SURLC 18-007

The Impact of Oil Boom and Bust Cycles on Western North Dakota

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Cover Photo Credit: "Williston, North Dakota 10-18-2008" by Andrew Filer from Seattle (ex-Minneapolis).

ABSTRACT

Discoveries of shale gas reserves along with the development of horizontal drilling and hydraulic fracturing techniques, as well as the initiative to move the United States toward greater energy independence led to the most recent oil boom in western North Dakota (U.S. Congress 2007). Overall, the boom brought a billion-dollar surplus for the state budget in North Dakota from severance taxes and extensive mineral rights. The population doubled in some areas, e.g., the city of Williston grew by 67% from 2010 to 2014 (Scheyder 2016). After almost a decade of production of North Dakota shale oil, prices dropped from about $100 a barrel in 2014 to about $30 in early 2016 and the industry went into the bust portion of the economic cycle where oil production and affiliated employment and spending contracted and where the industry and state are waiting for crude oil prices to rise again (Scheyder 2016).

Transit livability index measures showed large increases from 2008 to 2012 followed by overall corrections from 2013 to 2016. These measures declined as oil production and economic advances diminished. Further, transit fleet size failed to increase with population growth, and pedestrian safety has become a concern along both rural and city highways. System dynamics simulations focused on potential mode shifts from private automobile to transit, finding that seemingly small shifts (1-2%) from auto to transit would result in millions of dollars of fuel savings in the oil patch alone.

Various models of either fixed-route or flex-route busing should be considered by transit agencies and local policy makers for the larger communities of Williston and Dickinson, while more rural providers need to update their fleets to meet demand as well. Because of recent cutbacks in state and local funding, agencies should also strive to better coordinate services while continuing to provide rides to county population centers that offer goods and services required by rural residents.

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1. INTRODUCTION

The western half of North Dakota has experienced tremendous change in recent years due to oil exploration and drilling. Transportation issues including congestion and road quality initially affected the area during the expansion boom years, but after almost a decade of producing North Dakota shale oil, prices dropped from around $100 a barrel in 2014 to about $30 in early 2016 and the industry went into the bust portion of the economic cycle where oil production and affiliated employment and spending contracted. This has been followed by state and local funding cutbacks that have led to uncertainty regarding economic and social conditions. Local businesses have experienced tremendous fluctuations in sales leading to uncertainty and delayed growth plans as well.

1.1 Objectives

This study was conducted in western North Dakota (Figure 1.1) to analyze topics focusing on public transportation and vehicle mode choice. This research builds on previous work done by Peterson and Ndembe (2015). Objectives included determining the impact of oil boom and bust cycles on transit ridership for individuals living in the oil patch as well as how variables such as income, land use, population, and local operating investments affect livability. System dynamic models were also applied to analyze mode share and potential transportation investments in western North Dakota.

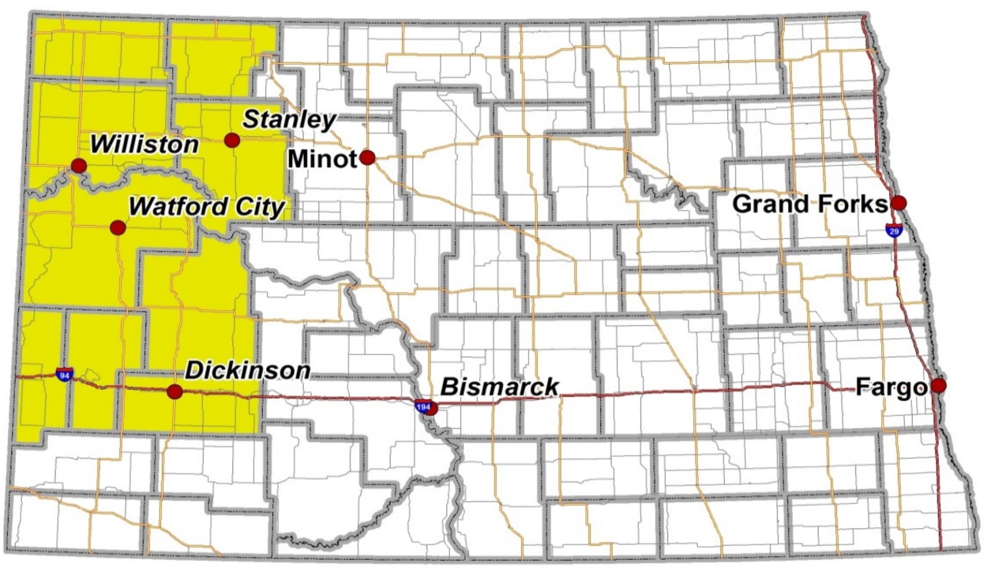

Figure 1.1 Nine County Study Region

1.2 Organization of Content

The study begins with a literature review including research focusing on oil boom and bust cycles as well as livability and system dynamic overviews. Following the literature review is an overview of the research methodology used in this study. Next, results from both livability index calculations and system dynamics simulations are discussed. Finally, an overall summary provides recommendations based on the research findings.

2. LITERATURE REVIEW

2.1 Boom

Oil booms, periods of rapid growth in oil production and affiliated employment and economic activity, are familiar to the U.S. oil industry. The earliest oil boom was the Pennsylvanian oil rush in 1859 during which the region produced a third of the world's oil at the peak of the boom (E.P. Corporation 2018). Soon after the Ohio oil rush in the 1880s and 1890s, Texas experienced an oil boom in the early 1900s. Oil booms are not limited to the United States They have also occurred in Mexico, Canada and other regions. Discoveries of shale gas reserves along with the development of horizontal drilling and hydraulic fracturing techniques, as well as the initiative to move the United States toward greater energy independence led to the most recent oil boom in western North Dakota (Figure 2.1) (U.S. Congress 2007).

Figure 2.1 Bakken Formation

Figure 2.2 illustrates the hydraulic fracking technique compared to the traditional vertical drilling technique. Vertical drilling uses relatively shallow depths to extract oil while hydraulic fracking utilizes greater depth and horizontal drilling to reach oil and gas deposits. Because of the tremendous depth of the drill, often more than 10,000 feet in the Bakken Formation, it must also include a vertical well, thus resembling the letter "L" in the figure.

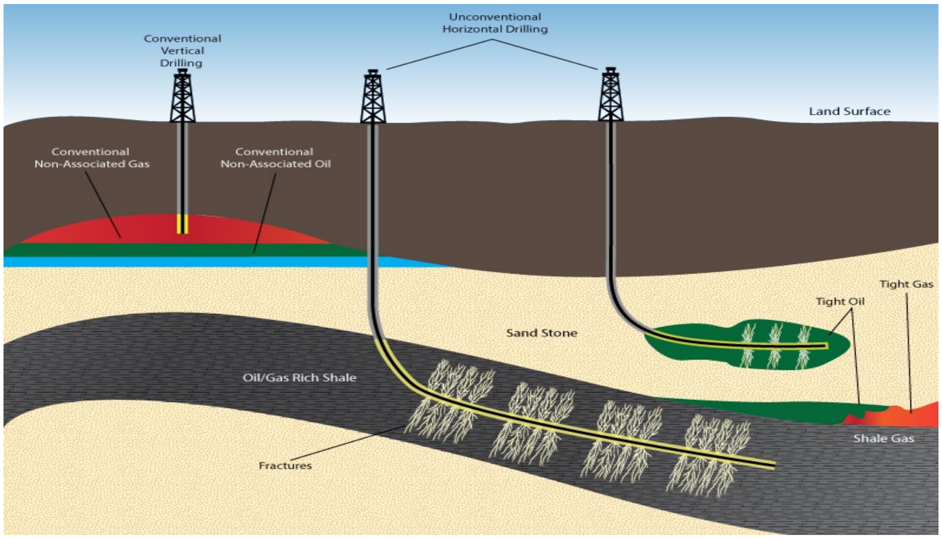

Figure 2.2 Vertical vs. Horizontal Drilling (Curtis 2011)

Overall, the boom brought a billion-dollar surplus to the state budget in North Dakota from severance taxes and extensive mineral rights. The population doubled in some areas, e.g., the city of Williston grew by 67% from 2010 to 2014 (Scheyder 2016).

Demographics changed because newcomers were mainly single men without families, and quality of life decreased as resources were exhausted in response to this transition. Pedestrian safety, for example, became a concern for those who walk for exercise along rural roads without paved shoulders. Inadequate walkways are a major problem related to pedestrians involved in motor vehicle crashes (NHTSA 2018). On the other hand, the boom resulted in a massive investment in the infrastructure in western North Dakota. Williston made a significant investment in infrastructure and amenities to catch up with the growth and prepare for the next boom. Expenditures included: $110 million for water-treatment plants, $56 million for a high school, $20 million for a jail expansion, and $70 million for a recreational center. North Dakota's Legacy Fund is now worth $3.5 billion, prompting debate over spending and management of the fund. These figures are based on records officially available as of June 30, 2017 (Scheyder 2016).

2.2 Bust

After almost a decade of production of North Dakota shale oil, prices dropped from around $100 a barrel in 2014 to about $30 in early 2016, and the industry went into the bust portion of the economic cycle where oil production and affiliated employment and spending contracted and is the industry and state are waiting for crude oil prices to reach $60 per barrel again (Figure 2.3). There is, to some extent, an analogy between the Klondike gold rush and the western North Dakota oil boom. From an economic perspective, there have been two competing dynamics: 1) Positive spillover as the oil industry fuels labor demand and a broad variety of other economic activity; and 2) Crowding-out effect which refers to a disruption in the labor market. The oil industry offers good-paying jobs and other industries have no alternative but to raise wages. The Williston Walmart increased the base pay to $17 per hour, which was among the highest pay rates of any retailer in the country. This hurt companies in other sectors such as manufacturing and agriculture as they had to compete in markets with aggressive competitors (Wegmann 2014).

