of future residential and commercial development in the vicinity of a STH segment. High development pressure indicates the need for increased level of service or capacity on the highway segment. Currently, WisDOT determines development pressure based on three factors: population growth, employment growth, and land conversion rate. The population growth is measured by the GEH statistic, computed based on the population size of the base year (2000) and the projected population for year 2020. The employment growth is also measured by the GEH statistic and computed in a similar fashion. Land conversion is measured by the number of conversions from agricultural/vacant land to residential, commercial, or manufacturing uses. The values for all three factors are computed for each city, town, and village (CVT) before being mapped to the individual STH segments. Score values are then assigned to the segments based on their respective factor values.

There are at least two issues with WisDOT's current approach for evaluating the development pressure along STH segments. First, since CVTs are large administrative areas that may contain up to hundreds of STH segments, the mapping of population growth, employment growth and land conversion rates from CVTs to STH segments inevitably leads to high homogeneity in the factor values, and the corresponding scores, among the STH segments. This lack of spatial variation and accuracy prevents planning agencies from being able to pinpoint the location of problematic corridors. Therefore, a computational approach that provides higher spatial variation and accuracy is much needed. The second issue with the current approach lies in the fact that only three factors are currently used to measure development pressure. Since richer and more detailed geographical data are becoming available both within and outside of WisDOT, it is highly desirable to identify and include additional, and perhaps better, indicators of development pressure in the computation of corridor priority scores.

In view of the abovementioned issues, in this study we have developed a new Development Pressure Index (DPI) that will be used to replace WisDOT's current set of three development pressure-related scores. The remainder of this report describes the development and application of the DPI. Chapter 2 discusses the data considerations underlying the development of the DPI. Chapter 3 provides an overview of the new DPI computation framework. Chapter 4 presents the results obtained from applying the proposed framework to Wisconsin. Finally, Chapter 5 summarizes the report and discusses the directions for future research.

2. Data Considerations

As discussed earlier, the development of the new DPI is motivated by the need to incorporate additional, and more detailed, geographic data into the corridor prioritization process. During the course of this study, there has been much discussion between the WisDOT staff and the research team on what data should be incorporated into the proposed DPI. Much effort has also been devoted to acquire the desired data items. In this chapter, we discuss the various data-related issues and challenges faced in this study. Specifically, Section 2.1 discusses the different development pressure indicators that are considered in this study. Section 2.2 describes the challenges encountered during the process of collecting data for the different development pressure indicators. Section 2.3 lists and describes the data items successfully acquired and processed for the study. Section 2.4 explains why a subset of data items is subsequently dropped from the study.

2.1. Development Pressure Indicators

Based on discussions with WisDOT staff, three categories of data indicators are believed to reflect emergent development pressure: existing inclusion indicators, new inclusion indicators, and new exclusion indicators. These data categories are defined below.

Existing Inclusion Indicators

This category refers to the factors currently used in WisDOT's process for identifying priority management corridors that should be retained and be incorporated into the new DPI. These indicators include population growth, employment growth, and land conversion rate. In addition, the Average Growth Rate (AGR) of Traffic that was used as a factor of mobility is now included as an indicator of development pressure.

These indicators are referred as *inclusion indicators* because the strengths of these indicators are thought to be positively related to the level of development pressure. For instance, higher (vs. lower) population growth near a STH segment is an indication of greater (vs. weaker) emergent development pressure.

New Inclusion Indicators

In addition to the 5 exiting inclusion indicators discussed above, new indicators of a similar inclusion nature are sought to expand the scope of the proposed DPI. Such indicators considered include real estate development, utility systems extensions, access management plans, and school and business expansions.

New Exclusion Indicators

In contrast to the inclusion indicators, the *exclusion indicators* are those thought to be negatively related to the level of development pressure. Examples of these types of indicators include flood plains and protected forestry. The presence of the exclusion factors near a STH segment is expected to slow down, or prohibit, future development near the segment.

2.2. Data Collection Challenges

While it is relatively straightforward to identify good candidates for inclusion and exclusion indicators, collecting the necessary data for each of these potential indicators is a challenging process. This is because sometimes data are not readily available in the desired electronic format, or they do not cover the entire study area (state of Wisconsin). Some of the data considered are proprietarily owned by other agencies and therefore are not accessible or need to be purchased by WisDOT. Some of the data of interest are simply unavailable from any of the agencies that the research team has contacted.

Among the forty-or-so indicators considered during the initial stage of this study, about 1/3 of them were eventually excluded from the DPI computation due to data quality and availability issues. A list of these problematic data items are provided in Table 2.1.

Table 2-1 Data items considered but excluded from the current study

<table>
<tr><th>Data Item / Desired Indicator</th><th>Problem</th></tr>
<tr><td>HAMS (Highway Access Management System)</td><td rowspan="5">Incomplete spatial coverage</td></tr>
<tr><td>TUMS (Transportation Utility Management System)</td></tr>
<tr><td>SAMP (Statewide Access Management Plan)</td></tr>
<tr><td>Floodplain</td></tr>
<tr><td>Soil type</td></tr>
<tr><td>Crime rates</td><td rowspan="2">Unavailable in desired format</td></tr>
<tr><td>Real estate transfers</td></tr>
<tr><td>Water/power/sewer line extensions</td><td>Proprietary</td></tr>
<tr><td>Wetland</td><td>Purchase required</td></tr>
<tr><td>Emerging residential/commercial/recreational development</td><td rowspan="4">No suitable data sources were found</td></tr>
<tr><td>Economic outputs by CVT</td></tr>
<tr><td>Commodity movement</td></tr>
<tr><td>State university expansion plans</td></tr>
</table>

2.3. Data Acquired and Processed

A total of 24 data items that represent potential indicators of development pressure were successfully acquired. Some of these data came readily useable for DPI analysis while others required substantial processing. The steps involved in processing and preparing each of these data items are described in Appendix 2. After the appropriate processing, all data items are in a geographic format, containing both spatial and attribute elements. The source, geographic feature and content of these 24 data items are listed in Table 2-2 and grouped under the 3 indicator categories defined in Section 2.1.

Under the 'Data\' directory in the data CD produced by this study, there is one folder corresponding to each of these 24 data items. The raw files obtained from the respective source agencies are provided in the 'original' subfolder; whereas the processed geographic files, if any, are provided in the 'processed' subfolder.

