Saint Cloud APO Travel Demand Model Calibration & 2050 Population Forecasts

Model Calibration / Validation Report

Report Version 1.2

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SRF

In Partnership With

METROANALYTICS

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Table of Contents

Introduction

The Saint Cloud Area Planning Organization (APO) retained SRF Consulting Group and Metro Analytics to update the existing travel demand modeling platform, with assistance from Transportation Collaborative & Consultants (TC2).

The model inputs and assumptions were revisited and updated. The updated model was validated to 2021 observed traffic data available from the Minnesota Department of Transportation (MnDOT)'s Traffic Mapping Application in the Traffic Forecasting and Analysis website[1].

The model was developed on the CUBE VOYAGER platform. The most recent update was performed in 2022 using the CUBE software version 6.4.5 (August 13, 2019). It is recommended to verify or validate model results if other versions are used.

The purpose of this document is to describe each of the tasks performed as part of this effort.

[1] http://www.dot.state.mn.us/traffic/data/tma.html

Project Overview

The Saint Cloud APO (Area Planning Organization) Model Calibration-Validation Study represents the third of four phases aimed at updating the area's regional travel model and Metropolitan Transportation Plan (MTP). The first phase, Travel Demand Model Improvements, was completed in 2020 by Metro Analytics, and involved defining new model components, assumptions, and file structures. The second phase, the Regional Mobility Survey (RMS), was completed in 2021, and comprised a comprehensive household travel survey of the Saint Cloud area. The third phase, and the subject of this report, is a 2020 base year model calibration and validation study that combines the model and file structures from the first phase with findings from the RMS for a complete calibration and validation of the regional travel demand model. This phase, completed at the end of 2022, will be followed by an update of the MTP to a new horizon year 2050 during 2023, to be led by APO staff.

The work approach for the Model Calibration-Validation Study reflects dialogue with APO staff, discussions among key team members, review of available materials from the RMS, and an understanding of recent APO model refinements. A series of 10 tasks were identified to complete model calibration and validation. These tasks are itemized below and form the basis for remaining chapters of this report:

1. Base and horizon year demographic data
2. Traffic count data update
3. Model Estimation/Household survey analysis
4. Calibrate/validate trip generation
5. Calibrate/validate trip distribution
6. Validate auto occupancy/mode choice
7. Validate trip assignment
8. Model sensitivity testing
9. 2050 model forecasts
10. Project coordination/management documentation

The consulting team of SRF Consulting and Metro Analytics was selected to conduct this study. SRF led Tasks 1 through 3 plus Tasks 8 and 9 while Metro Analytics led Tasks 4 through 7. The product of Task 10 is this report, a collaborative effort of the two primary consulting firms. A third firm, Transportation Collaborative & Consultants, assisted with Task 1 forecasting 2050 socioeconomic data (SED) used in subsequent Tasks 8 and 9. These socioeconomic forecasts will be a key input to the forthcoming 2050 MTP. Full validation of trip generation or trip distribution was not complete until the highway assignment was validated by iterating back through the model chain, making various adjustments.

The emergence of the COVID-19 pandemic provided challenges to the calibration and validation process. Base year 2020 household data were from April 2020, and reflect a full shutdown due to the pandemic, whereas 2020 employment data pre-dated the pandemic shutdown, with a base of early 2020. The household travel survey was conducted in late 2021 and thus reflected post-pandemic conditions while the model network was developed to mimic mid-2020 roadways conditions. External trips were previously estimated during the 2020 study using 2019 big/passive data from StreetLight InSight. Traffic counts for both 2020 and 2021 were used to validate the trip assignment model. In the end, it was determined that 2021 traffic counts better reflect travel patterns reported in the RMS.

Base and Horizon Year Demographic Data

Base Year Employment and Household Data

Base year employment data was provided by the Saint Cloud APO. For households, the 2020 Decennial Census provides the baseline data inputs for base year. Census blocks, the smallest geographic unit used by the Census, nest within traffic analysis zones (TAZs) and can be aggregated. Each TAZ is assigned the sum of households and population of the census blocks that fall within it.

The model also uses socioeconomic information like household size, vehicles per household, and workers per household in the trip generation models. This information comes from 2020 American Community Survey (ACS) data. Census block groups, a geography bigger than census blocks, are the smallest geography that has these more detailed variables. TAZs tend to nest within Census Block Groups. The distributions and averages of the household size, vehicle and worker data are assigned to the TAZs that fall within each block group.

Then data within each TAZ can be organized to reflect the block group characteristics. So, the total number of households matches the 2020 value, and those households are distributed between the different household sizes according to the ACS data. Once this is performed for all the ACS variables, the TAZ data set is ready to move forward through the rest of the modeling process. This includes the number of households (from sizes one person to five or more persons), the number of workers per household (from zero workers to three or more) and auto ownership per household (from zero to three or more).

The SED inputs used in the model is summarized in Table 1.

Future Year Employment and Household Data

The project team adopted a quantitative/qualitative approach to create the 2050 socioeconomic forecasts. The forecasting process for the travel demand model update is conducted in three stages:

- Initial forecast data estimates
- Stakeholder meetings
- Final forecast data estimates

Initial Forecast Data Estimations

In general, the initial estimation approach uses existing 2015-2045 data from the Saint Cloud MTP to derive growth rates. These growth rates were then applied to 2020 Census data and employment data to estimate 2050 data. Additionally, aggregate population growth rates are calculated from 2015 and 2045 population totals, by municipality, with MTP data.

Table 1. Socioeconomic Input Data

Column(s)	Variable Name	Descriptions
1	TAZ	Traffic Analysis Zone ID
2	POP	Population
3	HH	Number of Households
4	INDEMP	Industrial Employment
5	OFFEMP	Office Employment
6	RETEMP	Retail Employment
7	TOTEMP	Total Employment
8	SCHOOL	K-12 Enrollment
9	COLLEGE	Tertiary Education Enrollment
10	ATYPE	Area Type (used to compute terminal times)
11-15	HH1P/HH2P/HH3P/HH4P/HH5P	Percentage of Households by Person (1 to 5+)
16-19	AUTO0/AUTO1/AUTO2/AUTO3	Percentage of Households by Auto Ownership (0 to 3+)
20-23	W0PH/W1PH/W2PH/W3PH	Percentage of Households by Worker (0 to 3+)
24-43	HH1P0V/HH1P1V/HH1P2/HH1P3V HH2P0V/HH2P1V/HH2P2/HH2P3V HH3P0V/HH3P1V/HH3P2/HH3P3V HH4P0V/HH4P1V/HH4P2/HH4P3V HH5P0V/HH5P1V/HH5P2/HH5P3V	Percentage of Households by Person (1 to 5+) and Auto Ownership (0 to 3+)
44-59	W0V0/W0V1/W0V2/W0V3 W1V0/W1V1/W1V2/W1V3 W2V0/W2V1/W2V2/W2V3 W3V0/W3V1/W3V2/W3V3	Percentage of Households by Worker (0 to 3+) and Auto Ownership (0 to 3+)
60	Transit	Transit accessibility (basis for transit mode split)

After the 2050 totals are calculated, the data is distributed to TAZs based on the changes to associated land use within each TAZ in the MTP data.

Stakeholder Meetings

Communities within the model area were notified of the model update project and asked to submit any comments they may have regarding the socioeconomic data (SED) forecasts. The project team held "office hours" with representatives from the communities. These hour-long sessions were held over Zoom and consisted of going over the initial estimate with the stakeholders and noting feedback and clarifying any confusion. The communities of Saint Cloud, Sartell, Sauk Rapids, Saint Joseph, Waite Park, Haven Township, Benton County, Stearns County, and Sherburne County participated in the data review. Feedback was taken into account and when necessary additional rounds of meetings and/or changes for a community were performed.

Final Forecast Data Estimations

The final forecast data is the amalgamation of the initial estimates and the qualitative data gained from stakeholder feedback. The 2050 forecast information was presented to the Saint Cloud APO Technical Advisory Committee (TAC) October 2022 meeting and was accepted.

The final forecast data was broken down by TAZ for use within the forecast travel demand model. The tables below summarize the forecast estimates at municipal level.

Population and Household Forecast Tables

Table 2 shows population growth rates between 0.2% and 1.4%. The total growth rate is 0.7%. These numbers are consistent with expectations. The forecast shows that the Saint Cloud travel demand model area will grow by about 32,000 people in the next 30 years.

Table 2. Population Forecast by Municipality

Municipality	2020 Population	2050 Population	2020-2050 Change	Compound Annual Growth Rate (CAGR)
Saint Cloud	70,636	80,921	10,285	0.5%
Sartell	20,629	27,345	6,716	0.9%
Sauk Rapids	14,106	17,733	3,627	0.8%
Saint Joseph	7,112	9,341	2,229	0.9%
Waite Park	7,502	11,417	3,915	1.4%
Saint Augusta	2,883	3,069	186	0.2%
Other	16,899	22,084	5,185	0.9%
Total	**139,767**	**171,775**	**32,008**	**0.7%**

Source: 2020 Decennial Census, 2020–2050 Socio Economic Data Forecast, Compound Growth Rate: $r = \left(\frac{v_1}{v_0}\right)^{\left(\frac{1}{t_1 - t_0}\right)} - 1$

The growth rates in households are between 0.4% and 1.7%, as shown in Table 3. The total growth rate is 0.7%. These numbers are consistent with expectations. The forecast shows that the number of households in the Saint Cloud travel demand model area will grow by about 13,000 over the next 30 years.

Table 3: Household Forecasts by Municipality

Municipality	2020 Households	2050 Households	2020-2050 Change	Compound Annual Growth Rate (CAGR)
Saint Cloud	30,582	34,397	3,815	0.4%
Sartell	7,830	10,769	2,939	1.1%
Sauk Rapids	5,906	7,461	1,555	0.8%
Saint Joseph	2,747	3,076	329	0.4%
Waite Park	2,962	4,951	1,989	1.7%
Saint Augusta	712	1,192	480	1.7%
Other	6,602	8,549	1,947	0.9%
Total	**57,341**	**70,395**	**13,054**	**0.7%**

Source: 2020 Decennial Census, 2020–2050 Socio Economic Data Forecast

Employment Forecast Tables

Table 4 shows employment growth rates between 0.0% and 1.7%. The total growth rate is 0.8%. These numbers are consistent with expectations. The forecast shows that the employment in the Saint Cloud travel demand model area will grow by about 85,000 jobs over the next 30 years.

Table 4. Employment Forecast by Municipality

Municipality	2020 Employment	2050 Employment	Compound Annual Growth Rate (CAGR)
Saint Cloud	42,143	50,857	0.6%
Sartell	5,911	7,821	0.9%
Sauk Rapids	4,104	6,894	1.7%
Saint Joseph	2,725	3,698	1.0%
Waite Park	7,355	9,230	0.8%
Saint Augusta	221	221	0.0%
Other	4,914	6,719	1.0%
Total	**67,373**	**85,440**	**0.8%**

Source: Saint Cloud APO, Saint Cloud Metropolitan Transportation Plan 2015-2045, 2020–2050 Socio Economic Data Forecast

Table 5 and Table 6 show the base and future year values and compound growth rates for each of the employment types, Industrial, Office, and Retail. The largest overall growth rate is in the Retail category, 1.2%, and the smallest growth rate, 0.5%, is in the Industrial category. The overall employment growth rate is 0.8%. See Appendix A for maps of 2020 and 2050 data.