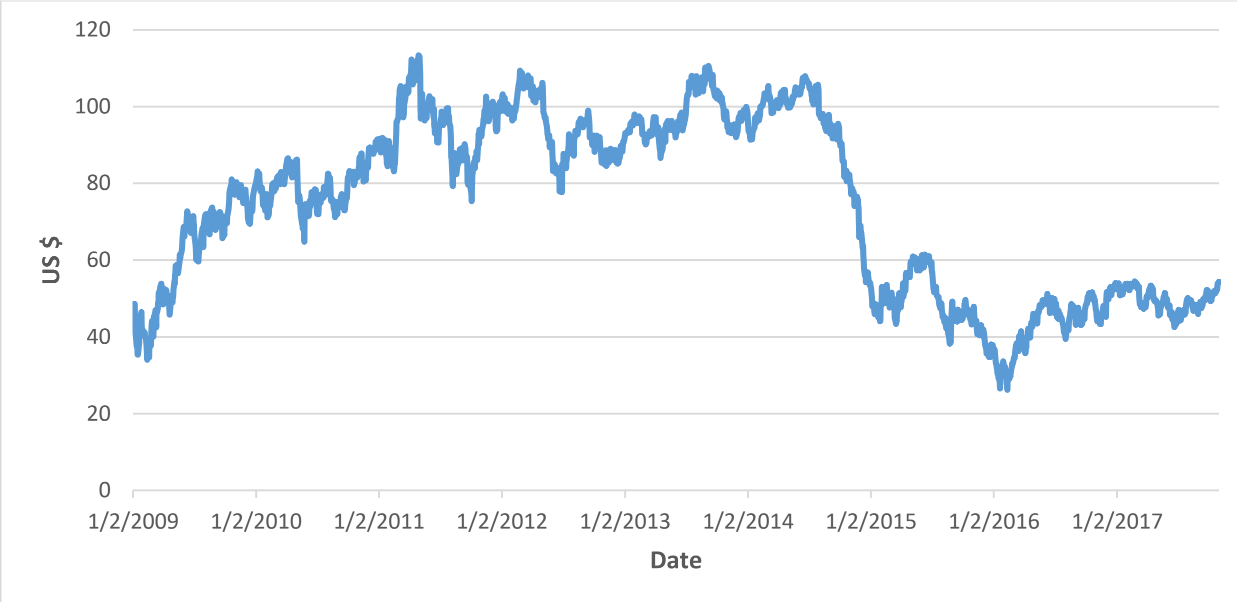

Figure 2.3 Historical Oil Prices

2.3 Rebound

The boom crashed as a result of a boost in oil production in countries like Saudi Arabia and Russia, causing significant financial losses and a contraction in the number of jobs. The situation, however, has recently begun to change. There are some signs of an unstable rebound in the oil industry. As of March 2018, there were 51 drilling rigs in North Dakota, up from a low of 27 in May 2016, but somewhat below the high of 218 in December 2012. Monthly oil production oscillated around the 1 million barrels-a-day mark during 2017, down from a peak of 1.23 million in December 2014 (Figure 2.4). Production is expected to be supported by completion of the Dakota Access pipeline, which is reducing the cost of oil transportation from the Bakken. In November 2017, OPEC also announced plans to reduce production, which tends to boost oil prices. However, oil inventories are still historically high. A price of $60 per barrel of oil is an attractive investment in the Bakken area. Finally, recent employment reports have showed larger employment in the Bakken area than previously thought. The local industry has also become more efficient, and new methods to forecast employment may be needed (Bangsund and Hodur 2017).

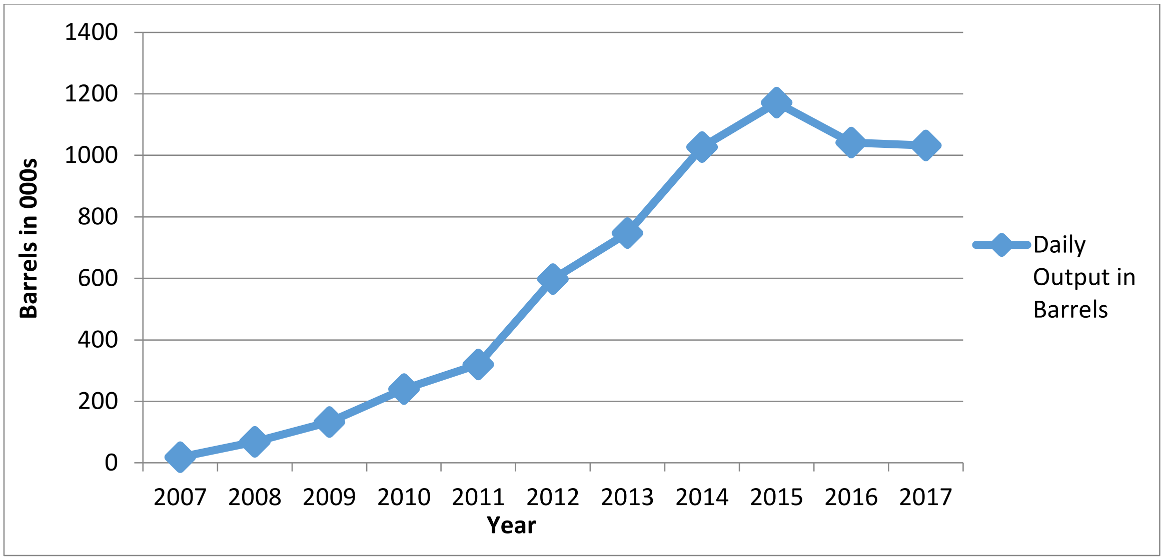

Figure 2.4 ND Oil Production

2.4 Livability

Livability is defined as suitability for human living according to the Merriam-Webster dictionary (Merriam-Webster 2018). Additionally, according to a TCRP research report, livability is “people having good access to opportunities they can use in the pursuit of improvements to their quality of life” (Transportation Research Board 2016). It is a metric for measuring quality of life (QoL) of a given geographical place. Livability is the subject of many studies that address objective conditions in a quantitative way (Veenhoven and Ehrhardt 1995, Lyubomirsky et al. 2005, Anderson and Van Kempen 2003). Such a ranking is just a number used to standardize the favorability scale of a place objectively. However, subjectivity is missing those rankings. In other words, one might live in a city with the highest ranking, but have no positive feelings toward that city’s quality of life. Kozaryn described the difference between rankings and perceptions by categorizing three levels of quality of life; 1) normative 2) subjective 3) objective (Figure 2.5) (Okulicz-Kozaryn 2013). He found that the relationship between subjective and objective measures is weak and concluded that perception is much more important than the ranking system.

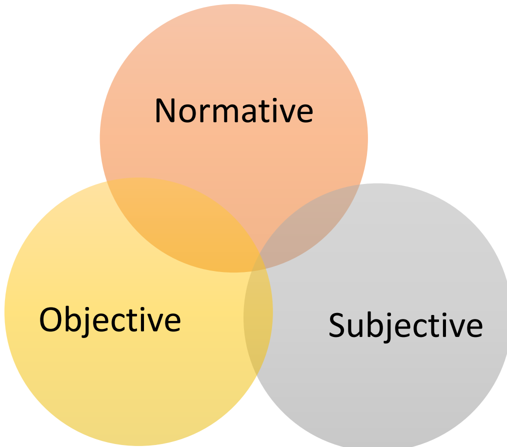

Figure 2.5 Livability Qualities of Life

2.5 System Dynamics

System dynamics (SD) is a powerful tool for analyzing large-scale, complex socio-economic systems. This methodology has been applied to various fields, including, but not limited to, global environmental sustainability, regional sustainable development issues, environmental management, water resource planning and ecological modeling, agricultural sustainability, regional environmental planning and management, national development programs, transportation, and land use.

All SD models have three types of variables: stock, rate, and auxiliary; and two kinds of flows: physical/material and information. Variables could interact with each other only through those two flows. Variables, together with flows, provide the fundamental structure of one dynamic system, called the stock-flow diagram. In SD, simulation is governed entirely by the passage of time known as ‘‘time-step’’ simulation. The common purpose of this approach is to understand the fundamentals of the dynamics of concern and to search for managerial decisions to improve the situation. These dynamics refer to the long-term, macro-level decision rules used by upper management. Figure 2.6 illustrates the general concept of the SD model incorporating both transportation supply and demand.

Abbas and Bell (1994) described the advantages of using a SD approach to transportation modeling as follows:

1. A systematic approach to the transportation problem
2. Feedback interaction between supply and demand vs. supply/demand equilibrium
3. Integrated and comprehensive view incorporating all other related subsectors vs. conventional
4. SD models capture the dynamic of the transportation system and generate results dynamically
5. SD models produce experimental tools, providing more flexibility for future analysis

However, there are limitations of SD

1. Reaching an optimal design is difficult. Some research has developed a heuristic optimization approach, but it is tedious work.
2. It is also difficult to validate the results of the SD model because transportation planners evaluate the usefulness of the results rather than numerical results.