Table 2-2 Datasets successfully acquired and assembled for the study

Name	Source	Geographic Feature	Content	Included in Analysis
Existing Inclusion Indicators				
AGR Traffic	Wisconsin Department of Transportation	Polyline (STH Segment)	Projected annual growth rate (AGR) of traffic from 2004 to 2024.	Yes
Employment Growth	Wisconsin Department of Transportation	Polygon (TAZ)	Projected growth in employment from 2000 to 2030. Employment projections were the same as those used in WisDOT's travel forecasting models. Growth rates were computed based on the GEH statistic.	Yes
Land Conversion	Wisconsin Department of Revenue (Research and Policy Division)	Polygon (CVT)	Growth in the total number of land parcels converted to residential, manufacturing and commercial use from 2000 to 2006. This is extracted from the DOR's property tax master file.	Yes
Population Growth	Wisconsin Department of Administration	Polygon (CVT)	Projected growth in population from 2000 to 2025.	Yes
Truck ADT	Wisconsin Department of Transportation	Polyline (STH Segment)	Truck proportion of total average daily traffic (ADT) for functional class group.	No
New Inclusion Indicators				
Access Points	Wisconsin Department of Transportation	Point	Points of access to the STH network.	No
Agriculture Land Cover [i]	Wisconsin Department of Natural Resources	Polygon	Location and area size of agricultural land use.	Yes
Bridge Expansion	Wisconsin Department of Transportation	Polyline (STH Segment)	Locations on the STH network where bridge expansion projects have been planned for 2007 to 2013.	No
Distribution Centers	Wisconsin Department of Transportation	Point	Locations of current, major distribution centers in Wisconsin.	No

Name	Source	Geographic Feature	Content	
DPI Student Enrollment	Wisconsin Department of Public Instruction	Polygon (School District)	Growth in number of enrollments from 2001/2002 to 2005/2006.	Yes
Industrial Parks	Wisconsin Department of Transportation	Point	Location and area size dedicated to industrial use	No
Land Value	Wisconsin Department of Revenue (Research and Policy Division)	Polygon (CVT)	Growth in total equalized value of residential, manufacturing and commercial land and improvement from 2000 to 2006. This is extracted from the DOR's property tax master file.	Yes
Local Roads ADT	Wisconsin Department of Transportation	Polyline	Selected local roads with an average daily traffic (ADT) over 2000 vehicle per day. These roads are considered as controlled access roads.	No
Planned Development	Wisconsin Department of Transportation	Polygon	Areas where a traffic impact analysis (TIA) has been conducted recently or where known real estate development has been planned	Yes
Railway Stations	Wisconsin Department of Transportation	Point	Point locations of existing and planned rail stations	Yes
Retailers	Wisconsin Department of Transportation	Point	Location, employment size, business type, and sales amount (in dollars) of major retails	No
Road Expansion	Wisconsin Department of Transportation	Polyline	Locations where roadway expansion projects have been planned for 2007 to 2013	No
Tax Incremental District (TID)	Wisconsin Department of Revenue	Polygon (CVT)	Number of active TIDs by CVT. TIDs are created by cities and villages to financially support new development or redevelopment of blighted areas, or areas in need of rehabilitation[ii].	Yes
Transition Lanes	Wisconsin Department of Transportation	Polyline	Location of 'tapers' – where the number of lanes reduces and traffic bottleneck is likely to occur – on the STH network	Yes

Name	Source	Geographic Feature	Content	
New Exclusion Indicators				
Elevation	Wisconsin Department of Natural Resources	Polygon (Grid)	Digital Elevation Model of Wisconsin that is used to determine terrain slopes of 100m by 100m grid cells	Yes
Poverty	Applied Population Laboratory, University of Wisconsin	Polygon (Census Tract)	Proportion of population below poverty line based on 2000 Census	Yes
Managed Forest Law	Wisconsin Department of Natural Resources	Polygon	Areas currently enrolled in the Managed Forest Law program, which prevents the land from being used for non-agricultural development	Yes
Managed Lands	Wisconsin Department of Natural Resources	Polygon	Areas that the WDNR has acquired in fee, easement, or lease	Yes
Wetland and Open Water Land Cover [i]	Wisconsin Department of Natural Resources	Polygon	Location and area size of wetland and open water areas	Yes

[i] The land cover data was downloaded from Wisconsin DNR's website. It was originally derived from 1992 satellite imagery as part of the Wisconsin Initiative for Statewide Cooperation on Landscape Analysis and Data (WISCLAND). See http://www.dnr.state.wi.us/maps/gis/datalandcover.html for more detailed description of the land cover data.

[ii] There are in fact four types of TID: blighted, rehabilitation or conservation, industrial, and mixed. However, for the purpose of this study, all four types of TID are considered to be equal indicators of development pressure. For additional information about TID, see http://www.legis.state.wi.us/lfb/Informationalpapers/2001/17.pdf.

2.4. Data Excluded

Out of the 24 data items processed, 8 are later considered as ‘lagging’ indicators. That is, they represent the after effects of existing development. This is in contrast to the ‘leading’ indicators, which occur before the development actually takes place. These 8 lagging indicators excluded from our subsequent analysis – as indicated in the last column of Table 2-2 – include Truck ADT, Access Points, Bridge Expansion, Distribution Centers, Industrial Parks, Local Roads ADT, Retailers, and Road Expansions.

3. DPI Computation

After the data cleaning and screening process, a total of 16 data items are retained for use in the DPI computation. The process by which these data items are combined to produce the final DPI is depicted in Figure 1. The process entails first mapping each of the 16 geographic data layers onto the STH layer to provide a vector of 16 attribute values for each STH segment (Geo-processing). The attribute values are then used to derive 16 scores, one corresponding to each indicator (Score Assignment). The scores are then weighted (Weight Assignment) and combined to yield the final DPI values (DPI Calculation). In the remainder of this chapter, we discuss each of these 4 steps in more details.

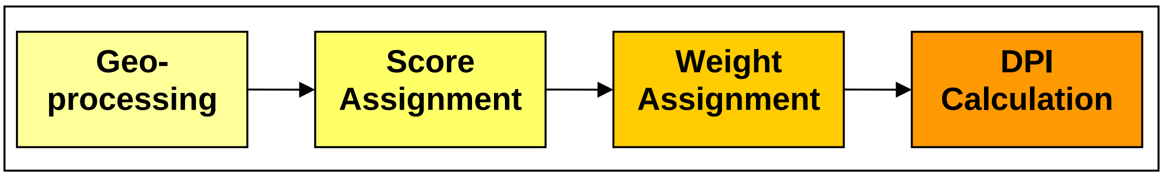


Figure 3-1 The process for computing the Development Pressure Index

3.1. Geo-processing

The goal of geo-processing is to derive from the various input data sources a set of attribute values that characterize the STH segments. Essentially, this step entails overlaying the 16 layers of geographical data onto the STH layer to give a vector of 16 attribute values (hereafter referred as the 'base values'). Depending on the geographic feature that an input layer is based on, different geo-processing procedures are used to accomplish the overlay. In all, six different cases have been identified and the procedure used for handling each case is described below. The base values obtained from applying these procedures can be found in the 'EDPI.dbf' file under the 'EDPI\' directory in the product CD.

<u>Case 1: Polylines</u>

The most straightforward case of geo-processing in this study is the mapping of a polyline layer to the target STH segment layer (as illustrated in Figure 3-1). Data that fall into this category include AGR Traffic and Transition Lanes. Both layers coincide spatially with the segments in the target layer. The geo-processing of this type of source data involves performing the following operations:

1. Join the source layer directly to the target layer (STH segments) based on spatial location.
2. As part of the join process, summarize the attribute values in the AGR Traffic layer by taking the maximum of the AGR field. Summarize the Transition Lanes layer by counting the number of intersecting polylines. These summary attribute values are used as base values.