Table 5. Employment Forecast by Industry

Municipality	2020 Industrial	2050 Industrial	2020 Office	2050 Office	2020 Retail	2050 Retail
Saint Cloud	9,120	10,170	23,172	28,336	9,851	12,351
Sartell	490	640	4,199	4,909	1,222	2,272
Sauk Rapids	1,504	2,124	1,921	2,921	679	1,849
Saint Joseph	1,059	1,432	1,217	1,217	449	1,049
Waite Park	2,215	2,665	2,291	2,966	2,849	3,599
Saint Augusta	25	25	154	154	42	42
Other	3,485	3,800	902	1,562	527	1,357
Total	17,898	20,856	33,856	42,065	15,619	22,519

Source: Saint Cloud APO, Saint Cloud Metropolitan Transportation Plan 2015-2045, 2020–2050 Socio Economic Data Forecast

Table 6. Industry Level Growth Rates (CAGR)

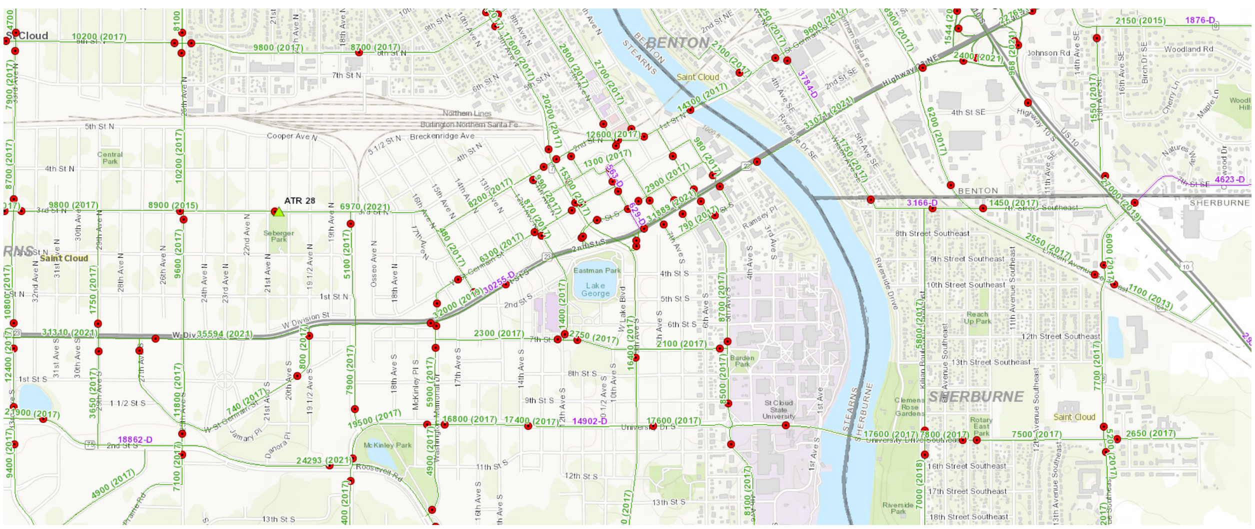
Municipality	Industrial	Office	Retail	Total
Saint Cloud	0.4%	0.7%	0.8%	0.6%
Sartell	0.9%	0.5%	2.1%	0.9%
Sauk Rapids	1.2%	1.4%	3.4%	1.7%
Saint Joseph	1.0%	0.0%	2.9%	1.0%
Waite Park	0.6%	0.9%	0.8%	0.8%
Saint Augusta	0.0%	0.0%	0.0%	0.0%
Other	0.3%	1.8%	3.2%	1.0%
Total	0.5%	0.7%	1.2%	0.8%

Traffic Count Data Update

The observed all-vehicle traffic counts were updated with the latest annual average daily traffic (AADT) throughout the network. Truck traffic counts were also added, where available. The data is sourced from MnDOT's AADT GIS Dataset and HCAADT GIS Dataset. This data was downloaded from MnDOT's website and then joined to model files using GIS. MnDOT maintains the Traffic Mapping Application, an interactive web tool that displays AADT and HCAADT data, shown in Figure 1.

A GIS process, followed by a manual reviewing process, was then performed to assign each traffic count to appropriate highway link locations for model calibration and validation purposes. A database consisting of 1,139 directional link count records (reflective of 599 two-way traffic count locations) was compiled in this effort.

Figure 1. Snapshot MNDOT AADT Mapping Interface



Initially, the project team adopted the 2020 MnDOT AADT for model validation purposes. However, due to the significant impact of COVID-19 in 2020 and the RMS being conducted in 2021, it was determined by the project team that adopting the 2021 traffic count data was more appropriate.

Model Estimation/Household Survey Analysis

This chapter outlines the model estimation analysis effort performed using the 2021 RMS and employment data provided by the Saint Cloud APO. An initial effort includes the reviewing of this current data set in terms of consistency against the previously documented metrics, weighting approaches, and analysis techniques. Once these aggregate comparisons were complete, the team conducted a deep analysis to estimate key model parameters and benchmarks for use in model calibration and validation. Perhaps the most important part of this analysis was to identify which household characteristics best explain the propensity to generate person trips. Explanatory variables evaluated included dwelling type, household income, household size, auto vehicle ownership, number of children and/or workers per household.

The previous APO model was comprised of two home-based trip purposes: home-based work (HBW) and home-based nonwork (HBNW) and a separate nonhome-based (NHB) trip purpose. The 2020 model improvement study recommended that home-based nonwork trips be stratified into home-based school (HBSC) and home-based other (HBO). This trip purpose stratification was used to estimate model parameters including cross classification matrices for trip generation; friction factors for trip distribution; and auto occupancy rates for mode choice. Validation benchmarks from the survey include aggregate trip rates; average trip lengths; transit mode splits; and trips by time-of-day.

Exploratory Regression Analysis Notes

This section outlines preliminary regression analysis results using the RMS and employment data. The results of two regressions of each of the trip types used in the model are presented in the tables below. One of these regressions is a standard linear regression and the other is a log-linear (exponential) regression.

A log transformation of the dependent variable is a common technique to increase the statistical reliability of models. By observing the R^2 values as well as the difference in the F Statistics, it is usually obvious if the log transformation is better or worse than the linear overall function.

Each model coefficient is also tested in terms of probability value (P-value) for statistical significance, which can change between the models. A single star represents a P-value of less than 0.05 and subsequent stars indicate lower P-values.

The model of all trips (Table 7) shows the linear model as superior to the log model as the R^2 value is 0.49 versus 0.31. All of the coefficients are statistically and practically significant.

Table 7. Standard and Log Linear Regression Results (All-Trips)

All Trips

	Dependent variable:	
	Linear (All)	Log (All)
Manufacturing/Industrial	2.154**	0.007***
	(0.671)	(0.002)
Trade/Retail	10.321***	0.011***
	(0.825)	(0.002)
Service/Office	2.683***	0.008***
	(0.472)	(0.001)
Observations	328	328
R^2	0.484	0.314
Residual Std. Error (d_f = 325)	2,099.289	5.370
F Statistic (d_f = 3; 325)	101.731***	49.677***
Note:	*p<0.05; **p<0.01; ***p<0.001	

The model of HBW trips (Table 8) shows the log model as superior to the linear model as the R^2 value is 0.49 versus 0.30. All of the log model coefficients are statistically significant.

Table 8. Standard and Log Linear Regression Results (HBW)

HBW Trips

	Dependent variable:	
	Linear (HBW)	Log (HBW)
Manufacturing/Industrial	0.554***	0.005***
	(0.159)	(0.001)
Trade/Retail	0.353	0.006***
	(0.195)	(0.001)
Service/Office	0.591***	0.005***
	(0.111)	(0.001)
Observations	162	162
R^2	0.304	0.485
Residual Std. Error (d_f = 159)	491.888	3.397
F Statistic (d_f = 3; 159)	23.112***	49.910***
Note:	*p<0.05; **p<0.01; ***p<0.001	

The model of HBO trips (Table 9) shows the linear model as slightly superior to the log model as the R^2 value is 0.39 versus 0.32. All model coefficients are statistically and practically significant.

Table 9. Standard and Log Linear Regression Results (HBO)

HBO Trips

	Dependent variable:	
	Linear (HBO)	Log (HBO)
Manufacturing/Industrial	0.944**	0.006**
	(0.323)	(0.002)
Trade/Retail	3.224***	0.010***
	(0.304)	(0.002)
Service/Office	0.368*	0.006***
	(0.176)	(0.001)
Observations	289	289
R^2	0.387	0.315
Residual Std. Error (d_f = 286)	770.508	4.419
F Statistic (d_f = 3; 286)	60.124***	43.824***
Note:	*p<0.05; **p<0.01; ***p<0.001	

The model of HBSC trips (Table 10) shows the log model as superior to the linear model as the R^2 value is 0.39 versus 0.32. All log model coefficients are statistically significant.

Table 10. Standard and Log Linear Regression Results (HBSC)

HBSC Trips

	Dependent variable:	
	Linear (HBSC)	Log (HBSC)
Manufacturing/Industrial	0.855	0.006**
	(0.488)	(0.002)
Trade/Retail	0.127	0.005**
	(0.360)	(0.002)
Service/Office	0.335	0.004***
	(0.206)	(0.001)
Observations	145	145
R^2	0.059	0.278
Residual Std. Error (d_f = 142)	874.735	4.110
F Statistic (d_f = 3; 142)	2.977*	18.196***
Note:	*p<0.05; **p<0.01; ***p<0.001	

The model of NHB trips (Table 11) shows the linear model as superior to the log model as the R value is 0.55 versus 0.33. All linear model coefficients are statistically and practically significant.

Table 11. Standard and Log Linear Regression Results (NHB)

NHB Trips

	Dependent variable:	
	Linear (NHB)	Log (NHB)
Manufacturing/Industrial	0.866*	0.006***
	(0.360)	(0.002)
Trade/Retail	6.502***	0.011***
	(0.437)	(0.002)
Service/Office	1.348***	0.007***
	(0.250)	(0.001)
Observations	311	311
R^2	0.548	0.327
Residual Std. Error (d_f = 308)	1,111.626	4.868
F Statistic (d_f = 3; 308)	124.276***	49.975***
Note:	*p<0.05; **p<0.01; ***p<0.001	

Regression analysis was also performed from the household side (see Table 12). These regressions look at the different household characteristics impact on the number of trips made each day by type. Many of the results are expected. Household size and vehicle ownership both appear to impact household trips but due to the changes in statistical significance whether the size variable is in or out of the regression suggests the vehicles and size can function as proxies[2]. Weekdays were shown to have higher trips. The strongest determinant of NHB trips was whether the day was a weekday, followed by the number of workers in the household. All these results confirm expectations regarding household characteristics and trip making.