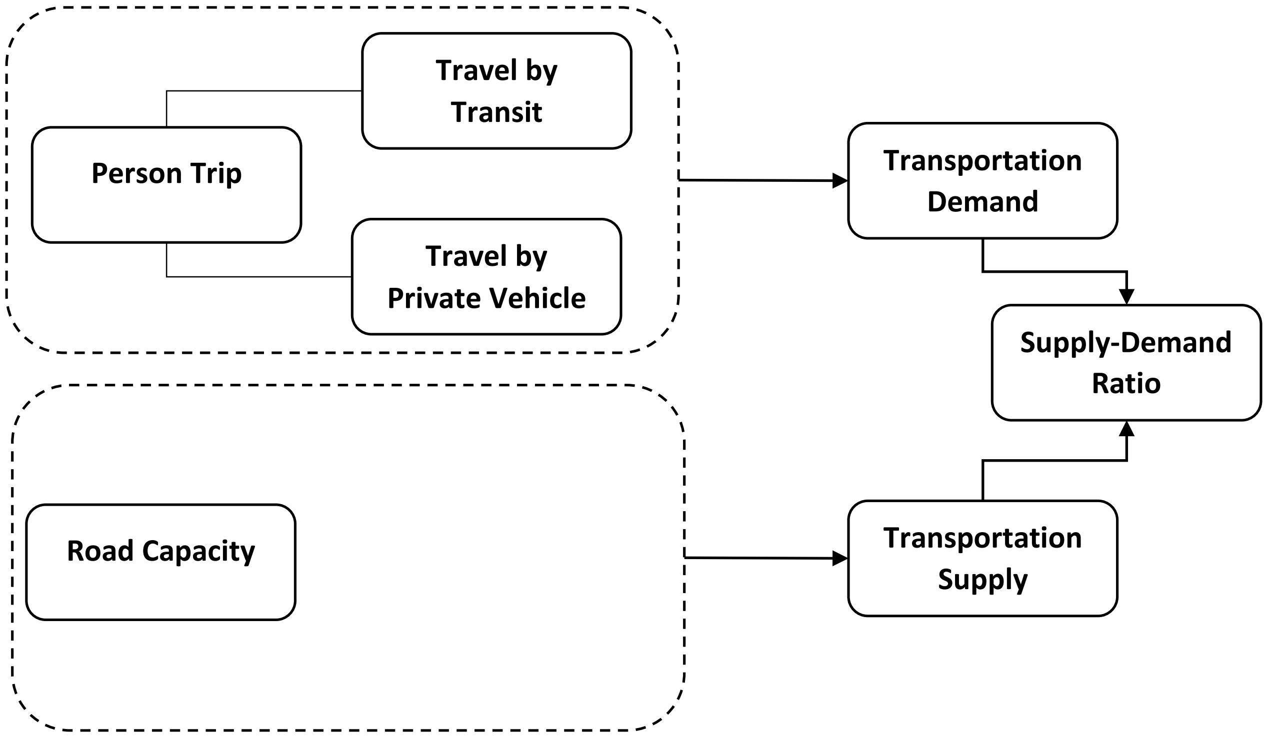

Figure 2.6 Supply-demand model

Rodrigue et al. (2017) describe the transportation system as a collection of several elements such as infrastructures, modes, and terminals, enabling individuals, institutions, corporations, regions, and nations among others. Such a system supports and drives the mobility of people, freight, and information. Mobility must occur over infrastructures with a fixed capacity which translates to transportation supply. In other words, the transportation system consists of two main components: travel demand and transportation supply (Rodrigue et al. 2017). On the one hand, transportation supply is the capacity of transportation infrastructures and modes over a geographic area for a specific period. Practitioners usually express the capacity in terms of infrastructures (capacity), services (frequency) and networks (coverage). On the other hand, transport demand is the need for mobility. Similar to transport supply, it can be expressed as number of people, volume, or tons per unit of time and space.

3. RESEARCH DATA AND METHODOLOGY

Data and methodology for both the livability index and system dynamics models are the focus of this chapter. Calculations were conducted for the nine-county region of North Dakota most heavily impacted by oil production fluctuations (Figure 3.1). The nine counties included in the index were Divide, Burke, Williams, Mountrail, McKenzie, Golden Valley, Billings, Dunn, and Stark. Both the livability index and system dynamics models included historical data calculations as well as forecasted scenarios dependent on regional estimates.

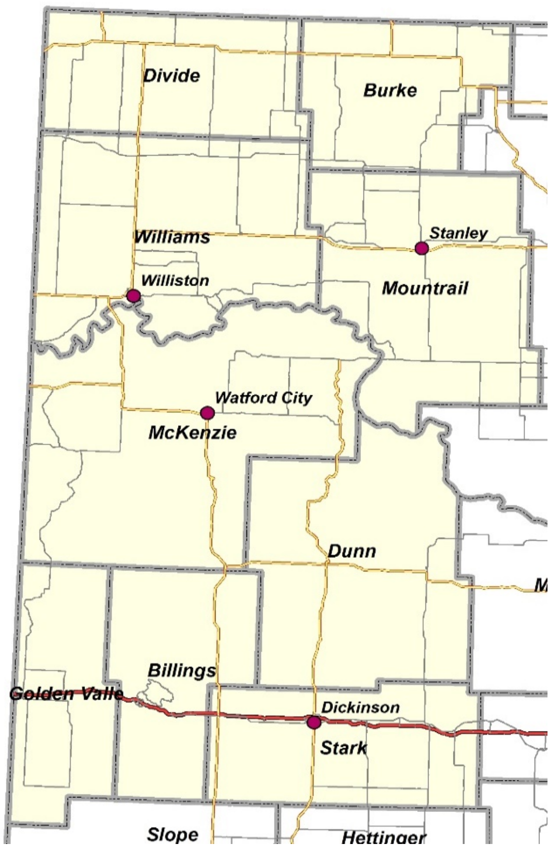

Figure 3.1 Nine-county region

3.1 Transit Livability Data and Methodology

Transit livability indexes were calculated based on six core livability principles developed by the Partnership for Sustainable Communities (Table 3.1) (DOT, HUD, and EPA 2014). Data used to calculate index measures were collected from both the National Transit Database (Federal Transit Administration 2016), and the American Community Survey (U.S. Census 2016).

Table 3.1 Livability Principles

Provide more transportation choices
Promote equitable, affordable, housing
Enhance economic competitiveness
Support existing communities
Coordinate policies and leverage investment
Value communities & neighborhoods

Table 3.2 lists each livability principle and its relationship to public transportation. Previous work by both Peterson and Ndembe (2015) and Brooks et. al. (2013) focused on the relationship between transit and livability. These relationships are defined in this research as well as in those previously mentioned. The transit livability index measures used in this study are shown in the third column.

Table 3.2 Livability's Relationship to Transit and Measurements

Livability Principle	**Relationship to Transit**	**Index Measure**
Provide more transportation choices	Transit service provides an alternative transportation choice.	Percent of workers that do not drive alone to work
Promote equitable, affordable housing	Transit provides a means to connect home owners to communities and can lower overall housing and transportation expenses.	Household income after transportation and housing expenses
Enhance economic competitiveness	Transit provides greater accessibility to workers for commuting and access to services, improving the economic competeveness of a community.	Revenue vehicles/county population
Support existing communities	Transit utilizes the existing built environment to serve and support an existing community.	Ridership/developed land area
Coordinate policies and leverage investment	Transit coordinates funding from federal, state, and local entities to provide quality service and operate cost-effectively.	State and local operating investment/operating expenses
Value communities & neighborhoods	Transit adds value to local communities by serving local residents who deserve safe, affordable transportation choices while often possessing mobility disadvantages.	Ridership/county mobility needs index

All transit livability index measures were calculated at the county level from 2008 to 2016. Time series data illustrates the impact of oil production on transit during the defined time period. Equal weighting was assigned to all measures as individual index measures illustrate a specific livability principle. Thus, no specific measure was quantified as being more important than any other. Also, after initial calculations were completed, the index was categorized in percentiles from 1 to 10 using a normal distribution. This provided consistency for analysis and comparison among results.

3.2 System Dynamics Data and Methodology

3.2.1 Model

In this section, we identified the variables and established the relevant equations based on the feedback and cause-and-effect loops as shown in Figure 3.3. We limited the scope of this part of the study to the cities located in nine North Dakota counties to address two dominate modes of transportation (personal vehicle vs. public bus). These cities are home to 62% of the entire population in the counties (U.S. Census Bureau 2012). The rest of population lives in very small towns or rural areas with little to no access to transit service.

3.2.2 Population sub-model

The population sub-model reflects the developing stage of selected cities in this model (Table 3.3). Population size influences the total transportation demand. We assumed the average population growth rate of 5% inclusive of birth rate, death rate, and net migration rate, which is reasonably close to official estimates (Figure 3.2).

- Population = populationGrowthRate * Population

Table 3.3 Population Trends by City

City	County	Population 2000	Population 2010	Population 2017
Alamo	Williams	51	57	69
Alexander	McKenzie	217	223	308
Ambrose	Divide	23	26	27
Arnegard	McKenzie	105	115	152
Beach city	Golden Valley	1,116	1,019	1,065
Belfield	Stark	866	800	976
Bowbells	Burke	406	336	340
Columbus	Burke	151	133	139
Crosby	Divide	1,089	1,070	1,310
Dickinson	Stark	16,010	17,787	22,186
Dodge	Dunn	125	87	100
Dunn Center	Dunn	122	146	179
Epping	Williams	79	100	115
Flaxton	Burke	73	66	66
Fortuna	Divide	31	22	22
Gladstone	Stark	248	239	351
Golva	Golden Valley	106	61	68
Grenora	Williams	202	244	287
Halliday	Dunn	227	188	197
Killdeer	Dunn	713	751	1,144
Lignite	Burke	174	155	230
Medora	Billings	100	112	132
New Town	Mountrail	1,367	1,925	2,528
Noonan	Divide	154	121	119
Palermo	Mountrail	77	74	85
Parshall	Mountrail	981	903	1,250
Plaza	Mountrail	167	171	198
Portal	Burke	131	126	143

Powers Lake	Burke	309	280	284
Ray	Williams	534	592	780
Richardton	Stark	619	529	538
Ross	Mountrail	48	97	113
Sentinel Butte	Golden Valley	62	56	63
South Heart	Stark	307	301	410
Springbrook	Williams	26	27	32
Stanley	Mountrail	1,279	1,458	2,645
Taylor	Stark	150	148	163
Tioga	Williams	1,125	1,230	1,499
Watford City	McKenzie	1,435	1,744	6,523
White Earth	Mountrail	63	80	91
Wildrose	Williams	129	110	131
Williston	Williams	12,512	14,716	25,586
	Total	**43,709**	**48,425**	**72,644**