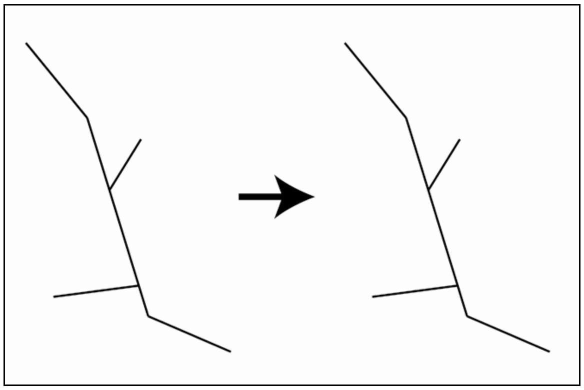


Figure 3-2: Overlaying polyline data onto STH segments

Case 2: Points

This case refers to the overlaying of a point source layer onto the target STH segment layer (as illustrated in Figure 3-2). In this study, the only data that falls into this category is the Railway Stations data. The overlaying process consists of the following steps:

1. Define a ¼ mile buffer around the target features (STH segments). This is considered as the catchment area within which railway stations would impact a segment.
2. Join the source layer to the buffer layer based on spatial location.
3. As part of the join process, summarize the attribute values in the Railway Stations layer by counting the number of intersecting points. The resulting counts gives the base values for the Railway Stations factor.

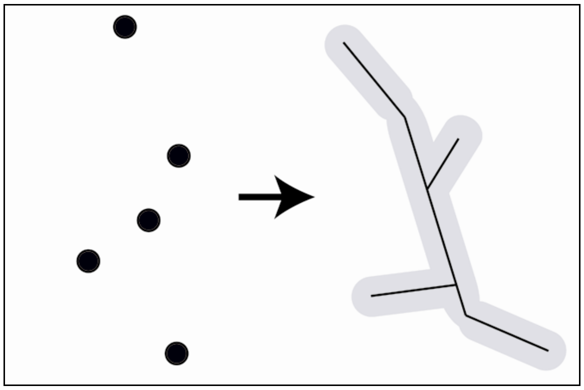


Figure 3-2 Overlaying point data onto STH segments

Case 3: Polygons

Several of our input data – including Agriculture Land Cover, Planned Development, Managed Forest Law, Managed Lands, and Wetland and Open Water Land Cover – are associated with polygon features. These polygons need to be overlaid onto the STH layer to produce the desired base values (as depicted in Figure 3-3). We assume that the impact of each of these factors on a highway segment is proportional to the amount of the corresponding polygons that fall within 1 mile of the segment. Therefore, the geo-processing of these data items consists of the following steps:

1. Create a 1 mile buffer around the target features (STH segments) – this becomes the Buffer layer. Each buffer can be related back to the corresponding STH segment through its FID (the field name of the unique feature ID for the STH segments).
2. In the Intersect tool in ArcGIS, set the source layer as the 1st Input Feature and the buffer layer as the 2nd Input Feature to produce a new layer of 'cookie-cut' polygons.
3. Use the Dissolve tool in ArcGIS to merge the polygons in the new layer by the FID that they inherited from the Buffer layer.
4. Create and populate a new column with the area size of the dissolved features. This column of area sizes gives the desired base values.

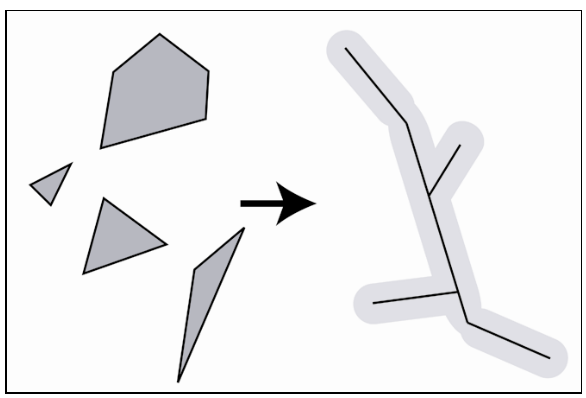


Figure 3-3 Overlaying polygon data onto STH segments

The above process is illustrated by a simple example shown in Figure 3-4, where X and Y represent two polygons in the source layer and the Buffer represents the 1-mile catchment area defined for a given STH segment. According to the above geo-processing procedure, the base value derived for the Buffer from the source layer is given by the sum of x2 and y2, which are the respective sizes of the overlapping areas between the Buffer and Polygons X and Y.

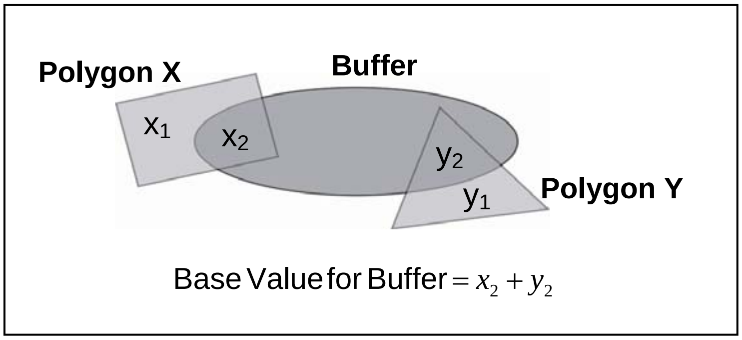


Figure 3-4 Example illustrating the derivation of base values from overlaying polygons onto a buffer defined around a STH segment

Case 4: Contiguous Polygons (Zones)

This case refers to the source data that describe a zoning system, i.e., a collection of contiguous and non-overlapping polygons that together cover the entire study area (as shown in Figure 3-5). The different zoning systems encountered in this study include CVT (Land Conversion, Population Growth, Land Value, TID), TAZ (Employment Growth), school districts (DPI Student enrollment), census tracts (Poverty), and grid cells (Elevation). With the exception of the Poverty and Elevation data, which will be discussed later as separate cases, these zonal data provide a pair of attribute values corresponding to two different points in time (for example, population size observed in year 2000 and population size projected for year 2025). The base values to be derived from these datasets are growth rates measured over the two time points. To obtain these growth rates, we first overlay the zonal data corresponding to both time points onto the STH layer. The pair of values assigned to each STH segments is then used to compute the growth rate. The specific steps used to accomplish this are described below:

1. Create a 1 mile buffer around the target features (STH segments) – this becomes the Buffer layer. Each buffer can be related back to the corresponding STH segment through its FID.
2. Use the Intersect tool in ArcGIS and set the source layer as the 1st Input Feature and the buffer layer as the 2nd Input Feature. This step essentially 'cookie-cuts' the zones by the buffer boundaries.
3. Apportion the zonal attributes of interest (e.g. population size for the base year and the projected year) among the cookie-cut pieces of the same zone based on their relative area size (as illustrated in Figure 3-6). Thus, if a zone of 1000 base year population and 100 mi^2 is split into two polygons of 40 mi^2 and 60 mi^2, the base year population will be split into 400 and 600 between the two polygons. The population size for the projected year is similarly apportioned.
4. Use the Dissolve tool in ArcGIS to merge the polygons in the new layer by the FID that they inherited from the Buffer layer. During the dissolve process, sum up the attribute values across polygons with the same FID.