[2] It is likely for larger households to own more cars. However, there are limitations to this statement, where household size is not directly proportional to car ownership for bigger households, while household income and lifestyle may also significantly affect this relationship. *Household, Individual, and Vehicle Characteristics*, US DOT Bureau of Transportation Statistics (2011).

Table 12. Household Trip Regression Analysis Results

Household Trip Regressions

	Dependent variable:									
	All		HBW		HBO		HBSCH		NHB	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Size	1.75***		-0.04*		1.24***		0.24***		0.30***	
Vehicles	0.09	0.55***	-0.01	-0.02	-0.14	0.18*	0.10***	0.17***	0.14	0.22*
Income	0.84***	0.93***	0.08***	0.08***	0.37***	0.43***	-0.09***	-0.08***	0.49***	0.50***
Workers	0.42**	1.75***	0.37***	0.34***	-0.56***	0.39***	-0.17***	0.01	0.78***	1.01***
Weekday	1.02***	0.96***	-0.14***	-0.14**	0.40**	0.36*	-0.11**	-0.11**	0.86***	0.85***
Constant	0.01	1.02**	0.01	-0.01	0.40*	1.12***	0.09	0.23***	-0.49*	-0.32
R^2	0.25	0.16	0.11	0.11	0.21	0.06	0.11	0.03	0.11	0.10
Note:							*p<0.05; **p<0.01; ***p<0.001			

Trip Production

Household Survey Trip Categorization

The primary assumption related to the production side of this estimation is categorizing trips into trip types and determining which days of the week will be included in the analysis. Table 13 and Table 14 below show how the trips are categorized. While accurate classification is important, so is the size of the dataset for each trip type that results from the categories.

Note that while travel demand models tend to focus on the mid-weekdays (Tuesday through Thursday), in order to get the necessary number of observations, data from Monday through Friday were used in the analysis.

Table 13: Household Survey Trip Categories

Categories

Home	Work
Work-Related	School
School-Related	Escort
Shop	Meal
Errand (not observed)	Change Mode
Overnight	Other

Table 14: Daily Person Trip Classification

Production	Attraction	Trip Purpose
Home	Work	HBW
Home	Work-Related	HBW
Home	Escort	HBO
Home	Shop	HBO
Home	Meal	HBO
Home	Social-Recreation	HBO
Home	Change Mode	HBO
Home	Overnight	HBO
Home	Other	HBO
Home	School	HBSC
Home	School-Related	HBSC
All Non-Home	All Non-Home	NHB

Cross-Classification

Once all trips are classified, cross-classification trip tables are estimated.

Table 15 shows the raw rates resulting from the mathematical cross-classification. Elements of the trip rates do not make sense, like a 2-worker household with 1 vehicle producing more trips than a 2-worker household with 2 vehicles. Rates are commonly "smoothed" in order to function correctly with the larger modeling framework. The values of raw and smoothed rates for HBW are shown in Table 15 and Table 16, and graphically in Figure 2 and Figure 3. See Appendices B and C for final trip tables.

Table 15. HBW Daily Person Trip Production Rates (Raw)

		No. of Vehicles per HH			
		0	1	2	3+
No. of Workers per HH	0	0.00	0.02	0.05	0.33
	1	1.19	0.71	0.69	0.64
	2	0.00	1.26	1.17	0.85
	3+	0.50	0.33	0.00	1.51

Figure 2. HBW Daily Person Trip Production Rates (Raw)

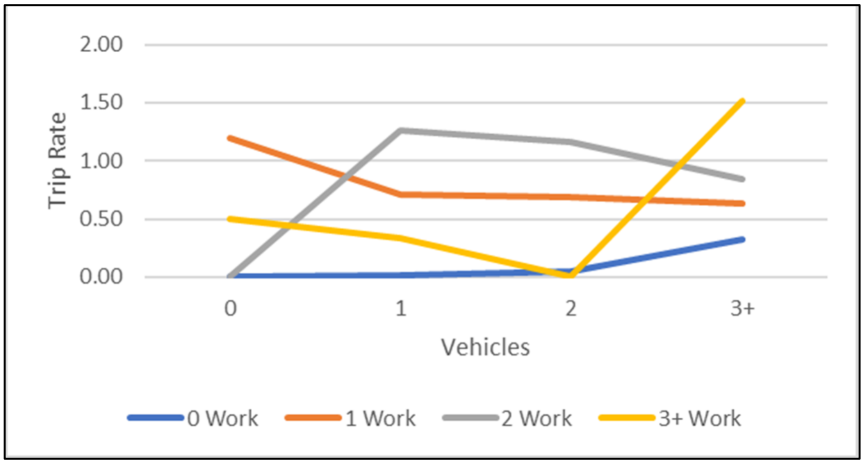
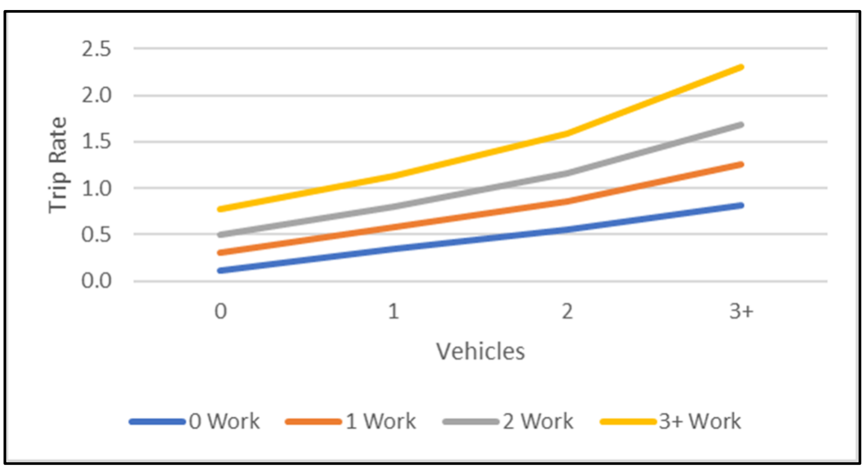


Table 16. HBW Daily Person Trip Production Rates (Smoothed)

		No. of Vehicles per HH			
		0	1	2	3+
No. of Workers per HH	0	0.1	0.4	0.6	0.8
	1	0.3	0.6	0.9	1.3
	2	0.5	0.8	1.2	1.7
	3+	0.8	1.1	1.6	2.3

Figure 3. HBW Daily Person Trip Production Rates (Smooth)



The HBW trip production rates are smoothed by applying a normal distribution to the observed data. Then this resulting trip rate matrix is smoothed with a normal distribution to the *row* data. This makes the rates "well-behaved" without altering their distribution too much.

Trip Attractions

Table 17 shows the daily person trip totals that were computed from the 2021 RMS data. Using data from the household survey, attraction trip ends are linked to specific TAZs using GIS. These equations were further adjusted within the calibration process itself. This is consistent with the standard modeling approaches.

Table 17. Estimated Daily Total of Trip Purpose

Trip Purpose	Daily Person Trip Total
HBW	38,726
HBO	211,975
HBSC	23,514
NHB	215,234
Total	489,449

All of the trip ends were then summed by type in each TAZ to get an estimate of daily attraction rates by trip type. These trip ends are then compared to the employment inputs of various types being used. The equations below show the initial estimates using linear regression. Full results are provided in Appendix D.

$$HBW = 0.57 * Total\ Employment$$

$$HBO = 0.98 * Manu.Ind + 0.47 * Retail.Trade + 1.79 * Service.Office + 2.35 * Households$$

$$HBSC = 2.10 * School\ Enrollment$$

$$NHB = 0.65 * Manu.Ind + 0.81 * Retail.Trade + 2.25 * Service.Office + 2.13 * Households$$

Calibrate/Validate Trip Generation

The process of calibrating and validating the trip generation model included testing both weighted and unweighted trip production rates derived from the RMS during Task 3, in conjunction with a set of trip attraction rates also estimated from the household survey. A model validation spreadsheet developed during the 2020 APO study was used to monitor calibration and validation progress throughout this study. The new 2020 base year model includes the following trip purposes:

1. Home-based work (HBW)
2. Home-based other (HBO)
3. Home-based school (HBSC)
4. Nonhome-based (NHB)
5. Truck trips (TT)
6. Internal-external passenger trips (IEP)
7. Internal-external truck trips (IET)

Trip purposes 1-4 are person-trip-based using cross-classification trip production rate matrices estimated from the RMS, as described in the previous chapter of this report. The HBW cross-class trip rate matrix includes workers per household (HH) by HH vehicle ownership while the other person trip purposes use HH size by HH vehicle ownership. Trip attraction rates for these same four purposes were also derived from survey analysis and adjusted iteratively during model validation.

The remaining three trip purposes are vehicle based. Truck trips are generated using trip attraction rates derived from *NCHRP 716, Travel Demand Forecasting: Parameters and Techniques*. External trips are controlled based on traffic counts along the study area boundary. The split of external trips into internal-external and external-external components was initially derived from analysis of 2019 StreetLight InSight data, as well as the split between passenger and truck trips. These initial settings were updated iteratively during model validation to reflect 2020 and 2021 truck counts and available counts on other segments of key highways such as I-94 and US 10.

Calibration consisted of testing the Cube model to ensure consistency with the number of trips reported in the weighted household travel survey data. During this iterative process, cross-class trip rates were adjusted to exclude internal-external trips, which were already accounted for in the IEP purpose. This adjustment improved highway assignment results, by removing duplicative trips, and the resulting trip productions match survey results for each person trip purpose, as indicated in Table 18.

Table 18. Comparison of Model Trips vs. Survey Trips

Trip Purpose	Total	Both O/D Outside of Region	At Least One End within Region (II+IE)	Both O/D within Region (II)	Either end Outside Region (IE)	%IE	Final 2020 II No. of Model Person Trips	Percent Difference from Survey
HBW	59,880	17	59,864	52,829	7,034	12%	52,719	-0.2%
HBO	201,963	464	201,499	186,326	15,173	8%	186,550	0.1%
HBSC	26,140	0	26,140	23,012	3,128	12%	23,785	3.4%
NHB	163,277	25,139	138,137	120,798	17,339	11%	189,507	56.9%
Total	451,259	25,620	425,640	382,966	42,674	9%	452,561	18.2%

Validation of the trip generation model was an iterative process that included testing weighted vs. unweighted trip production rates. Unweighted HBSC trip rates were later updated to include College and University trips, in addition to K-12 school trips. It was also determined that the slightly lower weighted trip rates worked better for assignment validation. The initial trip rates were further adjusted to better match RMS weighted trips by purpose. Trip production rates were further adjusted to exclude the IE component of trip rates as noted earlier. This was needed to eliminate duplication of work trips produced in Saint Cloud and attracted to locations in the Twin Cities region.