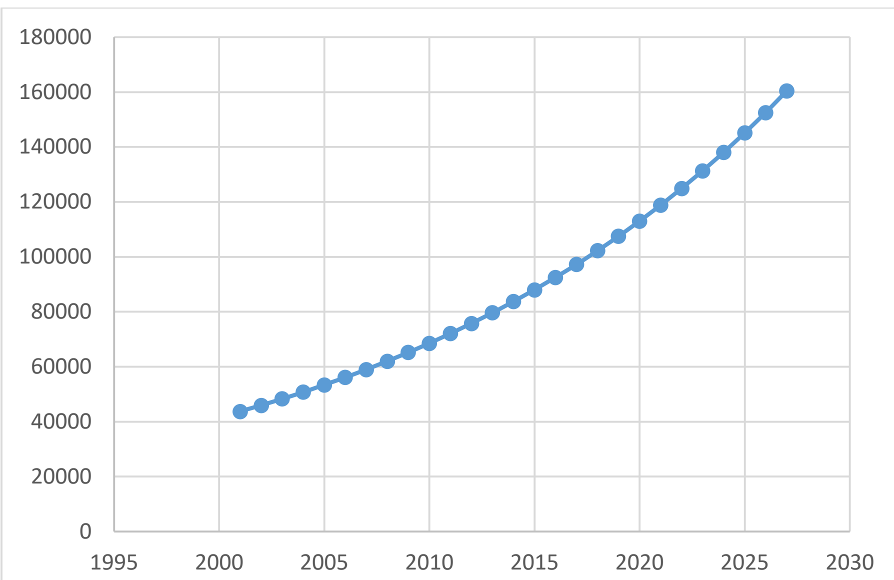

Figure 3.2 Population Estimates

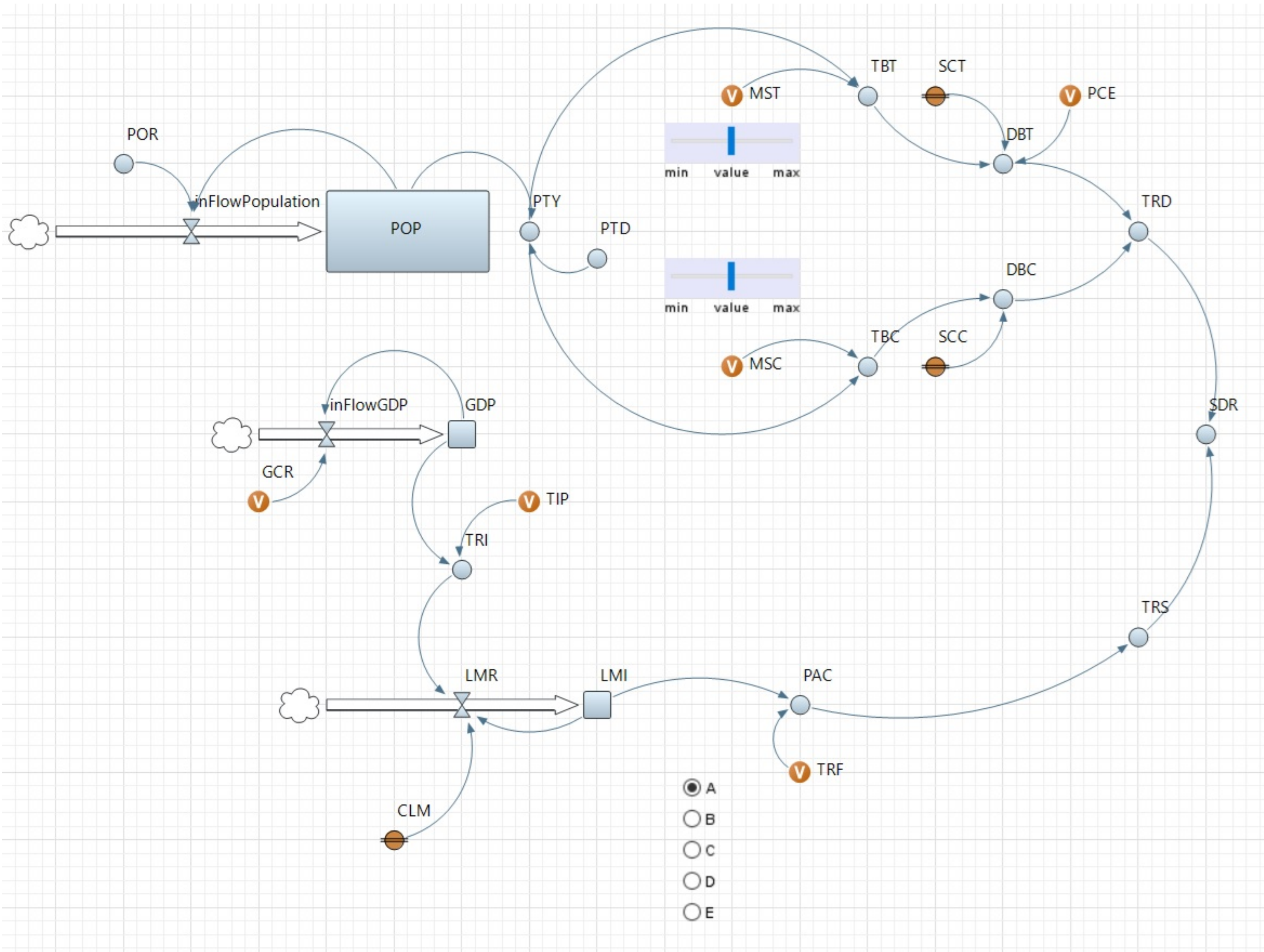

Figure 3.3 Cause-and-effect loop

3.2.3 Transportation demand sub-model

Transportation demand is heavily dependent on population. Transportation demand D is the sum of the demand for transit and private car and can be expressed as:

$$D = D_{transit} + D_{private\_car}$$

The variables of this sub-model include the average daily person trips, trips by transit, trips by private car, the demand for transit, the demand by private car and the total demand for transportation. We used data from 2009 National Household Travel Survey for person trips per day, mode share by transit, and mode share by private car (U.S. DOT 2011) . According to the 2017 *Rural Transit Fact Book*, the average seating capacity for buses and automobile are 26.4 and 4.32 persons respectively. Given level terrain for city streets, passenger car equivalent (PCE) for buses varies with flow rates of 1.7, 1.2, 1.1 for less than 600, between 600 and 1200, more than 1200 passenger car per hour respectively, according to the *Highway Capacity Manual* (HCM 2010). The average daily number of trips is 3.79 trips per person[1]. The equations of this sub-model are:

Population growth rate	POR
Person trips per year	PTY
Person trip per day	PTD[2]
Population (annual)	POP
Trips by transit	TBT
Trips by private car	TBC
Mode share by transit	MST
Mode Share By Private Car	MSC
Average seating capacity by transit	SCT
Average seating capacity by private car	SCC
Passenger car equivalent for transit	PCE

- POP_{annual} = POR * POP
- PTY = POP_{annual} * PTD * 365
- TBT = PTY * MST
- TBC = PTY * MSC
- DBT = (TBT / SCT) * PCE
- DBC = TBC / SCC
- TRD = DBT + DBC

3.2.4 Economy sub-model

The economy sub-model reflects the forces driving rural transportation development. The level of the economic development is one of the city competitiveness indicators and directly affects transportation investment because the government has to increase spending on transportation infrastructure to

[1] https://nhts.ornl.gov/2009/pub/stt.pdf - Table 3

[2] National Household Survey defined person trip as a trip from one address to another by one or more persons in any mode of transportation. Each person is considered as making one person trip. For example, four persons traveling together in one auto are counted as four person trips https://nhts.ornl.gov/2009/pub/stt.pdf.

accommodate traffic. We defined GDP as a level variable (annual), annual GDP growth rate as a rate variable, and transportation investment rate as an auxiliary variable. Because GDP was not available at the county level, we used the GDP values from Bureau of Economic Analysis (2018) for calculating GDP growth rate. For the base year, we used the per capita GDP of North Dakota multiplied by the base year population (U.S. Bureau of Economic Analysis 2018). For transportation investment rate, we considered the investment data as percent of GDP from the Congressional Budget Office report (Musick and Petz 2015). The annual transportation investment rate follows a uniform distribution with a mean of 1.03 percent. The equations of this sub-model are as follows:

Gross domestic product	GDP
GDP per capita growth rate	GCR
Transportation investment as percentage of GDP	TIP
Transportation investment	TRI

- GDP_{annual} = GCR * GDP
- TRI = GDP * TIP

3.2.5 Transportation supply sub-model

Transportation supply reflects the level of built rural infrastructure and maintains a dynamic equilibrium with transportation demand. The level of transportation supply depends on the investment in infrastructure construction and improvement. The equations of this sub-model are as follows:

Lane miles	LMI
Cost per lane mile	CLM
Lane mile growth rate	LMR
Passengers cars	PAC
Traffic flow	TRF
Passenger car equivalent per hour	PCH
Transportation supply	TRS
Supply to demand ratio	SDR

- LMI = TRI / CLM
- PAC = PCH * 24 * 365

The *North Dakota Transportation Handbook* estimates that it costs almost $2 million per lane-mile for total reconstruction including grading and asphalt surfacing. However, this cost does not cover all construction-related costs. To estimate traffic flow rate (in passenger cars per hour per lane) on a daily basis, we use the 2010 *Highway Capacity Manual* speed-flow curve for a speed limit of 25 mph at different levels of service (H.C. Manual 2010). The transportation supply S is the capacity of city streets in terms of the number of passenger car equivalent.

Finally, the transportation supply-demand ratio used to quantitatively describe the transportation system state is the ratio between transportation supply and travel demand. As the value of this ratio increases, rural transportation would become less obstructed. Figure 2.6 shows the supply-demand ratio estimating framework. We define α as the transportation supply-demand ratio where S and D are transport supply and travel demand, the model can be written as:

$$\alpha = {}^{S}/_{D}$$

4. INDEX AND SIMULATION RESULTS

4.1 Livability Index Results

Transit agencies in the North Dakota oil boom region saw tremendous ridership growth from 2008 to 2011. Ridership remained at or above 100,000 rides per year through 2014, but recently fell to 80,000 rides per year in 2016 (Figure 4.1). The largest decreases in ridership from 2014 to 2016 occurred in Williams and Stark counties. These are the two most populated counties in the nine-county oil boom region and their economies have been greatly affected by the recent decline in oil prices. However, comparing 2008 to 2016 ridership shows that overall ridership still nearly doubled during this time frame.