5. The pair of values derived for each STH segment is then used to compute the GEH statistic. This provides a measure of growth rate between the two points in time for which the source data are available. The GEH statistics form the base values to be used subsequently in score assignment.

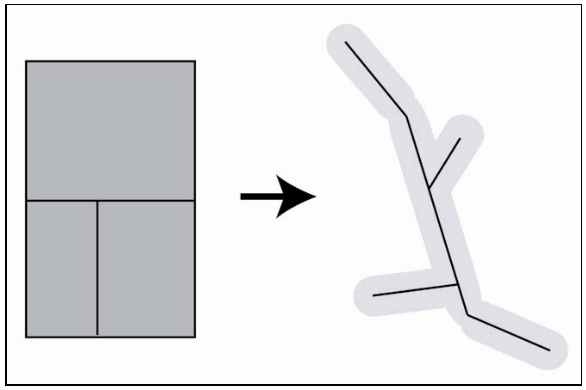


Figure 3-5 Overlaying zonal data onto STH segments

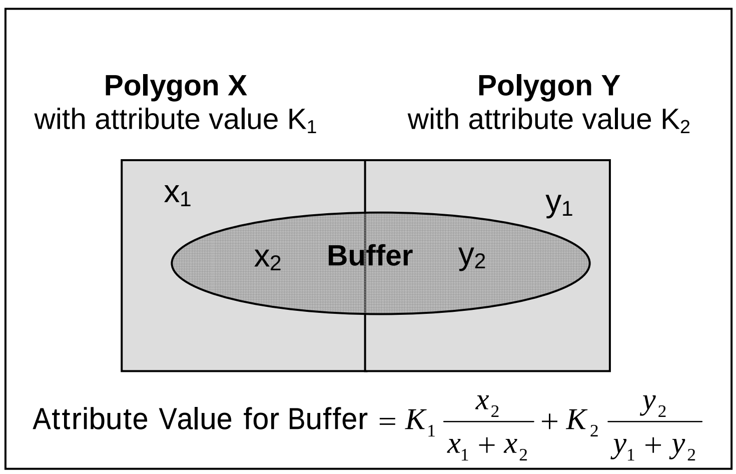


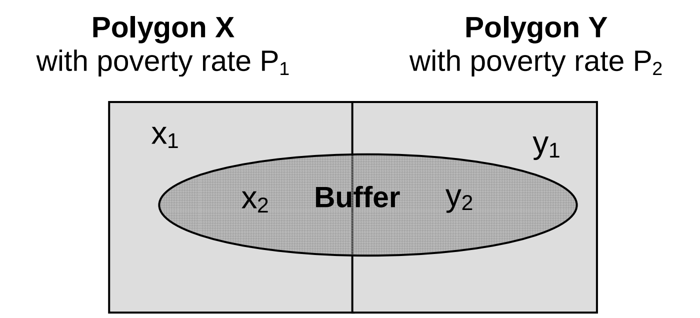
Figure 3-6 Example illustrating the derivation of base values from overlaying zonal data onto a buffer defined around a STH segment

<u>Case 5: Poverty</u>

The poverty data differs from the zonal data discussed in the previous case in that it is a measure of proportion (percentage of population under poverty line by census tract), as opposed to counts. Also, the poverty data is a cross-sectional data (i.e. available for only year 2000, when the Census was last conducted).

The procedure for deriving the Poverty base values for the STH segments consists of the same steps 1 and 2 as for the previous case, but differs in the subsequent steps. Specifically, in step 3, in stead of apportioning the zonal counts by area sizes, each piece of the cookie-cut polygons inherits the same poverty rate value from the parent zone.

The rates associated with all polygons that fall within the same buffer are then weighted and averaged based on their area size during the dissolve process. This weighted averaging is illustrated in Figure 3-7.



$$\text{Poverty Rate for Buffer} = P_1 \frac{x_2}{x_2 + y_2} + P_2 \frac{y_2}{x_2 + y_2}$$

Figure 3-7 Example illustrating the derivation of poverty rate values for STH segments

Case 6: Elevation

The Elevation data provides the terrain slopes for 100m by100m grid cells. The slope values are mapped to the STH segments using a relatively simple join procedure described below:

1. Join the source (polygon) layer to the STH (polyline) layer based on spatial location.
2. As part of the join process, take the maximum of the slope values among the grid cells intersecting with one STH segment.

3.2. Score Assignment

Once all 16 columns (each derived from one input data item) of base values are obtained for the STH segments, the next step is to convert the base values to score values. Two types of score assignment procedures are employed: one uses the base values directly and the other is based on the ranked values. The two procedures are discussed separately below. The final score values cab be found in the 'EDPI.dbf' file under the columns prefixed with 'S_' in the product CD.

Using Base Values

This score assignment method involves first dividing the observed base values into 3 to 5 intervals and defining a score value for each interval. Score values ranging from 0 to 10 are assigned to each STH segment accordingly. A score value of 0 indicates a relatively low likelihood of emerging development due to that factor; whereas a value of 10 indicates a high likelihood of development. Indicators for which the scores are assigned using this method include AGR Traffic, Rail Stations, and Transition Lanes.

Using Ranked Values

For the remaining indicators of development pressure, the scores are assigned according to the percentage rankings of the STH segments based on the respective base values. For example, based on the TID base values derived for each STH segment, the STH segments are rank ordered and are assigned a score of 0 if the segment is among the bottom 40% in the ranking, 3 if between 40% and 60% of the ranking, 6 if between 60% and 80% of the ranking, and 10 if above 80% of the ranking. For exclusion indicators, the higher a segment is ranked, the lower its score value will be. For example, after STH segments are ranked based on the amount of Managed Land within 1 mile radius of the segments, a score value of 0 is given to those segments ranked 90% or above, 2 to those ranked between 80% and 90%, 5 to those ranked between 60 % and 80%, and 10 to those ranked in the bottom 60%.

During the ranking process, the mean rank of tied values is used for the ties. The percentage ranking computed as part of the score assignment process can be found in the EDPI.dbf file under the columns prefixed with ‘P_’.

It should be noted that the value intervals and their corresponding score values have been selected based on frequency and histogram analyses of the base values and resulting score values. They have been defined and verified with input from WisDOT staff. The complete set of score assignment rules are provided in Appendix 3.

3.3. Weight Assignment

Depending on the spatial accuracy, timeliness, and other qualities of the input data, the 16 indicators have varying degrees of strength in explaining emerging development pressure. In particular, we have identified Population Growth, Employment Growth, and Planned Development as better indicators of development pressure than the other indicators. These three indicators are therefore assigned with a weight of 2 while the remaining indicators receive a weight of 1. These weights are used in the calculating of the DPI as discussed in the next section.