Adjustments were made to the vehicle trips during validation as well. Truck trips from NCHRP 716 replaced earlier assumptions and trip productions were later balanced to attractions for the truck purpose. Internal-external trips were modified numerous times, including corrections to external control totals, adjustments to the internal-external/external-external splits, adjustments to truck splits, and adjustments to the external-external flows among the external stations at the model boundary.

Table 19 provides a trip purpose summary of model generated trips compared to prior APO models, travel surveys, other small MPO area models, and several guidance documents.

Table 20 presents aggregate trip rate comparisons of the updated 2020 model versus many of the same references. These comparisons confirm that the 2020 Saint Cloud trip generation model is generally consistent with survey data, similar models, and national guidance. While the number of 2020 trips are lower than those in the prior 2015 APO model, the 2015 model used vehicle trip rates from the Institute of Transportation Engineers (ITE), which tend to over-estimate the number of regional trips when added together.

Table 19. Daily Trip by Purpose Summary

Person Trip by Purpose	2015 APO Model		Final 2020 APO Model Run			Other Small MPO Models: % by Purpose			2021 St. Cloud APO RMS Person Trip % II Only	2021 St. Cloud APO RMS Person Trip % Purpose	2017 NHTS Midwest Region Trip Purpose%	[2]Typical MPO Model Trip Purpose %	NCHRP Trip Targets	
	Vehicle Trips	% Vehicle Trips	Person/ Vehicle Trips	% Person Trips	% All Trips	Huntsville 2015	Duluth 2018	ROCOG[1] 2018					NCHRP 716 (Urban)	NCHRP 735 (Rural)
HBW	211,764	17.6%	52,719	11.6%	8.6%	15.6%	15.4%	24.8%	13.8%	13.3%	19.0%	12-24	15.0%	12.1%
HBO	398,323	33.0%	186,550	41.2%	30.5%	43.2%	42.4%	0.0%	48.7%	44.8%	48.0%	5-8%	54.0%	55.2%
HBSC			23,785	5.3%	3.9%		12.0%	0.0%	6.0%	5.8%		14-28%		
NHB	595,906	49.4%	189,507	41.9%	31.0%	27.6%	24.3%	49.9%	31.5%	36.2%	33.0%	20-33%	31.0%	32.7%
Truck	0	0.0%	7,868	n/a	1.3%	4.3%	n/a	25.2%			n/a	n/a	n/a	n/a
I-E Passenger	-	0.0%	138,506	n/a	22.7%	9.3%	5.9%	0.0%			n/a	n/a	n/a	n/a
I-E Truck	-	0.0%	11,861	n/a	1.9%									
Total	1,205,993	100%	610,796	100%	100%	100%	100%	100%	100%	100%	100%	n/a	100%	100%

[1]Rochester, MN COG model

[2]FSUTMS-Cube Framework Phase II Model Calibration and Validation Standards

Table 20. Aggregate Trip Rate Comparisons

Validation Measure (Aggregate Rates)	Total HBW+HBSC+HBNW Productions			Total Attractions		Aggregate Trip Rates		Other Small MPO Models: Aggregate Trip Rates			2021 St. Cloud APO RMS		2017 NHTS Midwest Region Agg. Trip Rates	Typical MPO Model Agg. Trip Rates[2]	NCHRP Targets & Additional Small MPO Models
	2010 APO Model	2015 APO Model	Final 2020 APO Model Run	2015 APO Model	Final 2020 APO Model Run	2015 APO Model	Final 2020 APO Model Run	Huntsville 2015	Duluth 2018	ROCOG 2018[1]	Initial Analysis (II Only)	Initial Analysis			
Person Trips Per Household	610,087	1,205,993	*452,561*			16.38	7.89	10.08	9.23	12.20	7.24	7.87	7.78	8.0-10.0	5.41 - 10.33
Person Trips Per Person	610,087	1,205,993	*452,561*			6.21	3.24	4.14	n/a	5.39	2.74	3.23	3.25	3.3-4.0	1.95 - 4.25
HBW Trips Per Employee	211,764	211,764	*52,719*			1.66	0.78	1.25	1.28	1.47	0.78	0.89	1.22	1.2-1.55	1.38 - 1.73
P/A Ratio: HBW	211,764	211,764	52,719	228,715	80,848	2.62	0.65	1.0	1.1	0.93					0.9 - 1.1
P/A Ratio: HBO	n/a	398,323	210,335	642,264	220,235	1.81	0.85	0.9	1.0	0.66					0.9 - 1.1
P/A Ratio: HBSC					27,293		0.87								
P/A Ratio: NHB	n/a	595,906	189,507	585,879	222,597	2.68	0.85	1.0	1.4	1.00	59,880	59,880			0.9 - 1.1
Trips per TAZ (APO: 262/376)						6,170	1,204	3,092			451,259	451,259			<15k

[1]Rochester, MN COG model
[2]FSUTMS-Cube Framework Phase II Model Calibration and Validation Standards

Calibrate/Validate Trip Distribution

Calibration of the trip distribution gravity model reflected calibration of the preceding trip generation model. The focus of calibrating trip distribution largely focused on getting the model to replicate trip length frequency distribution (TLFD) graphs from the household travel survey. Coincidence ratios were used to quantify the levels of dispersion in comparing the model's TLFD distribution against weighted survey results. The coincidence ratio measures the percent of area that coincides for two TLFD curves, observed (survey) versus estimated (model). Calibration was achieved through adjustments to the calibrated trip distribution model friction factors and adjustments to other steps in the model chain described below.

Available model calibration guidance recommends achieving a coincidence ratio of 0.70 (70%) or higher. With a much smaller RMS sample size than other trip purposes, home-based school trips are slightly below the 0.70 threshold in the final 2020 APO model. Resulting coincidence ratios are as follows:

- HBW = 0.73
- HBO = 0.76
- HBSC = 0.68
- NHB = 0.79

Validation of distribution was impacted by adjustments from other model steps. Examples included adjustments to the model network configuration, speeds, terminal times, intrazonal assumptions, and modifications to trip generation described in the previous chapter. Bridge travel time penalties were added to all Mississippi River crossing and iteratively adjusted to achieve an acceptable match between counts and assignment volumes along this model screenline. Travel time penalties were also added to incoming ramps at both ends of CSAH 75 at I-94 as these ramps were found to over-assign trips.

Significant refinements were made to the base year 2020 highway network developed during the aforementioned model improvement study. It was found that the length of many network links was preventing the proper loading of trips from TAZ centroids. Thus, many links were split with new centroid connectors added. There were also a number of local circulator streets not included in prior versions of the APO network that were added to properly route trips between origins and destinations, especially since many zones were split during the model improvement study.

Some network changes were also deemed necessary for the proper routing of external trips. The most significant change in this respect was a simplified expansion of the model to include roadways passing through Rice, MN, which lies just outside the MPO boundary. The problem initially encountered here was that trips in the northern portions of the study area with origins and destinations on different sides of the river were being forced to travel along CR 1 and down to the Sartell Bridge. In reality, some of these trips instead cross the river on CR 2/125th Street NW and then using CR 55/NE River Rd or US 10.

In addition to comparing the model to trip distribution metrics from other sources, the goal would be to achieve a mean trip length by trip purpose that lies within +/- 5-10 percent of survey trip lengths. Table 21 presents a comparison of average trip lengths in the 2020 model against the prior 2015 model, other comparable small MPO models, travel survey results, and guidance documents.

Table 21. Average Trip Lengths in Minutes

Trip Purpose	2015 APO Model[1]	Final 2020 APO Run	Other Small MPO Models: % by Purpo			CTPP (2012-2016 ACS) for 3 APO Counties	2021 St. Cloud APO RMS (Wght'd)	2021 St. Cloud APO RMS (Unwght'd)	2017 NHTS Midwest Region Avg. Trip Lengths	NCHRP 716 Mean Auto TL (Pop LT 500k)	Typical MPO Model Range[2]
			Huntsville 2015	Duluth 2018	ROCOG[1] 2018						
HBW	24.60	14.25	19.67	15.68	12.47	20.5-31.0	17.04	15.91	15.5 - 26.0	20	12-35
HBO	n/a	12.36	15.81	14.20	10.70	n/a	12.96	12.92	n/a	15	7-16
HBSC	17.30	12.93		12.63-13.87		n/a	12.99	12.76	12.5 - 17.0	18	8-20
NHB	10.90	10.77	13.51	13.63	9.00	n/a	16.03	16.95	12. 5 -16.5	18	6-19
Truck	n/a	11.79	14.03	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
I-E Passenger	n/a	20.18	22.51	21.97	n/a	n/a	n/a	n/a	n/a	n/a	n/a
I-E Truck	n/a	19.35	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
Total	n/a	**n/a**	16.35	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

[1]2015 APO average trip lengths by purpose taken from 01-03-2019 Report
[2]FSUTMS-Cube Framework Phase II Model Calibration and Validation Standards

The percentage of intrazonal trips was also monitored continuously during validation to ensure a proper number of trips exiting TAZs for loading onto the highway network. Table 22 depicts intrazonal trips for the 2020 model, the previous 2015 model and typical MPO guidance.

Table 22. Intrazonal Trips: Number and Percentage

Trip Purpose	2015 APO Model		Final 2020 APO Model		Typical MPO Model Range[1]
	Intrazonal Trips	Percent Intrazonal	Intrazonal Trips	Percent Intrazonal	
HBW	1,219	0.6%	413	0.8%	1-4%
HBO	36,905	9.3%	8,837	4.7%	10-12%
HBSC			261	1.1%	3-7%
NHB	119,878	20.1%	14,852	7.8%	5-9%
Truck	n/a	n/a	1,284	16.3%	
All	158,002	13.1%	25,648	5.6%	3-5%

[1]FSUTMS-Cube Framework Phase II Model Calibration and Validation Standards

Travel time to work in minute increments from the model was also compared against those available from CTPP and the RMS. These comparisons are found in Table 23. The model numbers in this table exclude home-based work trips attracted to the Twin Cities region, that are instead part of the internal-external purpose in the model.