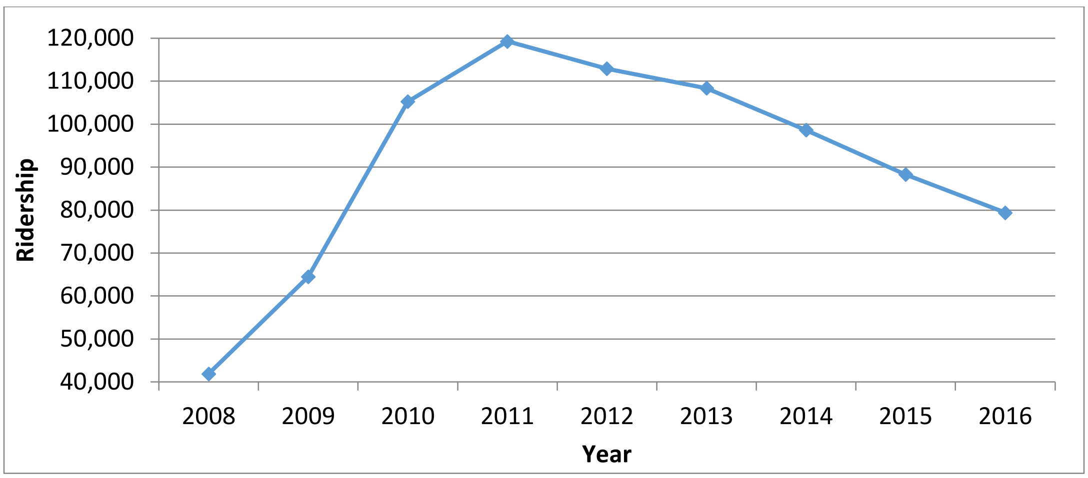

Figure 4.1 Western North Dakota Transit Ridership

Figure 4.2 shows the average transit livability index results from 2008 to 2016. The county indexes were classified ranging from 1 to 10, with Mountrail County showing the highest index value for the time period while Divide County generated the lowest. Overall, index values ranged from 4.34 to 5.70 which was relatively consistent considering the differing community sizes, demographics, and locations of the counties relative to the center of the oil patch. All raw data calculations can be found in the Appendix.

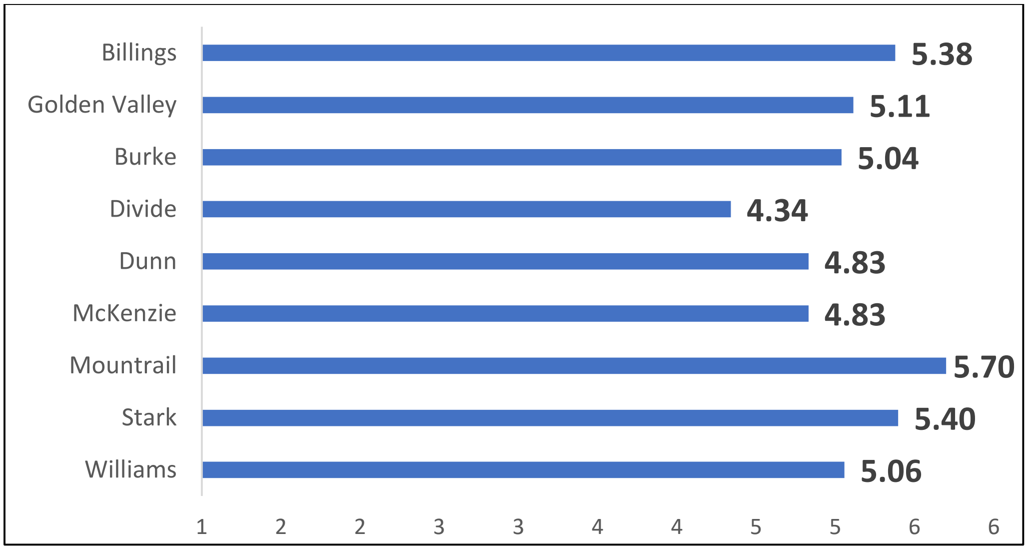

Figure 4.2 Transit Livability Indexes, by County, 2008-2016

The time series livability index results were categorized by county population. Table 4.1 shows the nine counties studied with their respective populations. The third column shows the categorization made for the analysis. Comparing counties with populations greater than 30,000 to those with fewer than 2,000 was not practical. For example, a relatively small change in either transit ridership or county population had much more influence on index values compared to a similar change among counties with larger populations. For this main purpose, and also because illustrating nine counties within one figure was both confusing and cumbersome, counties were segregated.

Table 4.1 County Population

County	Population	Size
Williams County	33,349	Large counties
Stark County	30,209	
McKenzie County	12,724	Medium counties
Mountrail County	10,265	
Dunn County	4,289	
Divide County	2,288	Small counties
Burke County	2,131	
Golden Valley County	1,789	
Billings County	940	

Figure 4.3 illustrates the nine-year transit livability indexes for Williams and Stark counties. Both counties showed an overall increase in their respective indexes from 2008 to 2013 primarily because of rapid population and transit ridership increases. However, from 2014 to 2016 their respective indexes have leveled off and have even begun to decrease. This is, undoubtedly, because of to the downturn in oil production. For example, in Williams County alone, transit ridership fell by roughly 40% between 2013 and 2016. Average income levels, however, have increased substantially since 2008, resulting in only recent minor declines within the overall index.

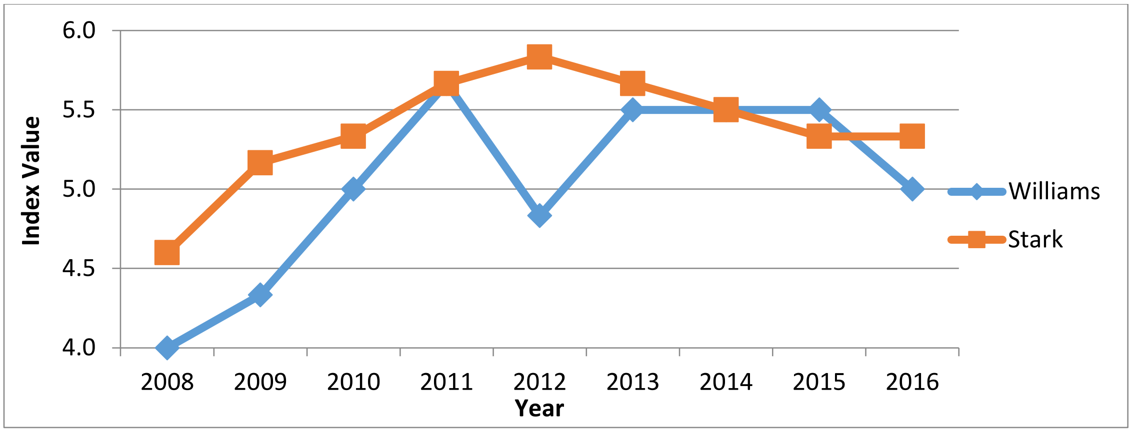

Figure 4.3 Transit Livability Indexes for Williams and Stark counties

Figure 4.4 shows the transit livability indexes for Mountrail, McKenzie, and Dunn counties. A combination of increased funding from state and local sources along with population growth, and a substantial increase in household income caused a significant increase in index values from 2008 to 2013. However, primarily because of the downturn in the oil patch, local funding and household incomes have decreased and population growth has stagnated from 2014 to 2016. For example, Dunn County has seen a decrease of nearly 15% in real household income in just 2 years, between 2014 and 2016, while Mountrail County has realized similar decreases as well.

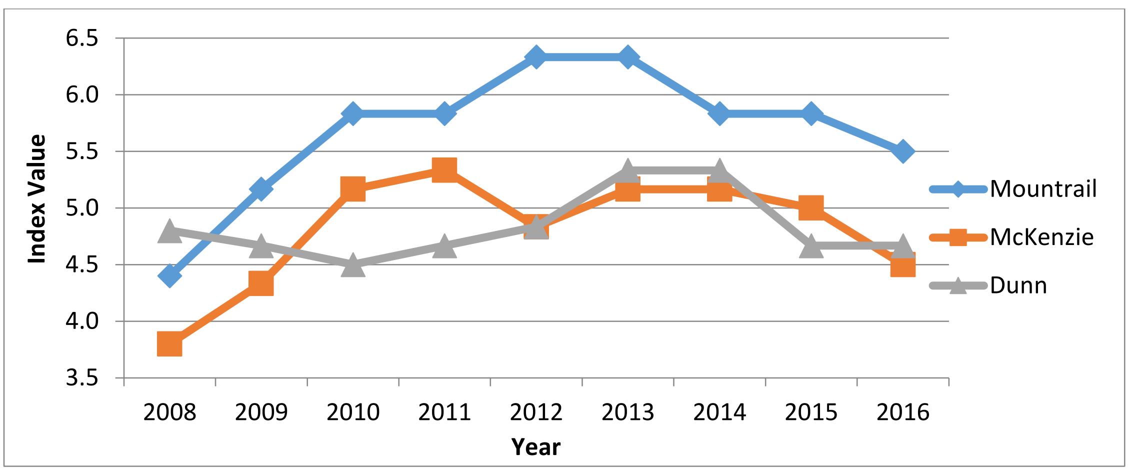

Figure 4.4 Transit Livability Indexes for Mountrail, McKenzie, and Dunn counties

Figure 4.5 shows transit livability indexes for Divide, Burke, Golden Valley, and Billings counties. These results are not as easy to interpret as those from larger counties. All of the indexes peaked for each county represented from 2013 to 2015. Overall transit ridership declined in Divide County while remaining relatively constant in the other three counties during the past few years. Also, real household incomes, along with state and local funding, have not fluctuated substantially compared to the larger counties in the oil patch. Overall, the smaller counties have not seen the dramatic boom and bust cycles from oil production that have been present in larger counties, resulting in lower volatility among index values.