3.4. DPI Calculation

Once the score values are assigned and the weights are defined for each indicator, we compute a raw DPI value for each STH segment as the weighted sum of score values:

$$Raw\_DPI_l = \sum_k w_k \cdot S_{lk} \ ,$$

where:

Raw_DPI_l is the raw DPI value of the l^{th} STH segment

w_k is the weight given to the k^{th} factor

S_{lk} is the score assigned to the l^{th} STH segment for the k^{th} factor

Using the column names from the EDPI.dbf file, we can write out the above equation as:

$$Raw\_DPI = 2 \cdot S\_EMP + 2 \cdot S\_POP + 2 \cdot S\_PLDEV + S\_AGR + S\_LAND + S\_AGRICULT + S\_DPI + S\_LDSALE + S\_RAIL + S\_TID + S\_TRLANE + S\_SLOPE + S\_MFLAW + S\_MLAND + S\_POV + S\_WETLAND .$$

Based on the above equation, the highest raw DPI value that a highway segment can possibly attain is 190. In reality, however, the highest value found across all STH segments is lower (162). We denote this highest observed value by Max_Raw_DPI. This value is then used to normalize all DPI values as follows so that the final DPI takes a value between 0 and 10:

$$DPI_l = \frac{Raw\,DPI_l}{Max\_Raw\_DPI} \cdot 10$$

This concludes the computation of the new DPI.

4. Results

In this chapter, we present the results obtained from applying the DPI computational process described in the preceding chapter to the STH of Wisconsin. The results have been verified using statistical analysis and thematic mapping. The statistical characteristics of the score values and the final DPI values are presented in Section 4.1. The thematic map of the results is discussed in Section 4.2

4.1. Statistical Characteristics

Since the DPI values are computed as a function of many scores, the level of correlation among the constituting scores is a concern. The simultaneous inclusion of highly correlated indicators should be avoided as it would lead to biased results. Our analysis of correlation coefficients between all pairs of 16 scores (as shown in Table 4-1) reveals that the highest correlation is between the scores for TID and Land Value, with a correlation coefficient of 0.53. The correlation between most of the remaining pairs of scores is mostly low, suggesting that little 'double-counting' effect has been introduced into the DPI values.

The normalized DPI values obtained for the 14912 segments on the Wisconsin STH are found to have an average value of 4.85 and a standard deviation of 1.60. The frequency and cumulative frequency distributions of the values are shown in Figure 4-1. Overall, the frequency distribution resembles a bell shape, which typically suggests a normal distribution.

Table 4-1 Correlation Coefficients between all pairs of scores constituting the DPI

Correlation Coefficient	AGR Traffic	Employment Growth	Land Conversion	Population Growth	Agricultural Land Cover	DPI Student Enrollment	Land Value	Planned Development	Railway Stations	TID	Transition Lanes	Elevation	Poverty	Managed Forest Law	Managed Lands	Wetland and Open Water Land Cover
AGR Traffic	1.00															
Employment Growth	0.06	1.00														
Land Conversion	0.26	0.03	1.00													
Population Growth	0.13	0.36	0.21	1.00												
Agricultural Land Cover	0.20	0.01	0.43	0.19	1.00											
DPI Student Enrollment	-0.03	0.01	0.02	0.04	0.02	1.00										
Land Value	0.22	0.26	0.50	0.27	0.27	0.05	1.00									
Planned Development	0.26	0.10	0.29	0.22	0.25	0.03	0.41	1.00								
Railway Stations	0.06	0.02	0.12	0.04	0.01	0.01	0.13	0.05	1.00							
TID	0.11	0.22	0.18	0.10	0.16	0.01	0.53	0.21	0.09	1.00						
Transition Lanes	0.07	0.24	0.06	0.12	0.01	0.04	0.51	0.22	0.06	0.46	1.00					
Elevation	0.00	0.03	0.02	0.07	0.07	0.02	0.09	0.07	0.01	0.08	0.18	1.00				
Poverty	0.02	0.15	0.09	0.10	0.13	-0.01	0.15	0.04	0.02	0.09	0.12	0.05	1.00			
Managed Forest Law	0.05	0.14	0.07	0.13	0.08	-0.04	0.18	0.06	0.04	0.13	0.12	0.01	0.42	1.00		
Managed Lands	0.13	0.00	0.30	0.18	0.36	0.06	0.12	0.12	-0.04	-0.21	-0.05	0.10	0.08	0.03	1.00	
Wetland and Open Water Land Cover	0.02	0.23	0.03	0.20	0.05	0.06	0.13	0.07	0.00	0.12	0.15	0.01	0.11	0.12	0.07	1.00

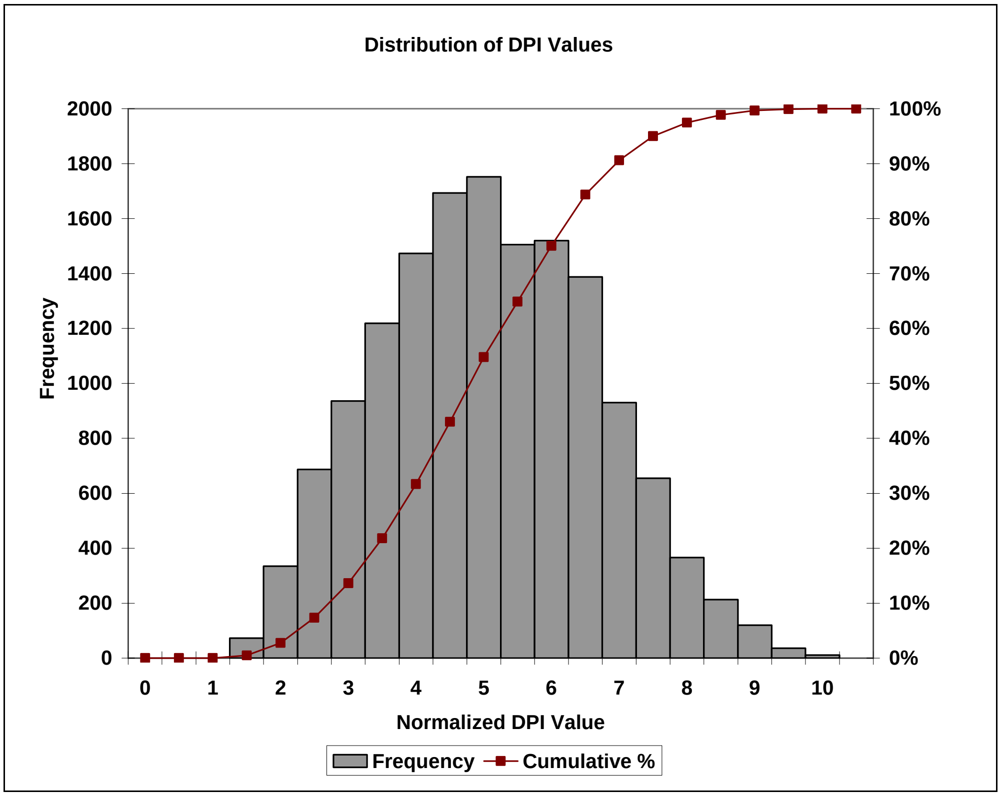


Figure 4-1 Distribution of DPI values computed for Wisconsin STH segments

4.2. Thematic Map

In addition to examining the statistical characteristics of the score and DPI values, we have verified the results from this study by examining the spatial distribution and variation of the DPI values. This is based on a thematic map of the normalized DPI values, as shown in Figure 4-2. The darker the line color, the higher the development pressure is. The thematic map suggests that there is significant variation in DPI values across space. The map also shows spatial clusters of segments with similar DPI values.