Table 23. Travel Time to Work in Minute Increments

Travel Time to Work in Minute Increments			
Minute Range	**2012-2016 ACS All APO Counties**	**2021 St. Cloud APO RMS (Weighted)**	**Final 2020 APO Model**
Less than 5 minutes	4.5%	1.7%	1.4%
5 to 14 minutes	29.3%	34.0%	51.3%
15 to 19 minutes	16.5%	26.6%	34.4%
20 to 29 minutes	17.8%	21.1%	19.2%
30 to 44 minutes	16.0%	12.3%	2.2%
45 minutes or more	15.8%	4.4%	0.0%
60 to 74 minutes	5.4%	0.7%	0.0%
75 to 89 minutes	1.0%	0.3%	0.0%
90 minutes or more	2.4%	2.1%	0.0%

Validate Auto Occupancy/Mode Choice

Mode choice model calibration would require considerable data on transit riders from both the household travel survey and a transit onboard survey. Previous discussions with APO staff confirmed that the focus of this step in the updated model should be on an accurate conversion of person trips to auto trips that generally excludes transit trips on the Metro Bus system. The 2020 model improvement study resulted in a multi-step process that does the following:

- Separates auto trips from Metro Bus transit trips
- Merges external-external trips with internal, internal-external, and external-internal trips
- Applies auto occupancy factors to convert from person trips to vehicle trips
- Converts trip tables from production/attraction format to origin/destination format

APO staff provided weekday ridership estimates for each transit route and transfer estimates from Metro Bus staff for Fiscal Year 2018. This data provided the basis for developing overall targets for linked and unlinked transit trips. A simplified auto/transit split process was developed with transit percentages included in the SED data file. These percentages reflect whether or not transit is accessible for any given zone and amplifies access to transit around major activity centers. This process allows for testing future scenarios where transit is available in zones that do not currently have access to transit.

The key to validating the transit trip table was confirming that the resulting number of linked transit trips from the model matched ridership data from Metro Bus. Validation was achieved by adjusting the percent transit utilization by zone in the SED data until the number of linked transit trips in the model was consistent with Metro Bus estimates. Table 24 provides a summary of the resulting transit/auto mode split. The final model estimated 5,451 weekday transit trips in 2020 compared to 5,231 weekday transit trips estimated by Metro Bus for 2018, a difference of only 4 percent.

In the updated 2020 model structure, external-external (EE) trips do not enter the model stream until the mode choice step. Changes to EE trips happened in conjunction with changes to internal-external trips, which impacted trip generation and distribution as well. While the flow of EE trips between external zones are based on 2019 StreetLight InSight analysis, further refinements to these assumptions by zone were necessary. Total external trips also needed adjustment to match 2020 and later 2021 traffic counts. Adjustments were largely focused on the I-94 corridor to achieve a balance between volume/count ratios on mainline links vs. ramps. Adjustments were also made in corners of the model boundary where movements between external zones were essentially right or left turns due to their proximity.

Auto occupancy factors are key to the proper conversion of person trips to auto trips. These factors were derived from the 2021 RMS data. Testing was done with weighted and unweighted auto occupancy factors from the RMS. It was determined that a blend of weighted (HBW, HBSC) and unweighted factors (HBO, NHB) provided the best highway assignment match of model volumes to counts.

Table 24. Transit/Auto Mode Split by Trip Purpose

Trip Purpose	Person or Vehicle Trips Generated	Final Model Person Trips Generated	Final Model Run Transit Per. Trips	Percent Transit Trips	Final Model Run Auto Person Trips	Percent Auto Trips	Transit plus Auto Trips	Final Model Run Vehicle Trips
HBW	Person Trips	52,719	578	1.1%	52,158	98.9%	52,735	44,780
HBO	Person Trips	186,550	2,046	1.1%	184,542	98.9%	186,588	108,737
HBSC	Person Trips	23,785	241	1.0%	23,546	99.0%	23,787	8,075
NHB	Person Trips	189,507	2,586	1.4%	186,964	98.6%	189,550	122,339
Truck	Vehicle Trips	n/a	n/a	n/a	n/a	n/a	n/a	7,887
I-E Passenger	Vehicle Trips	n/a	n/a	n/a	n/a	n/a	n/a	138,560
I-E Truck	Vehicle Trips	n/a	n/a	n/a	n/a	n/a	n/a	11,878
E-E Passenger	Vehicle Trips	n/a	n/a	n/a	n/a	n/a	n/a	17,556
E-E Truck	Vehicle Trips	n/a	n/a	n/a	n/a	n/a	n/a	1,836
All	Combination	452,561	5,451	1.2%	447,210	98.8%	452,661	461,648
Average Weekday Linked Bus Trips			5,231					
Diff: Model vs. Actual Linked Bus Trips			219	4%				

Table 25 provides the number of vehicle trips achieved in the final model, compared to targeted estimates applying the auto occupancies to vehicle trip totals by trip purpose. Auto occupancy comparisons are also included between weighted and unweighted RMS, NHTS, other Minnesota models, and NCHRP guidance. These comparisons confirm that the RMS auto occupancies are consistent with other potential sources.

Table 25. Auto Occupancies by Trip Purpose

Trip Purpose	Person or Vehicle Trips Generated	Final Model Run Auto Person Trips	Final Model Run Vehicle Trips	Targeted Vehicle Trip Total	Person/ Vehicle Trip Ratio	2021 St. Cloud APO RMS (Wght'd)	2021 St. Cloud APO RMS (Unwght'd)	2017 NHTS Midwest Region Auto Occ.	Duluth Model Vehicle Occ.	NCHRP 735 Rural Auto Occ.	NCHRP 716 Urban Auto Occ.
HBW	Person Trips	52,158	44,780	44,964	1.16	1.16	1.08	1.10	1.12	1.11	1.10
HBO	Person Trips	184,542	108,737	108,554	1.70	1.64	1.70	1.60	1.95	1.69	1.72
HBSC	Person Trips	23,546	8,075	8,064	2.92	2.92	2.80		1.90-2.20	n/a	n/a
NHB	Person Trips	186,964	122,339	122,199	1.53	1.28	1.53	1.40	2.04	1.67	1.66
Truck	Vehicle Trips	n/a	7,887					1.70	1.00	n/a	n/a
I-E Passenger	Vehicle Trips	n/a	138,560					2.40	1.00		
I-E Truck	Vehicle Trips	n/a	11,878					1.00	1.00	n/a	n/a
E-E Passenger	Vehicle Trips	n/a	17,556								
E-E Truck	Vehicle Trips	n/a	1,836								
All	Combination	447,210	461,648							1.54	1.55

Validate Trip Assignment

The 2020 model improvement study included the addition of a time-of-day assignment process. Diurnal factors were calculated for AM peak, Midday, PM peak, and overnight periods using 2019 StreetLight InSight data and added to a model script. Steps in the assignment process now include the following:

- Apply time-of-day factors to daily vehicle trip table
- Compute time-of-day capacities
- Conduct time-of-day assignments for each period
- Combine time-of-day assignments into a daily loaded network

The calibration of the assignment model was largely a product of adjustments from preceding steps in the model chain, as well as adjustments to the assignment process, that may include modifying the time-of-day capacities; testing different assignment algorithms and parameters; or adjusting the diurnal factors calculated from StreetLight InSight data. After performing 54 model runs, there did not appear to be a need to adjust the assignment algorithms, while the adjustments to other model steps sufficed for assignment validation.

Volume-over-count plots were produced for each validation run to identify how the model was validating along specific corridors. This process was used to depict where centroid or connector locations could be adjusted; changes to the coding of area type, facility type, or lanes; incorrect traffic count or screenline locations; local circulation roadways that could be added to the network; travel movements that should be prohibited; and potential problems with trip generation or distribution that do not show up until trips are loaded to the network. Model accuracy standards were consistent with the *FHWA Model Validation and Reasonableness Checking Manual* and *FSUTMS Model Calibration and Validation Standards*, based on several different statewide standards from around the U.S.

Assignment validation included the following metrics:

- Vehicle-miles traveled per HH and person
- Vehicle-hours traveled per HH and person
- Volume over count ratios by volume group
- Root-mean square error by volume group
- Volume over count ratios by area type, facility type, and lanes
- Root-mean square error by area type, facility type, and lanes
- Volume over count ratios by screenline

Table 26 provides a summary of vehicle-miles traveled (VMT) and vehicle-hours traveled (VHT). Original targets for VMT/person and VMT/household were updated during validation based on

2020 MnDOT VMT estimates for the APO study area. The final 2020 model estimated VMT (3.6 million) is very close to MnDOT regional target numbers (3.2 million), though lower than VMT from the previous 2015 APO model (3.9 million). VHT was not reported properly in the previous APO model and targets were not available from the APO or MnDOT.

Table 26. Vehicle-Miles/Hours Traveled

Measure	2015 APO Model	Final 2020 APO Model Run	Original Targets[1]	Updated Targets[2]
Total VMT per Person		25.87	17-24	23
Total VMT per Household		63.05	40-60	45-82
Total Modeled VMT	3,917,392	3,615,136		3,208,652
Total Modeled VHT	n/a	92,507		
Total RMSE			44.0%	45%

[1]FSUTMS-Cube Framework Phase II Model Calibration and Validation Validation Standards

[2]Updated VMT per person (per capita) target provided by MnDOT/APO

A detailed breakdown of VMT by functional classification (FC) is provided in Table 27. Tri-County VMT and percent VMT by FC were available from the Highway Performance Monitoring System (HPMS), as provided by MnDOT through the APO. Model VMT were compared against HPMS; however, HPMS VMT by functional class is only available at the County level or higher. Since the APO model study area only includes portions of three counties, APO staff were able to arrive at regional VMT targets that were similar to those from the model, as noted in both Table 26 and Table 27. It should be noted that the APO model reclassifies several HPMS principal arterial segments as "Other Expressways" to reflect higher speeds and capacities, and the presence of ramps and overpasses on sections of US 10 and MN 15.

Table 27. Vehicle-Miles Traveled by Functional Classification (FC)

Functional Class Group	HPMS Number[1]	HPMS Percent[1]	Model VMT by FC	Model Percent
Interstates	1,429,333	18%	524,267	11%
Other Expressways	15,764	0%	291,826	8%
Principal Arterials	3,391,167	42%	1,292,932	34%
Minor Arterials	1,226,880	15%	743,780	25%
Collectors/Local	2,057,375	25%	762,331	22%
Total	8,120,519	100%	3,615,136	100%

[1]MnDOT 2020 Daily VMT estimate for tri-county region by functional class

A typical accuracy standard for groups of laneages or area types is +/-15 percent error. All roadways in the Saint Cloud APO study area are either 1 or 2 lanes per direction (i.e., generally 2 or 4 lane roadways). Both laneage categories easily best the +/-15 percent standard, as noted below.

- 1 lane/direction = 1.05 volume/count ratio (+5 percent error)
- 2 lanes/direction = 0.98 volume/count ratio (-2 percent error)

Nearly all categories of area type also meet the aforementioned +/-15 percent error standard. The only exception is CBD Fringe roadways, as noted below:

- Central Business District (CBD) = 0.91 volume/count ratio (-9 percent error)
- CBD Fringe = 0.81 volume/count ratio (-19 percent error)
- Residential = 1.06 volume/count ratio (+6 percent error)
- Outlying Business District (OBD) = 0.96 volume/count ratio (-4 percent error)
- Transitioning = 1.02 volume/count ratio (+2 percent error)
- Rural = 1.06 volume/count ratio (+6 percent error)

Table 28 provides a summary of volume/count ratios and root mean square error (RMSE) for each FC category in the 2020 APO model network, along with accuracy standards from the *FHWA Travel Model Validation and Reasonableness Checking Manual.* Statistics for the earlier 2015 APO model were not available at the FC level, so only overall 2015 metrics are included in the table. The 2020 model meets all available FHWA percent accuracy error standards by FC, except for interstate highways. The aforementioned FHWA manual does not include standards for ramps or local streets, which tended to have a higher percent error rate than other FC groups. Likewise, the 2020 APO model meets RMSE standards for most FC groups but not for Interstate Highways.