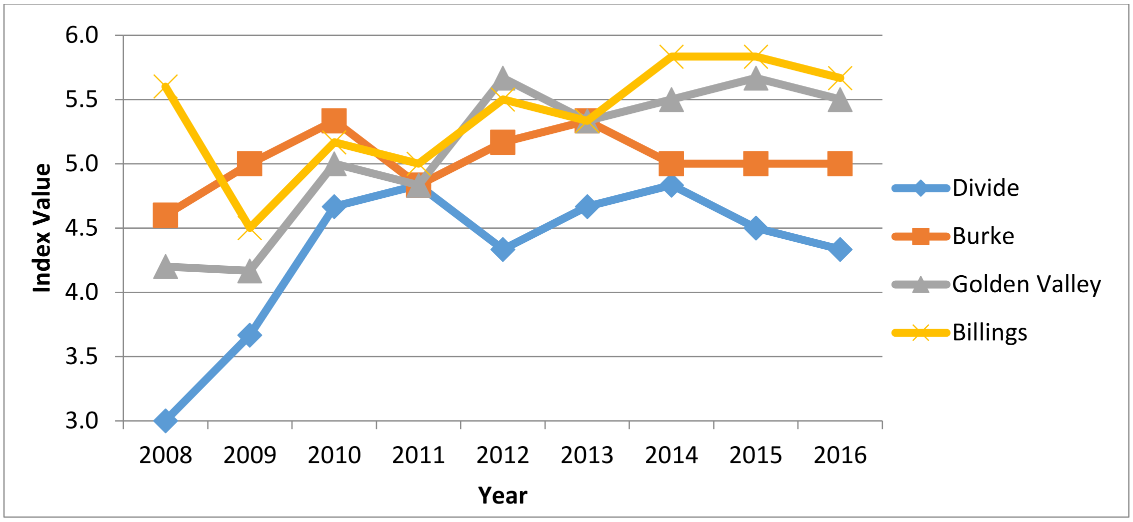

Figure 4.5 Transit Livability Indexes for Divide, Burke, Golden Valley, and Billings counties

The previous figures highlight livability indexes averaged across all six livability measures. Disaggregating the data to look more closely at individual measures yields some interesting findings. The individual livability measures not mentioned below can be found in Appendix A. Figure 4.6, for example, shows the index values for supporting existing communities. This measure is calculated by dividing transit ridership by the developed land area of a given county. Notice that values increased dramatically from 2008 to 2011 as ridership increased while the developed land area remained relatively constant. However, dramatic land development, especially within the larger counties of Stark and Williams coupled with decreased ridership, caused this measure to drop significantly from 2011 to 2016. This also raises concerns for pedestrian safety as more land is developed around communities and traffic begins to increase. Coupled with oil production traffic, pedestrians now have fewer options when contemplating walking for exercise along once primarily rural roads and must choose either different exercise alternatives, or relatively unsafe walking conditions.

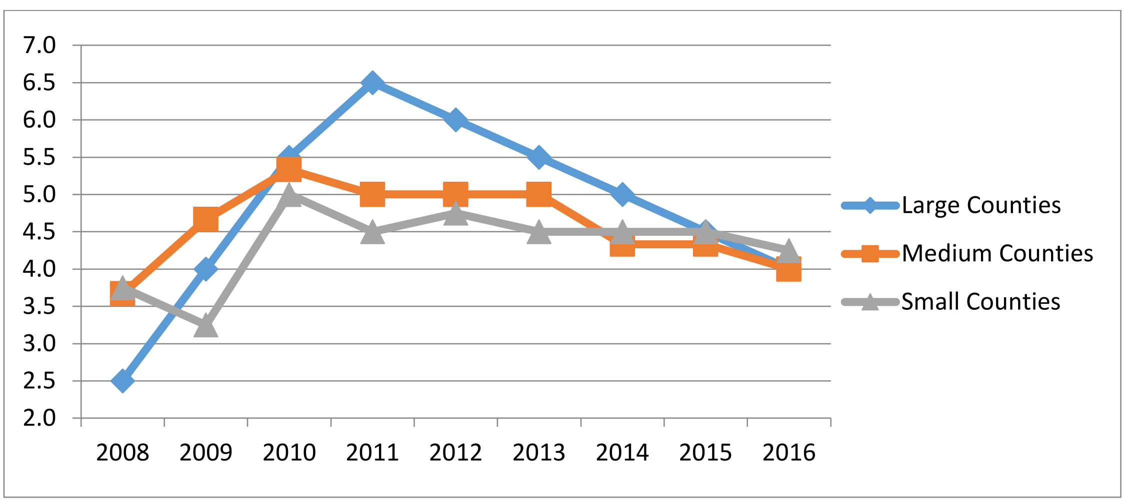

Figure 4.6 Support Existing Communities

Results from the livability measure for enhancing economic competitiveness also raise concern. Figure 4.7 illustrates that for, both small and large counties, this index measure has fallen from its 2011 high. It is calculated by dividing the number of transit vehicles by the population they serve. Results indicate that as populations increased in recent years throughout the oil producing region, the number of transit vehicles has not increased proportionally. This is predominantly true among larger counties which have seen tremendous gains in total population with little to no increase in transit vehicles to serve their populations.

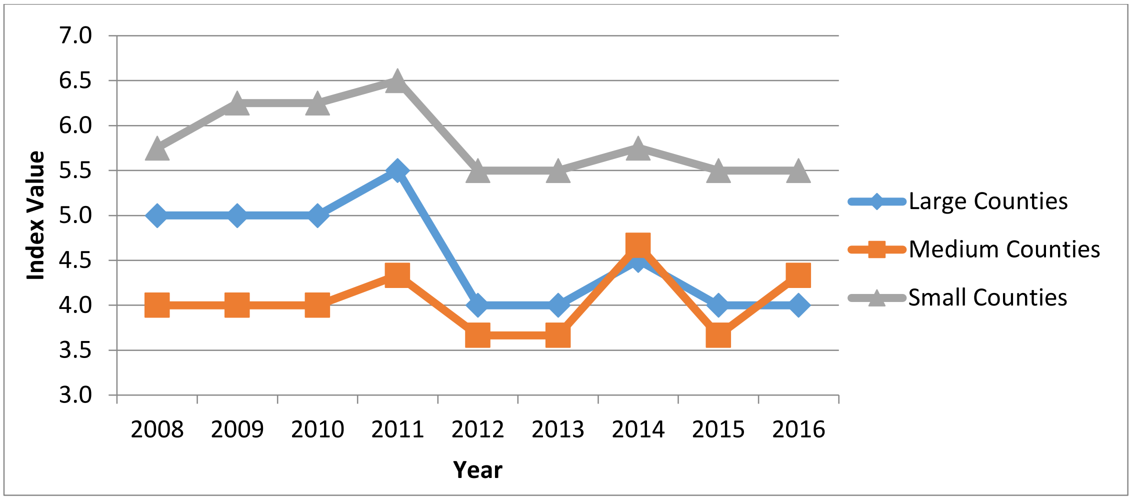

Figure 4.7 Enhance Economic Competitiveness

Figure 4.8 shows the index measure for valuing communities and neighborhoods. This variable is calculated by dividing transit ridership by the mobility needs index of a given county. Once again, this particular measure has steadily decreased or remained constant for all counties during the past three to four years. This corresponds to decreased ridership seen in Figure 4.1 as well as an increasing mobility needs index among both large- and medium-sized counties. Mobility needs indexes have grown along with the increasing populations of these counties while the largest counties are showing needs indexes approaching those in some of North Dakota's most heavily populated areas.

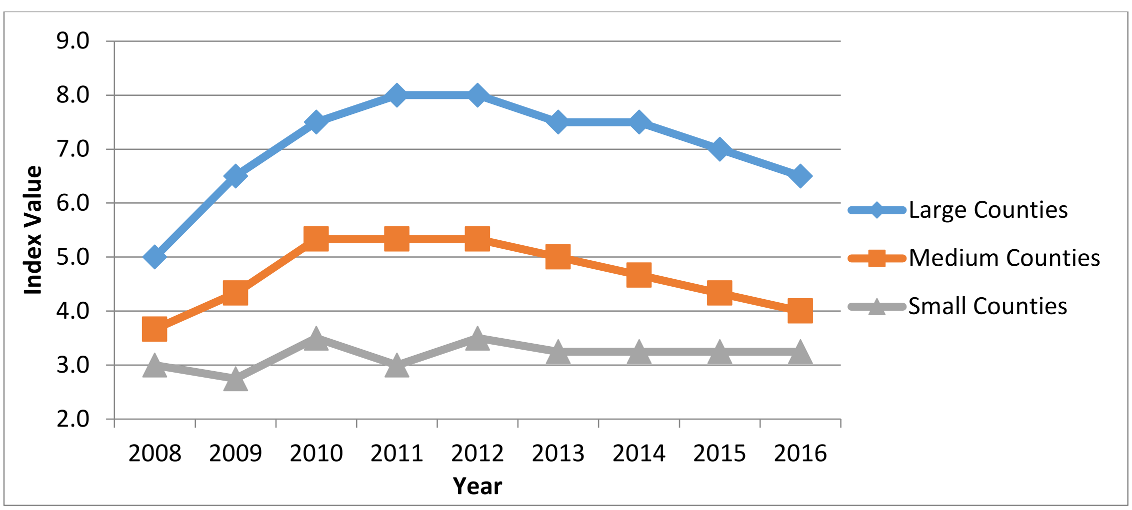

Figure 4.8 Value Communities and Neighborhoods

4.2 System Dynamics Simulation Results

In this section, two different scenarios are considered including: 1) change in mode share; 2) increase in transportation investment as a percentage of GDP by checking the sensitivity of the supply-demand ratio.

4.2.1 Scenario 1

As expected, because of several generalizations throughout the model development and the nature of rural transportation system, there is excess supply throughout the forecasting period from 2017 to 2027. However, the percentage change was checked by shifting the mode share from private cars to transit by 0.5, 1, 1.5, and 2%. The percentage change corresponding to the supply-demand ratio change are 0.497%, 0.998%, 1.505%, and 2.016% for 0.5%, 1%, 1.5%, and 2% change in mode shift. The change in supply-demand ratio reasonably corresponds to percentage change for the mode shift from private cars to transit alternative.