The areas with a concentration of high DPI values are highlighted in Figure 4-3. These areas include Appleton, outskirts of Milwaukee, south of Madison, and Eau Claire. Discussions with WisDOT staff suggest that these areas are indeed among those witnessing significant growth and expecting increased traffic volumes in the near-term future. It should also be noted that, although currently urbanized areas tend to receive relatively high DPI values, the highest DPI values are found in the urban fringes where spill-over growth and development is imminent.

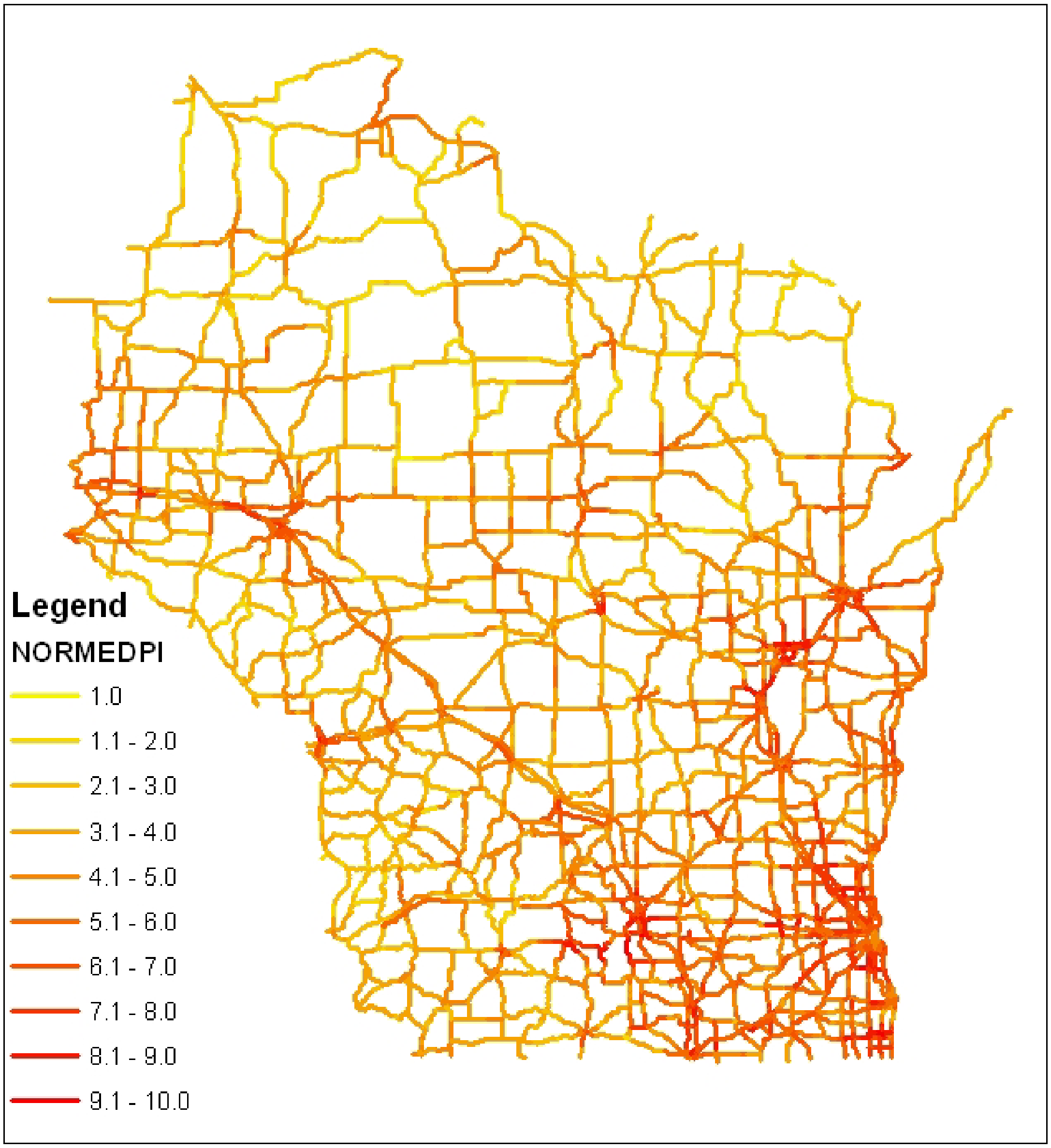


Figure 4-2 Thematic map based on normalized DPI values

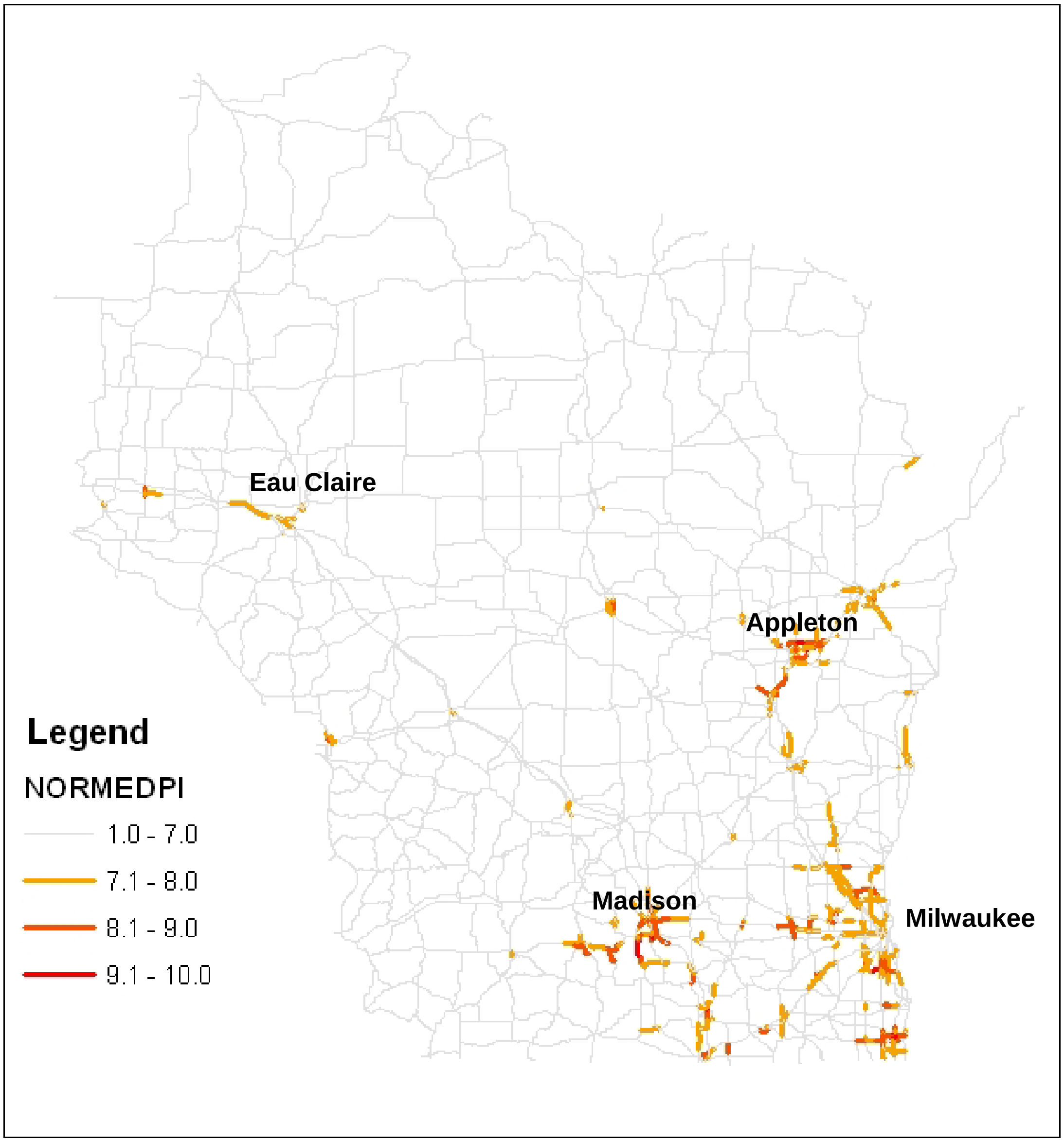


Figure 4-3 Areas with highest levels of development pressure as indicated by the proposed DPI

5. Conclusions

This report has described the development and application of a DPI that can be used as a predictor of emerging development pressure along a STH segment. The DPI represents an integration of a rich set of geographical data that are considered as preliminary indicators of development pressure. The DPI is to be used in conjunction with additional indices of mobility and safety to help WisDOT planners identify priority corridors for further planning activities. Our empirical results and the subsequent assessment of the results reveal that the proposed methodology provides an effective and objective way to account for multiple influencing factors of development pressure.

It should be noted that the general methodology presented in this study is applicable to the planning-level evaluation and prioritization of corridors in future planning horizons. It is also potentially applicable to communities other than the state of Wisconsin. However, the methodology must be tailored to the planning goals and the data available for the planning activities. In particular, the design of the scoring and weighting schemes depends greatly on the quality of the data available for the indicators of consideration. The scoring and weighting schemes also need to be based on the relative emphasis that the public agency and other stakeholders place on the various indicators.

Many challenges related to data availability and data quality have been encountered during the course of this study. These challenges arise from the fact that the analysis of development pressure is a data intensive exercise. The analysis calls for data produced by many different agencies that often differ in format and nature, making the task of acquiring and integrating these various datasets laborious and difficult. Moreover, as the data are updated by the different agencies over time, tracking down the latest data and keeping the DPI values up-to-date presents yet another challenge. The lessons learnt from this study points to the need for improving the data inter-operability and data accessibility within WisDOT and across various state departments in order to support the planning process in Wisconsin.