Table 28. Model Error by Functional Classification Categories (FC)

Functional Class Group	2015 APO Model			Final 2020 Model Run			Updated Targets	
	No. of Links	Percent Error	% RMSE	No. of Links	Volume/ Count	RMSE	FHWA % Error Target	FHWA % RMSE Target
Interstate Highways				13	0.94	27.10	+/- 7%	18.33
Other Freeways & Expressways				9	1.03	10.60	+/- 7%	36.77
Other Principal Arterials				93	1.00	18.00	+/- 10%	43.90
Minor Arterials				349	1.01	39.90	+/- 15%	77.48
Urban Collectors/Major Collectors				315	0.93	68.30	+/- 25%	n/a
Minor Collectors				192	0.91	147.90	+/- 25%	n/a
On-Ramps				32	1.19	66.10	n/a	n/a
Off-Ramps				29	1.17	64.20	n/a	n/a
Local Streets				102	0.72	73.50	n/a	n/a
Overall	650	9%	37%	1,134	0.99	44.00	+/- 5%	45

Considerable effort was expended on adjusting internal-external/external-external splits on I-94, as well as speeds for interstates and ramps. While error by FC indicates that Interstate highways under-assign and ramps over-assign, this is not the case for every link along the I-94 corridor. Thus, adjustments to speeds or IE/EE split improve validity on some links while increasing error on other links. As part of the forthcoming 2050 Metropolitan Transportation Plan Update, additional research could be conducted on each I-94 segment, crossroad and ramp to ensure there are not some historic traffic count anomalies impacting validation along this corridor.

Screenlines, cutlines, and cordon lines are included in model networks to sum model volumes, traffic counts, and/or capacities across broad corridors within a model study area. Eight screenlines were established during the earlier 2015 APO model validation and coded to updated 2020 model network links, consistent with available traffic count locations. A new cordon line was added to the model network that follows the model study area boundary. This new cordon line, also designated as Screenline #9, was used to monitor the validation of external trips during a series of adjustments and corrections over the course of the study.

Table 29 provides a validation summary for each screenline, including accuracy standards, model volumes, traffic counts, percent error, and truck estimates. Percent error standards are more stringent for screenlines with the highest volumes and more flexible for lower volume screenlines. Accuracy standards were met for 6 out of 9 screenlines, as well as a sum of non-screenline links. Screenline results are better for the 2020 model than the previous 2015 model for 5 out of 8 screenlines.

Table 29. Model Error by Screenline

Screenline Number	Screenline Names/Descriptions	Maximum Desirable Percent Deviation[1]	2015 APO Screenline Validation[2]				Final 2020 APO Run Screenline Validation				
			Count	Volume	Percent Deviation vs. Counts	% RMSE	Count	Volume	Volume to Count Ratio	Percent Deviation vs. Counts	Percent Deviation vs. Truck Counts
0	Non-Screenline Links	(+/-) 5%	121,326	104,300	16%	25.5%	2,638,478	2,563,607	0.97	-3%	-17%
1	Mississippi River	(+/-) 10%	121,326	104,300	16%	25.5%	112,447	111,228	0.99	-1%	
2	North-South Roadways N of CR 75/SR 23	(+/-) 10%	132,501	132,150	0%	29.1%	161,905	161,353	1.00	0%	
3	East-West Roadways W of CBD	(+/-) 20%	78,464	84,800	-7%	17.1%	46,896	44,584	0.95	-5%	
4	East-West Roadways W of Waite Park	(+/-) 20%	46,394	49,350	-6%	43.9%	44,680	50,714	1.14	14%	
5	East-West Roadways E of St. Joseph	(+/-) 20%	37,373	33,300	12%	39.9%	32,377	41,875	1.29	29%	
6	East-West Roadways West of US 12	(+/-) 20%	60,872	43,900	39%	51.5%	51,909	54,231	1.04	4%	
7	North-South Roadways N of St. Cloud	(+/-) 20%	29,621	28,400	4%	36.2%	27,811	34,488	1.24	24%	
8	North-South Roadways S of 2nd/Roosevelt/Universit	(+/-) 20%	80,164	54,700	47%	69.5%	73,679	91,042	1.24	24%	
9	External Cordon Line	(+/-) 5%	0	0	n/a	n/a	185,972	187,587	1.01	1%	-15%
	TOTAL (ALL SCREENLINES)	(+/-) 5%	708,041	635,200	11%	n/a	3,376,154	3,340,709	0.99	-1%	-16%

[1]FSUTMS-Cube Framework Phase II Model Calibration and Validation Validation Standards

[2]2015 APO Screenline numbers taken from 01-03-2019 Report that differ from model outputs

Model Sensitivity Testing

As part of the model validation, two sensitivity tests were performed to base year SED and network scenario to examine the logic and responsiveness of the model. The sensitivity analyses are:

- Upgrading continuous segments of CSAH 75 and MN 23 from I-94 to Mississippi River through downtown Saint Cloud
- Accelerating of land-use development to 2050 FY level at 33rd St South and Cooper Avenue South in Saint Cloud

Upgrading Existing Roadway Facility

The first sensitivity test is to assess the impact of upgrading the east-west thoroughfare of CSAH 75 from I-94 to MN 15, and MN 23 from MN 15 to Mississippi River in Saint Cloud (Figure 4), and the diversion of traffic due to the upgrade.

Under this hypothetical scenario, this 11-mile roadway segment is subjecting to the following improvements:

- Upgrading from 4-lane to 6-lane roadway by adding one (1) traveling lane on each direction
- Conversion from Principal Arterial (FC = 3) to Expressway (FC = 2) for roadway segments as shown in Figure 5

The model estimated traffic diversion in the vicinity of CSAH 75/MN 23 is shown in Figure 6. The diversion pattern shows that the traffic was diverted to the upgraded segments (in orange) from the following roadways (in blue):

- I-94
- MN 23 West of MN 15
- Veterans Drive
- 3rd Street N
- 2nd Street S/Roosevelt Road/University Drive S

As expected, the daily traffic along the upgraded roadway segments increased significantly under the sensitivity test scenario. Table 30 shows the increases between 24% to 67% at daily level, which appear to be reasonable.