On the other hand, as shown in Figure 4.9, the number of trips saved by such a mode shift increased relatively linearly. For example, in year 2018, almost 220, 440, 660, 880 thousand trips might have been saved by 0.5%, 1%, 1.5% 2% mode shifts, respectively. Given a 36.13 mile average trip length and an average fuel efficiency of 23.4 miles per gallon for private vehicle type, almost 1.36 million gallons of fuel would be saved with a mode shift of only 2%.

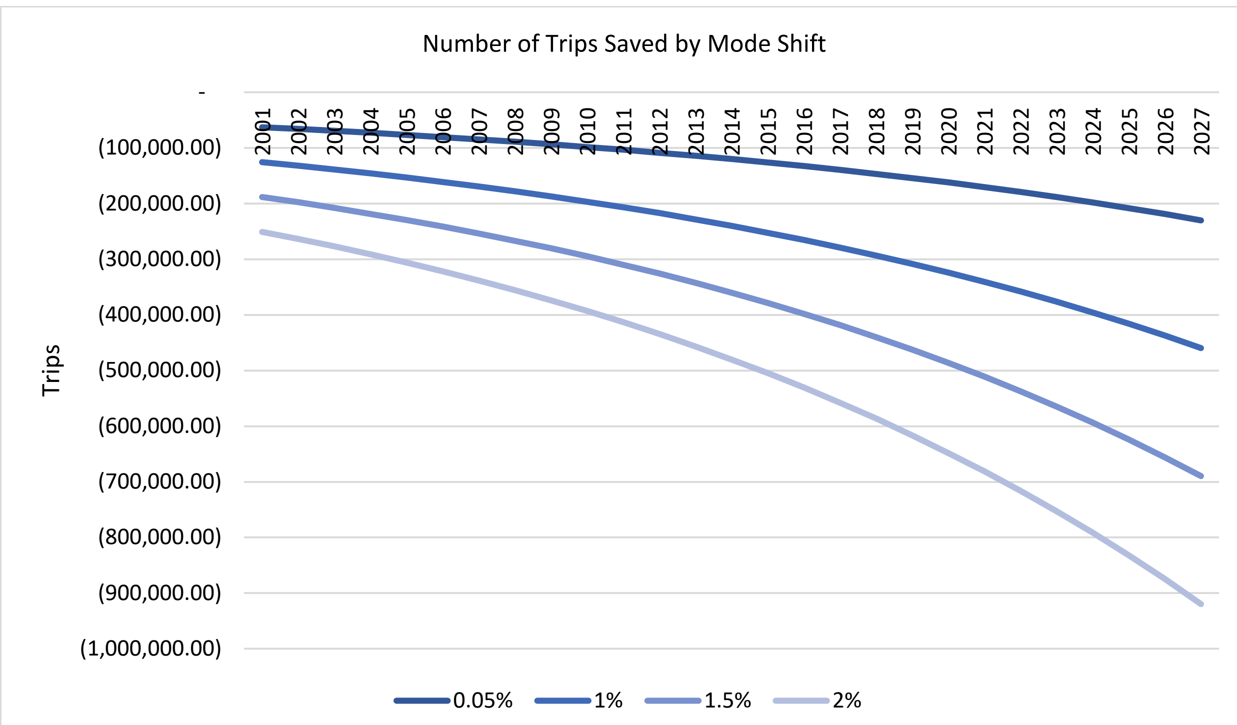

Figure 4.9 Trips saved by mode shift

4.2.2 Scenario 2

In scenario 2, the investment as the percentage of GDP from the base year mean value of 1.03 was increased by 5% each year. Surprisingly, as shown in Figure 4.10, the impact of a change in mode shift is much more significant on supply-demand ratio than the change in investment. With 20% percent change increase in investment, the supply-demand ratio changes only 1.4 percent.

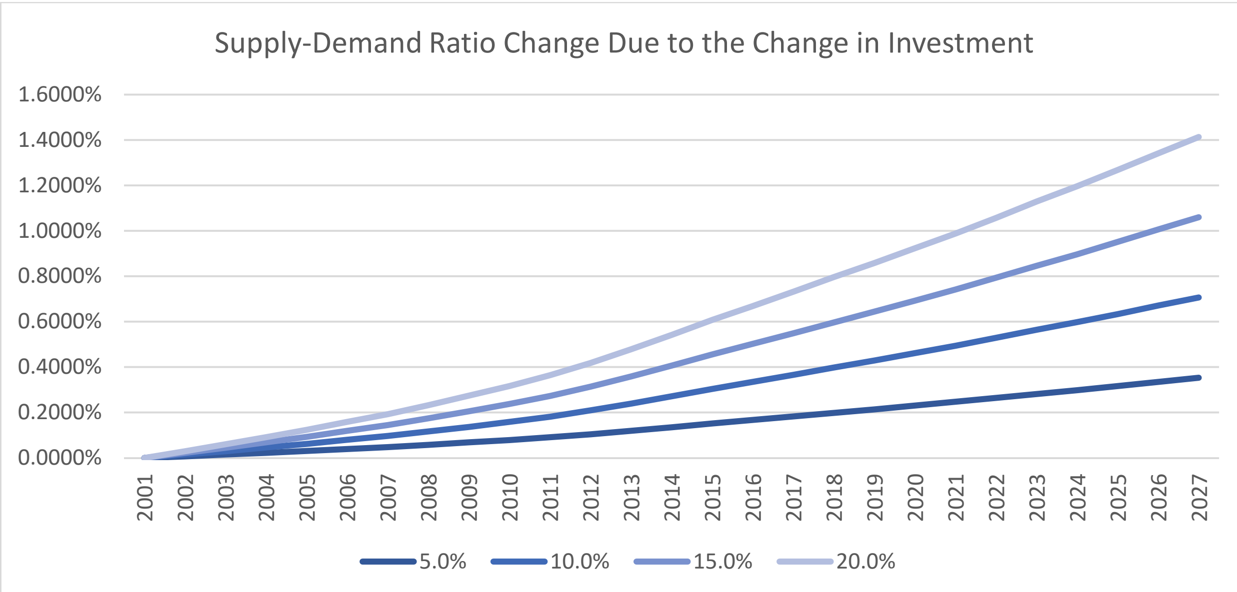

Figure 4.10 Supply-demand ratio by change in investment

4.2 Summary

The main objective of the transit livability index measures in this chapter was to determine the effect of the western North Dakota oil boom on livability in the region, especially as it pertains to public transportation. Overall, measures have been decreasing in recent years as oil production and economic advances have diminished. Fewer workers are utilizing transit and more commuters are commuting alone to work on a daily basis. Also, an increasing mobility needs index, primarily in Stark and Williams counties, has led to lower measurements within the valuing communities and neighborhoods index associated with communities located in these counties. Further, the size of the transit fleets within these counties has not increased proportionally to population growth from 2008 to 2016 and this has caused the measure of economic competitiveness to decrease and/or stagnate. Finally, pedestrian safety has become a concern as more land in and around local communities has been developed, and, when coupled with traffic increases from oil production, pedestrians may no longer feel safe while walking on rural roads for exercise.

System dynamics simulation findings showed that a relatively small mode shift of 2% from private vehicle to transit could have a substantial effect on oil patch traffic flows. However, the most noticeable improvement would be financial, as this same 2% mode shift was estimated to save more than 1.36 million gallons of fuel in the oil patch during the forecast time period.

5. SUMMARY AND CONCLUSIONS

Discoveries of shale gas reserves along with the development of horizontal drilling and hydraulic fracturing techniques, as well as the initiative to move the United States toward greater energy independence led to the most recent oil boom in western North Dakota (U.S. Congress 2007). Overall, the boom resulted in a billion-dollar surplus for the state budget in North Dakota from severance taxes and extensive mineral rights. The population doubled in some areas, e.g., the city of Williston grew by 67% from 2010 to 2014 (Scheyder 2016). After almost a decade of production of North Dakota shale oil, prices dropped from around $100 a barrel in 2014 to about $30 in early 2016 and the industry went into the bust portion of the economic cycle where oil production and affiliated employment and spending contracted and the state and industry are waiting for crude oil prices to reach $60 per barrel again (Scheyder 2016).

Transit livability index measures showed large increases from 2008 to 2012 followed by overall corrections from 2013 to 2016. These measures declined as oil production and economic advances diminished. Further, transit fleet size has failed to increase with population growth and pedestrian safety has become a concern along both rural and city highways. System dynamics simulations focused on potential mode shifts from private automobile to transit, finding that seemingly small shifts (1-2%) from auto to transit would result in millions of dollars of fuel savings in the oil patch.

A major finding of this research shows that although the recent oil bust has caused considerable concern in western North Dakota, the population and transit ridership are considerably larger today than they were in 2008. For example, transit ridership nearly doubled from 2008 to 2016 (Figure 4.1), due largely to the expanding local economy. Various models of either fixed-route or flex-route busing should be considered by transit agencies and local policy makers for the larger communities of Williston and Dickinson, while more rural providers need to update their fleets to meet demand as well. Policy makers should also consider that the majority of local rural transit riders are elderly and need quality vehicles with updated suspensions to provide comfortable rides for their aging clientele. Because recent cutbacks in state and local funding, agencies should also strive to better coordinate services while continuing to provide rides to county population centers that offer the goods and services many rural residents require.