It is envisaged that, as geographic data of higher quality becomes available in the future, the DPI computational methodology proposed in this study can be further refined in at least a couple of ways. First, the DPI is currently computed for highway segments with a priori defined start and end nodes. The definitions of these segments are often too coarse and too inflexible to support the accurate identification of localities with emerging development. A computational method that is not bound by the STH segment definitions and that allows the DPI to be computed at a higher spatial resolution is desired. Yet, such a refined methodology would be effective only if data of high spatial resolution were available. Second, the DPI is currently computed based on variables and weights that have been selected in an ad hoc fashion. If historic data were available about the traffic volumes (endogenous variable) and the various development pressure indicators (exogenous variables) being considered, one can develop a time-series model to determine the statistical significance, and the relative explanatory power, of the exogenous variables. The model estimation results can then be used to inform the selection of input variables and the associated weights.

Appendix 1 Prior Approach to Computing Corridor Priority Scores

Stage One—Overall Factors and Weighting*

STAGE ONE FACTORS	WEIGHT
Mobility	**50%**
Functional Class/Corridors 2020 Designation	15%
Year 2030 Level of Service	20%
Truck ADT	10%
Recreation Factor Group	**5%**
Safety	**20%**
Crash Rate	10%
Crash Severity	10%
Development Pressure	**30%**
Population Projections by CVT To 2020	15%
Land Conversion Rate by CVT from Ag/Vacant to Residential, Commercial, Manufacturing, 1990-2000	15%

Source: *Executive Summary and Technical Report of the Corridor Management Workgroup*, WisDOT, p.17, June 2004.

Appendix 2 Data Processing for DPI Analysis

This appendix documents the cleaning and processing required for preparing the 24 data items for DPI analysis. The data items are discussed in the same order as they appear in Table 2-2 of this report.

AGR Traffic

Data was provided in GIS shape format ('trkyr0_agr20') and so no processing was needed. The attribute field of interest is [AGR].

Employment Growth

The original data came from two sources: HNTB Corporation and WisDOT Traffic Forecasting Division. HNTB Corporation provided the 'all_taz' shapefile (statewide coverage of TAZ plus external zones), 'ZONEDATA1.dbf' (employment by TAZ for year 2000) and 'Zonedata1_F.dbf' (projected employment by TAZ for year 2030). WisDOT Traffic Forecasting Section provided the 'taz_passenger' shapefile (statewide coverage of TAZ).

The shapefile from WisDOT was chosen over the one from HNTB because the former does not include external zones. Both dbf files were joined to the 'taz_passenger' shapefile based on TAZ ID to give a new shape file named 'Emp_ Growth'.

Land Conversion

The primary source of data for Land Conversion was the Property Tax Mater (PTM) files that came in Excel format. Each of the 5 PTM files corresponds to a different fiscal year. Only the 1991-92 and 2005-06 files were used to measure the land conversion rate change for this study.

From the two selected PTM files, the numbers of land parcels converted to residential, commercial, and manufacturing use were extracted and summed up separately for 1991-92 and 2005-06. The two columns were then joined to a CVT shapefile (provided by WisDOT). The join process required first matching the DOR's 5-digit municipality codes in the PTM files to the FIPS codes used in the CVT shapfile. This was achieved using the lookup table produced and stored in the 'geocodes.xls' file in the product CD. The end result was a shape file named 'Land_Convert' with two land conversion rates: PARCELS01 and PARCELS06.