Figure 4. Alignment of Sensitivity Test Roadway

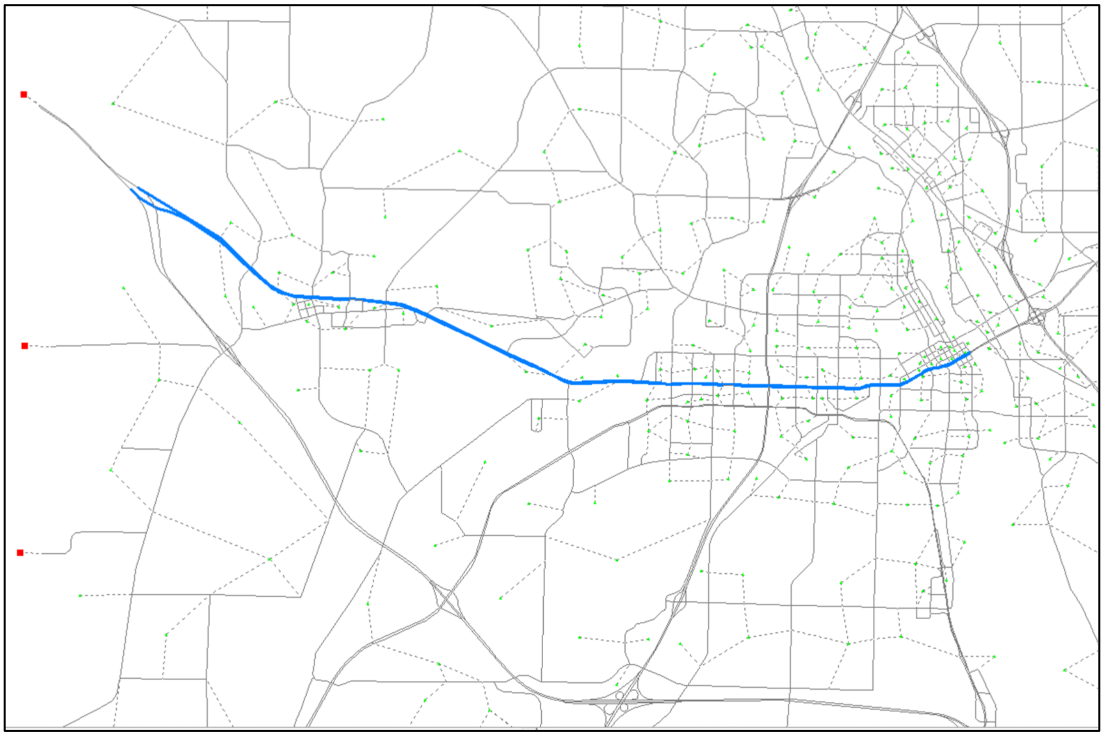


Figure 5. Conversion from Principal Arterial to Expressway

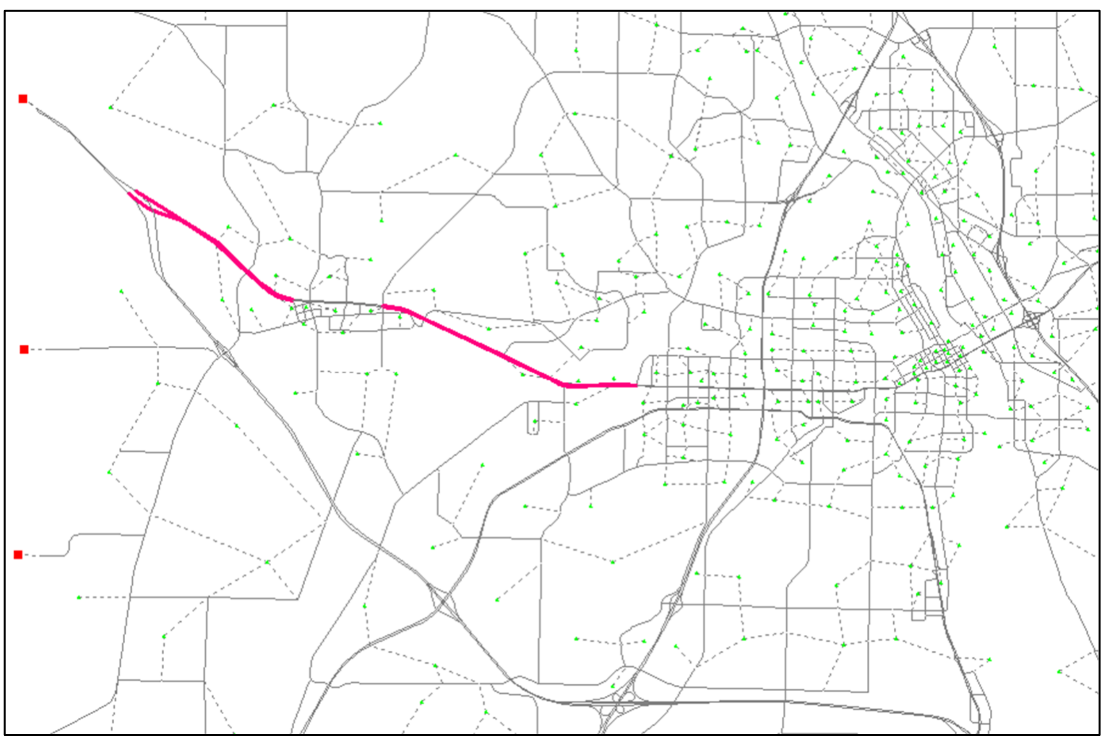


Figure 6. Change in Daily Traffic Pattern under Sensitivity Test 1

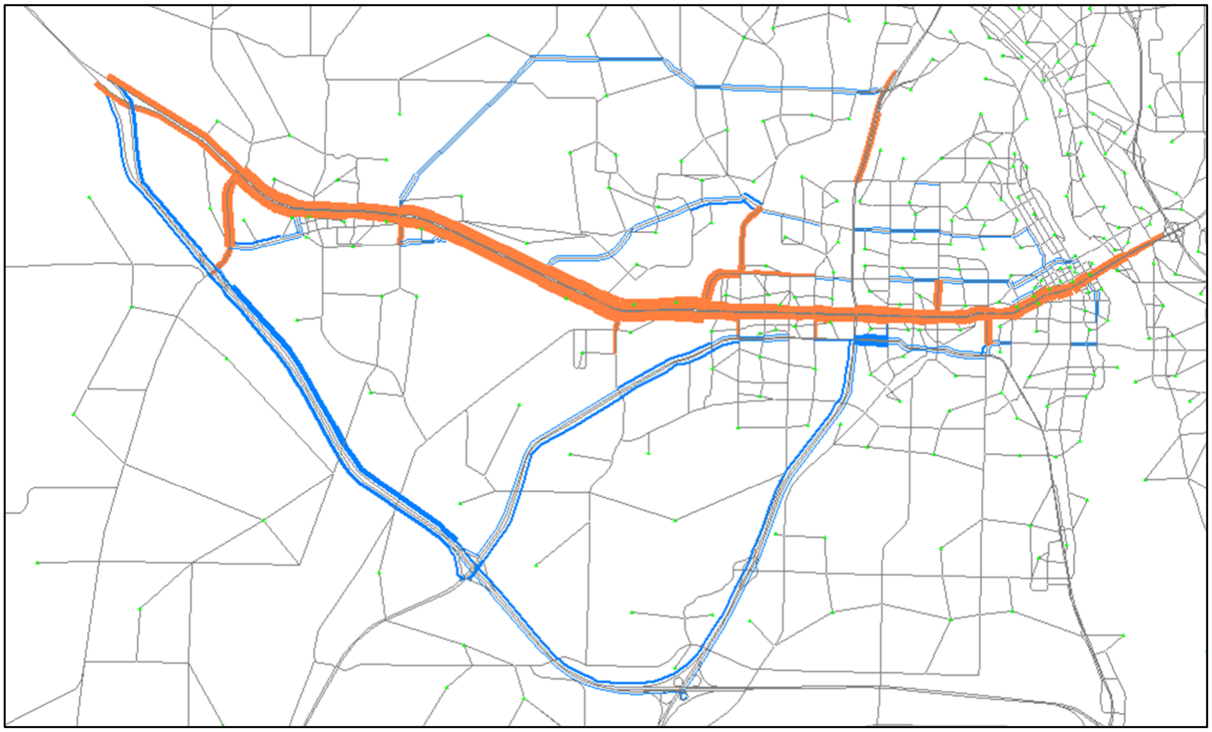


Table 30. Daily Traffic Volume Comparisons (Sensitivity Test 1 vs. Base)

Screenline	Roadway	Base	Sensitivity Test 1	Difference	%Diff
East of CSAH 133/Jade Road	322nd St	3,035	1,291	-1,744	-57%
	CSAH 75	23,913	36,066	12,153	51%
	I-94	27,163	19,798	-7,365	-27%
West of 10th Ave S	CSAH 4	14,879	12,531	-2,348	-16%
	Ridgewood Rd	6,118	3,381	-2,737	-45%
	CSAH 75	23,214	38,662	15,448	67%
	MN 23	20,522	16,876	-3,646	-18%
East of 25th Ave	Veterans Dr	7,366	6,317	-1,049	-14%
	3rd St N	5,193	3,738	-1,455	-28%
	MN 23	27,817	34,458	6,642	24%
	University Dr	22,659	20,592	-2,067	-9%

Alternative Land-Use Scenario

The second sensitivity test is to evaluate the impact of changing the socioeconomic assumptions in a suburban area of Saint Cloud (TAZ 350, as shown in Figure 7) by accelerating the land-use development to 2050 levels, where the total households are increased by 46%, while the total employment is increased substantially at 325%, as shown in Table 31.

Figure 7. Location of Land-use Development in Saint Cloud

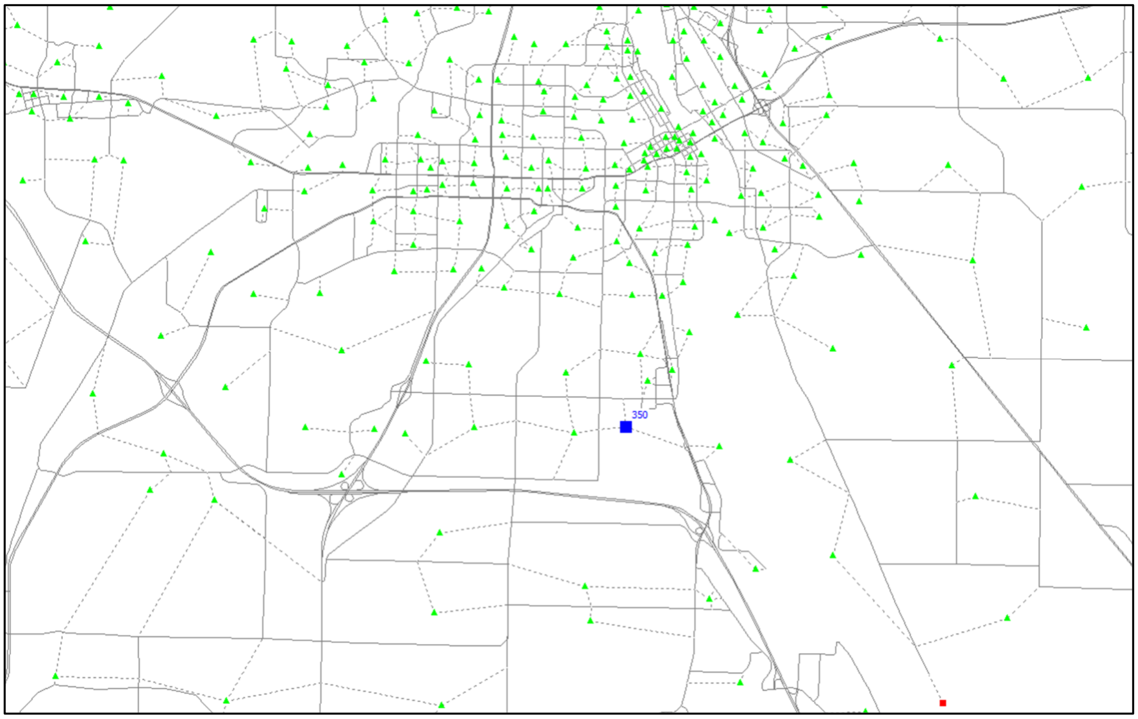


Table 31. Change in Socioeconomic Assumptions under Sensitivity Test 2

Variables	Base	Sensitivity Test 2	Difference	%Diff
HH	672	983	311	46%
INDEMP	106	406	300	283%
OFFEMP	125	600	475	380%
RETEMP	107	432	325	304%
TOTEMP	338	1438	1100	325%

Overall, the change in SED yields an additional 5,900 vehicle trips to the TAZ at daily level, which is in-line with the model's trip generation assumptions. As shown in Table 32, traffic is expected to increase at various levels in the network. As illustrated in Figure 8, the additional traffic is accessing the site through the following roadway segments:

- MN 15 from the south via 33rd Street S

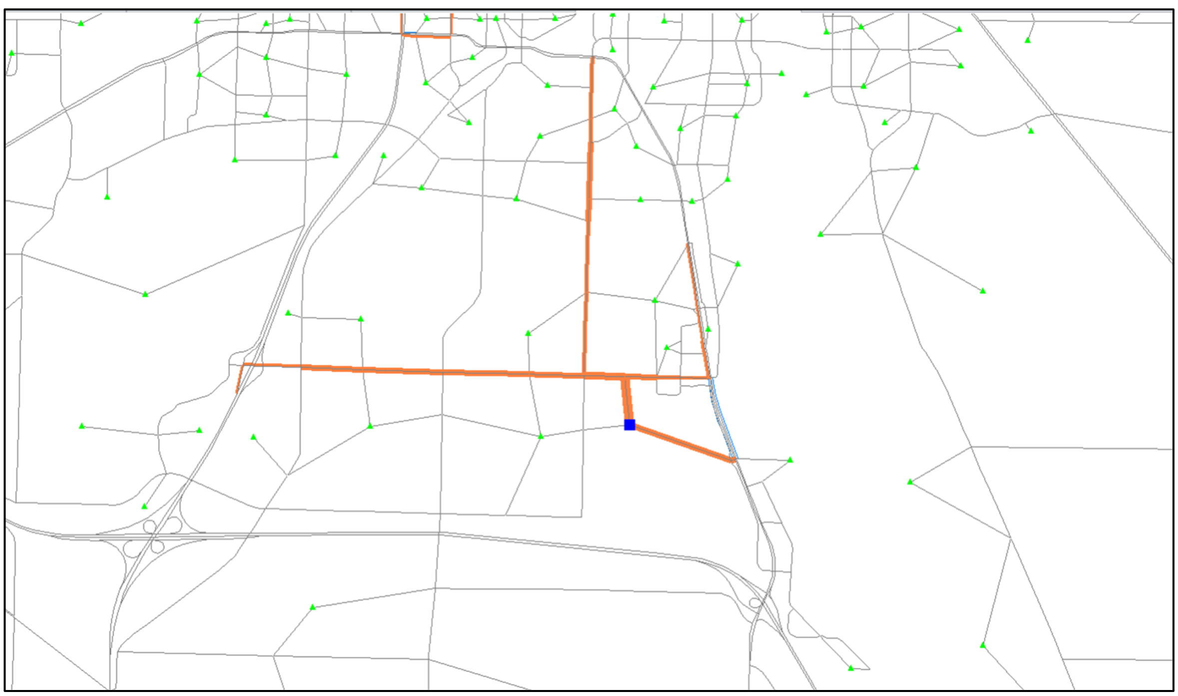
- Cooper Avenue S from north
- Roosevelt Road from both north and south via 33rd Street S

Otherwise, no other noticeable traffic impacts are observed in the model area.