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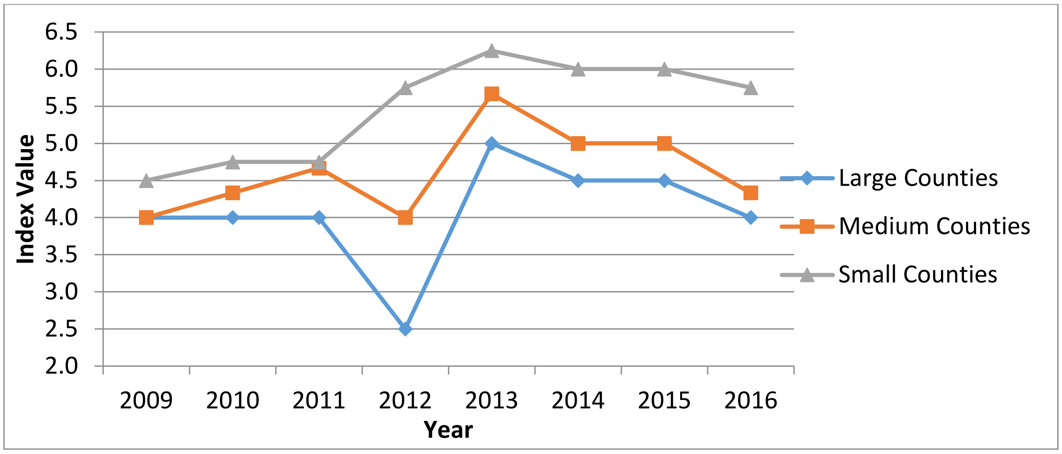
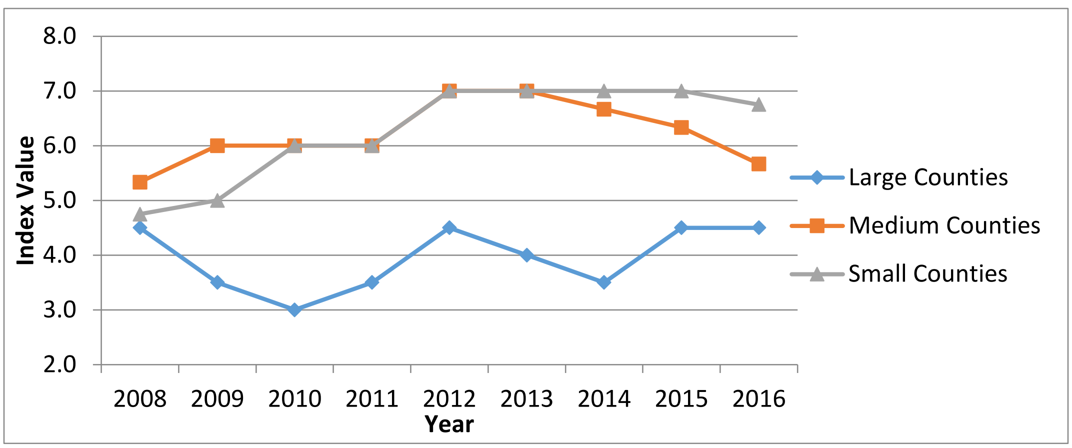
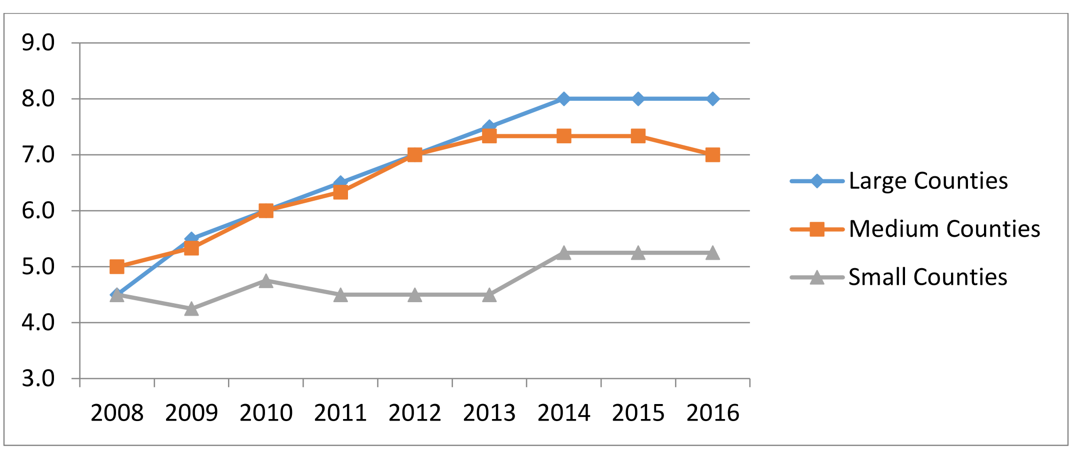
APPENDIX A: INDIVIDUAL LIVABILITY MEASURES



Coordinate Policies and Leverage Investments



Percent Who do not Drive Alone to Work



Promote Equitable and Affordable Housing

APPENDIX B: LIVABILITY MEASURES, RAW DATA

	Williams	Stark	Mountrail	McKenzie	Dunn	Divide	Burke	Golden Valley	Billings
C&L Fed Investment									
2009	38.1%	35.2%	39.8%	38.1%	37.1%	38.1%	39.8%	42.3%	42.3%
2010	40.0%	21.3%	36.1%	40.0%	39.0%	40.0%	36.1%	41.2%	41.2%
2011	41.8%	20.2%	39.3%	41.8%	40.4%	41.8%	39.3%	40.4%	40.4%
2012	18.7%	21.4%	43.6%	18.7%	44.2%	18.7%	43.6%	67.0%	67.0%
2013	40.9%	42.8%	52.8%	40.9%	52.8%	40.9%	52.8%	63.6%	63.6%
2014	43.7%	38.9%	46.8%	43.7%	43.6%	43.7%	46.8%	62.0%	62.0%
2015	41.1%	37.0%	43.4%	41.1%	48.0%	41.1%	43.4%	61.3%	61.3%
2016	37.1%	33.1%	44.5%	37.1%	36.7%	37.1%	44.5%	63.7%	63.7%
Value Communities and Neighborhoods									
2008	2838	2770	1798	1787	2502	888	1061	2348	1126
2009	4026	5399	2289	2534	2535	1259	1801	1182	567
2010	6209	8982	3520	3517	2043	2185	2308	1973	946
2011	5930	11495	3492	3111	1908	2318	1718	1589	762
2012	5775	10078	3614	3029	1997	2258	1778	2318	1111
2013	6100	8881	3112	2742	2319	2385	1722	1961	940
2014	5334	7831	3311	2398	1827	2085	1832	1993	956
2015	5066	6476	3043	2278	1680	1981	1684	1946	933
2016	3634	6375	3140	1634	1807	1421	1738	2382	1142
Enhance Economic Competitiveness									
2008	0.00028	0.00051	0.00042	0.00028	0.00022	0.00028	0.00042	0.00148	0.00148
2009	0.00027	0.00050	0.00042	0.00027	0.00022	0.00027	0.00042	0.00185	0.00185
2010	0.00029	0.00053	0.00046	0.00029	0.00022	0.00029	0.00046	0.00185	0.00185
2011	0.00030	0.00052	0.00048	0.00030	0.00022	0.00030	0.00048	0.00185	0.00185
2012	0.00024	0.00048	0.00042	0.00024	0.00022	0.00024	0.00042	0.00111	0.00111

2013	0.00022	0.00043	0.00042	0.00022	0.00025	0.00022	0.00042	0.00111	0.00111
2014	0.00029	0.00046	0.00040	0.00029	0.00033	0.00029	0.00040	0.00111	0.00111
2015	0.00022	0.00037	0.00040	0.00022	0.00024	0.00022	0.00040	0.00148	0.00148
2016	0.00022	0.00035	0.00038	0.00022	0.00036	0.00022	0.00038	0.00148	0.00148
Percent who do not drive alone to work									
2008	14.7%	15.6%	15.0%	14.0%	20.9%	11.1%	24.8%	12.8%	19.0%
2009	12.3%	14.0%	17.1%	13.8%	23.6%	13.9%	25.0%	12.1%	15.3%
2010	11.7%	14.0%	17.6%	15.1%	20.9%	16.3%	24.3%	13.1%	20.6%
2011	14.7%	12.7%	17.6%	15.1%	20.9%	16.3%	24.3%	13.1%	20.6%
2012	14.1%	15.6%	18.1%	16.9%	22.7%	19.0%	27.2%	17.4%	24.4%
2013	14.4%	14.9%	18.1%	16.9%	22.7%	19.0%	27.0%	17.4%	24.4%
2014	12.9%	14.3%	17.0%	17.4%	22.7%	20.0%	23.7%	18.3%	29.3%
2015	15.2%	13.3%	16.0%	16.2%	20.3%	17.0%	20.2%	19.8%	28.6%
2016	15.5%	14.9%	13.6%	16.1%	19.2%	20.0%	17.6%	19.6%	24.5%
Promote Equitable Affordable Housing									
2008	40,626	33,242	36,854	35,731	36,481	35,878	39,396	18,484	44,030
2009	42,897	35,196	42,755	37,402	38,844	34,405	38,982	22,092	40,056
2010	48,666	39,077	44,305	41,914	42,385	32,893	41,658	23,294	40,694
2011	50,554	39,647	47,489	43,770	41,596	34,083	40,937	23,752	37,378
2012	53,677	41,536	50,985	46,720	41,542	35,680	38,993	23,041	34,469
2013	57,067	43,665	52,210	48,365	45,357	35,774	37,636	22,804	40,982
2014	62,428	49,021	48,734	49,523	52388	39800	37411	25209	46290
2015	63,422	48,711	48,636	51,086	49572	36495	40306	25782	49134
2016	62,094	50,346	45,879	54,224	44353	41153	42909	21480	44047

Support Existing Communities									
2008	473	602	899	510	834	386	663	1381	938
2009	671	1125	1526	724	845	547	1126	695	472
2010	1140	1761	2011	1256	681	950	1506	1161	788
2011	1140	2169	1863	1166	596	966	1432	935	586
2012	1031	1866	1701	1069	624	903	1482	1288	855
2013	1034	1586	1556	1010	725	883	1325	1032	723
2014	904	1398	1655	884	571	772	1409	1049	735
2015	859	1156	1521	839	525	734	1295	1024	718
2016	616	1138	1570	602	565	526	1337	1254	878