Population Growth

Base (year 2000) and projected (year 2025) population data were obtained from Wisconsin Department of Administration's website in Excel format. The data are joined to a CVT shape file based on FIPS code. The resulting file is named 'Pop_Growth'.

Truck ADT

Data was provided in GIS shape format ('trkyr0_agr20') and so no processing was needed. The attribute field of interest is [TRKYR_0].

Access Intersection points

Data was provided in GIS shape format (‘DV_ACSI_PT’) and so no processing was needed.

Agriculture Land Cover

DNR’s land cover data was originally in a raster format. The data was first converted to a vector format using the Conversion Tools in ArcGIS. The resulting polygons with [GRIDCODE=110], which indicates agriculture use, were then selected and saved as a separate shapefile (‘Agriculture’).

Bridge expansion

Data was provided in shape format (‘FIIPSBRRPLE’) and so no processing was required. The information of interest is the spatial location of these expansions. Thus the attribute data were not used.

Distribution center

Data was provided in shape format (‘distribution40k+’) and was ready for subsequent DPI analysis.

DPI Student Enrolment

An Excel spreadsheet containing the student enrollments and the associated GEH statistic by school districts was provided by WisDOT staff. Geographic data that define the boundaries of all school districts was not available. Instead, three separate geographic data were obtained for the elementary school districts, secondary school districts, and unified school districts in Wisconsin. The student enrollment data was joined to the three geographic layers separately. The three layers were then merged into one shape file named ‘DPIUnified’.

Industrial Parks

Data was provided in shape format (‘combined_industrial_parks’) and ready for DPI analysis. In addition to the spatial information provided about the parks, the attribute field [TOT_ACRES] that descries the size of the parks was also used.

Land Value

This comes from the same 1991-92 and 2005-06 PTM files that were used to compile land conversion information. From each of the two Excel tables, the equalized values of residential, commercial, and manufacturing land use and improvement were extracted and totaled. The resulting two columns (LDVALE00 and LDVALE06) were then joined to a CVT shapefile named ‘Land_Value’.

Local Roads ADT

A shape file describing all local roads in the state was provided by WisDOT. From this file, we selected local roads with an average daily traffic of 2000 vehicles per day or higher. The selected features were then saved into a new shape file named ‘local_roads_avg_2000’.

Planned Development

Shape file describing the locations of recent TIA and known planned real estate development was provided by WisDOT and ready for use.

Railway Stations

Shape file was provided by WisDOT and was ready for DPI analysis.

Retailers

The shape file provided by WisDOT contained a [SALES] field, which indicates the sales bracket of each retailer. A new numerical field was created and calculated as the midpoint values of the sales brackets.

Road expansion

A shape file describing the locations of planned road expansion projects was readily provided by WisDOT.

Tax Incremental District – TID

Two Excel files were provided by DOR. Only the file named 'TID Types active 2006' was used for this study. The TID records were first aggregated to obtain the counts of TID by CVT. The information was then joined to a CVT shape file based on FIPS codes. The resulting file was named 'TID'.

Transition Lane

A shape file describing the locations of tapers was readily provided by WisDOT. No processing was required.

Elevation

The Digital Elevation Model data was in the raster format. The Surface Analysis tool in ArcGIS was first used to derive the slope percentages, which were subsequently coded as follows:

1 – level slope for 0 to 6 percent slope

2 – moderate slope for 6 to 15 percent slope

3 – strong slope for 15 to 30 percent slope

4 – very strong slope for 30 to 45 percent slope

5 – extreme slope for over 45 percent slope

The raster format data was then converted to polygons using the ArcGIS Conversion Tools.

Poverty

Poverty data (POVRATE) was originally obtained in Excel format. The data table was linked to a shape file of census tracts (obtained from the Census Bureau website) based on the tracts' FIPS codes.

Managed Forest Law

Data was readily available in shape format and no processing is required.

Managed Lands

Data was readily available in shape format and no processing is required.

Wetland and Open Water Land Cover

This was extracted from the same land cover data used to obtain Agriculture Land Cover information. After converting the raster file to polygons, the features with GRIDCODE values of 200 and 210 were selected and saved into a separate shapefile (‘Water_wetland’).

Appendix 3 Score Assignment

FACTORS	SCORE	FACTORS	SCORE	FACTORS	SCORE
Inclusion (Existing)		**Inclusion (New)**		**Exclusion (New)**	
AGR Truck	**S_AGR**	**Agriculture**	**S_AGRICULT**	**Elevation**	**S_SLOPE**
0 - 0.17	3	0%	0	Extreme Slope (above 45%) - 5	0
0.17 - 0.02	7	0 - 20% Rank	2	Very Strong Slope (30 - 45%) - 4	0
> 0.02	10	20 - 40% Rank	4	Strong Slope (15 - 30%) - 3	0
		40 - 60% Rank	6	Moderate Slope (6 - 15%) - 2	5
		60 - 80% Rank	8	Level Slope (0 - 6%) -1	10
		80 - 100% Rank	10		
Employment Growth	**S_EMP**	**DPI Student Enrollments**	**S_DPI**	**Managed Forest Law**	**S_MFLAW**
0 - 50% Rank	0	Lowest Growth - 1	0	> 90% Rank	0
50 - 70% Rank	3	Low Growth - 2	2	80 - 90% Rank	2
70 - 90% Rank	6	Flat Growth - 3	5	60 - 80% Rank	5
> 90% Rank	10	Growth - 4	8	0 - 60% Rank	10
		High Growth - 5	10		
Land Conversion	**S_LAND**	**Land Value**	**S_LDVALE**	**Managed Lands**	**S_MLAND**
0 - 50% Rank	0	0%	0	> 95% Rank	0
50 - 70% Rank	3	0 - 20% Rank	2	90 - 95% Rank	2
70 - 90% Rank	6	20 - 40% Rank	4	80 - 90% Rank	5
> 90% Rank	10	40 - 60% Rank	6	0 - 80% Rank	10
		60 - 80% Rank	8		
		80 - 100% Rank	10		
Population Growth	**S_POP**	**Planned Development**	**S_PLDEV**	**Poverty Rate**	**S_POV**
0 - 50% Rank	0	0 - 70% Rank	0	> 90% Rank	0
50 - 70% Rank	3	70 - 85% Rank	5	70 - 90% Rank	2
70 - 90% Rank	6	85 - 95% Rank	7.5	50 - 70% Rank	5
> 90% Rank	10	95 - 100% Rank	10	0 - 50% Rank	10
		Railway Stations	**S_RAIL**	**Wetland and Open Water**	**S_WETLAND**
		0	0	> 90% Rank	0
		1	7	70 - 90% Rank	2
		> 2	10	50 - 70% Rank	5
				0 - 50% Rank	10
		Tax Incremental District (T	**S_TID**		
		0 - 40% Rank	0		
		40 - 60% Rank	3		
		60 - 80% Rank	6		
		80 - 100% Rank	10		
		Transition Lanes	**S_TRLANE**		
		0	0		
		1 - 10	2		
		11 - 20	5		
		21 - 30	8		
		> 30	10		