Table 32. Daily Traffic Volume Comparisons (Sensitivity Test 2 vs. Base)

Roadway	Segment	Base	Sensitivity Test 2	Difference	%Diff
Cooper Ave S	at Meadow Rose Blvd	5,734	7,789	2,055	36%
Roosevelt Road	South of Oak Ridge Ln	24,640	25,081	441	2%
MN 15	South of 33rd St Interchange	28,597	28,817	219	1%
Roosevelt Road	at 36th St S	27,403	27,767	364	1%
33rd Street S	West of Cooper Ave S	2,215	3,186	971	44%
33rd Street S	West of Roosevelt Rd	2,706	3,699	993	37%

Figure 8. Change in Daily Traffic Pattern under Sensitivity Test 2



2050 Model Forecasts

Model Assumptions

As discussed in the earlier chapter, the total number of households is anticipated to increase by 0.7% annually, while employment is expected to grow by a similar margin at 0.8% annually regionally. The SED assumptions at county level are summarized in Table 33.

Table 33. SED Growth Assumptions by County

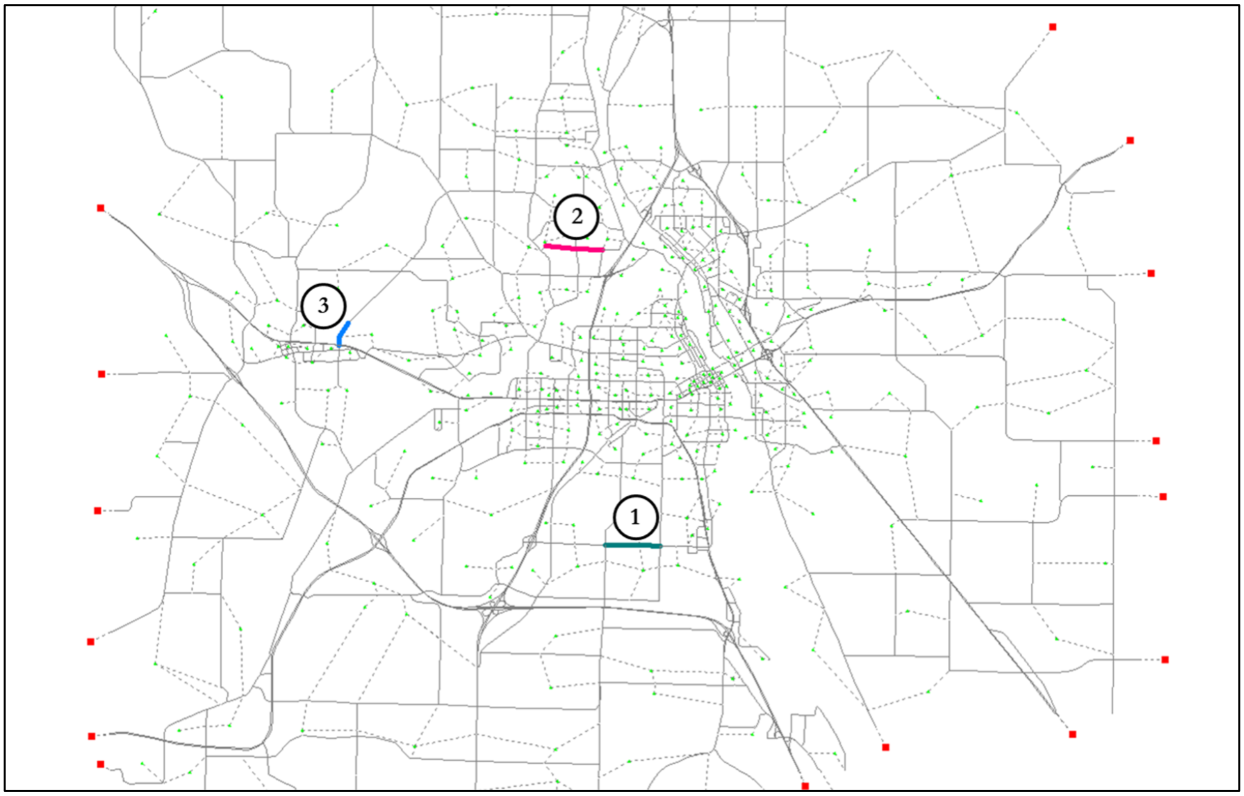
County	Base Year			Year 2050			CAGR		
	HH	Total Emp	School/ College	HH	Total Emp	School/ College	HH	Total Emp	School/ College
Stearns	43,468	53,429	33,730	53,072	65,691	35,622	0.7%	0.7%	0.2%
Benton	10,248	9,362	0	12,769	14,292	0	0.7%	1.4%	0.0%
Sherburne	3,625	4,582	881	4,554	5,457	931	0.8%	0.6%	0.2%
Total	57,341	67,373	34,611	70,395	85,440	36,553	0.7%	0.8%	0.2%

The Saint Cloud APO provided a list of committed projects/roadway changes to be incorporated into the 2050 "No-Build" (or E+C) highway network. These projects are summarized in Table 34. The locations of each project are as shown in Figure 9.

Table 34. Committed Highway Network Projects

Project	RIIP Project ID	Project	Description
1	2021-12	33rd St S	Expand and reconstruct 33rd Street S from 26th Avenue S to Cooper Avenue S
2	2022-36	Scout Drive/ Dehler Drive	New street and utility construction from the end of Scout Drive near Pinecone Road to Connecticut Avenue intersection with Dehler Drive
3	2024-12/2024-20	CSAH 133	Stearns CSAH 133 from Stearns CSAH 75 to 15th Avenue in Saint Joseph; Expand to four lanes, intersection improvements at Elm Street, dual left turn lanes from eastbound CSAH 75 to northbound CSAH 133 (Joint project with City of Saint Joseph 2024-12)

Figure 9. 2050 No-Build (E+C) Highway Network



Traffic Growth

The 2050 daily traffic as estimated from the SED and "No-Build" highway network are summarized in this section.

The daily trip ends by purpose from the trip generation model are summarized in Table 35. The growth is consistent with the SED assumptions.

Table 35. Daily Trip End Comparisons by Trip Purpose (2050 No-Build v. 2020 Base)

Trip Purpose	Daily Person Trip			
	Base (2020)	No-Build (2050)	CAGR	%Diff
HBW	52,719	65,029	0.70%	23.4%
HBO	186,550	231,138	0.72%	23.9%
HBSC	23,785	29,714	0.74%	24.9%
NHB	189,507	234,623	0.71%	23.8%
TRK	7,868	9,448	0.61%	20.1%
IEC	138,506	171,998	0.72%	24.2%
IETRK	11,861	14,636	0.70%	23.4%
Total	158,235	196,082	0.72%	23.9%

The corresponding growth from the traffic assignment modules are illustrated in Figure 10, where traffic growths are noticeable along the major corridors in the region:

- I-94
- MN 15
- US 10
- CSAH 75
- MN 23

In general, traffic growth in terms of VMT at 0.7% annually are consistent with households and employment assumptions, as shown in Table 36. However, the higher VHT increase at 0.8% may suggest the travel demand is out-pacing supply (i.e., limited highway capacity). As a result, the area would be experiencing increasing levels of congestion in 2050 under the No-Build scenario, as summarized in Table 37.

Figure 10. Daily Traffic Growth from 2020 Base to 2050 No-Build

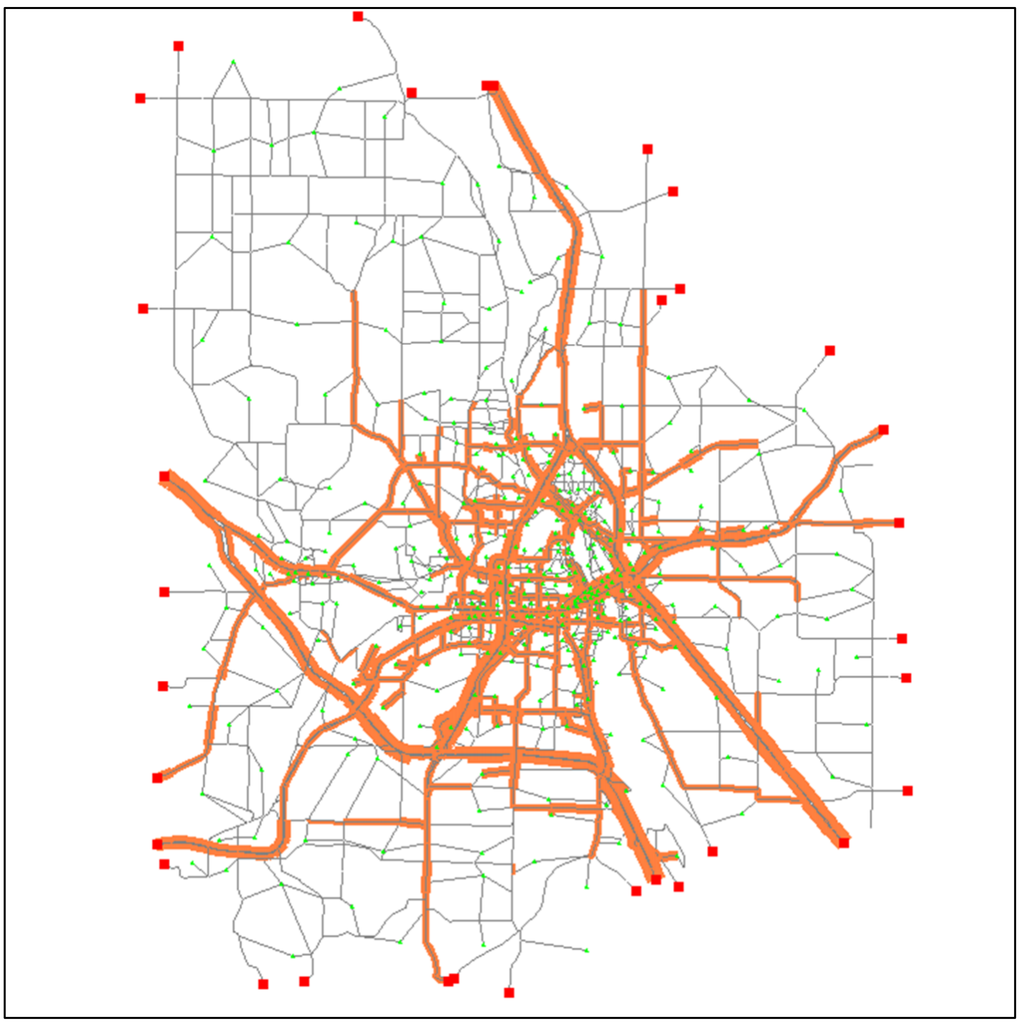


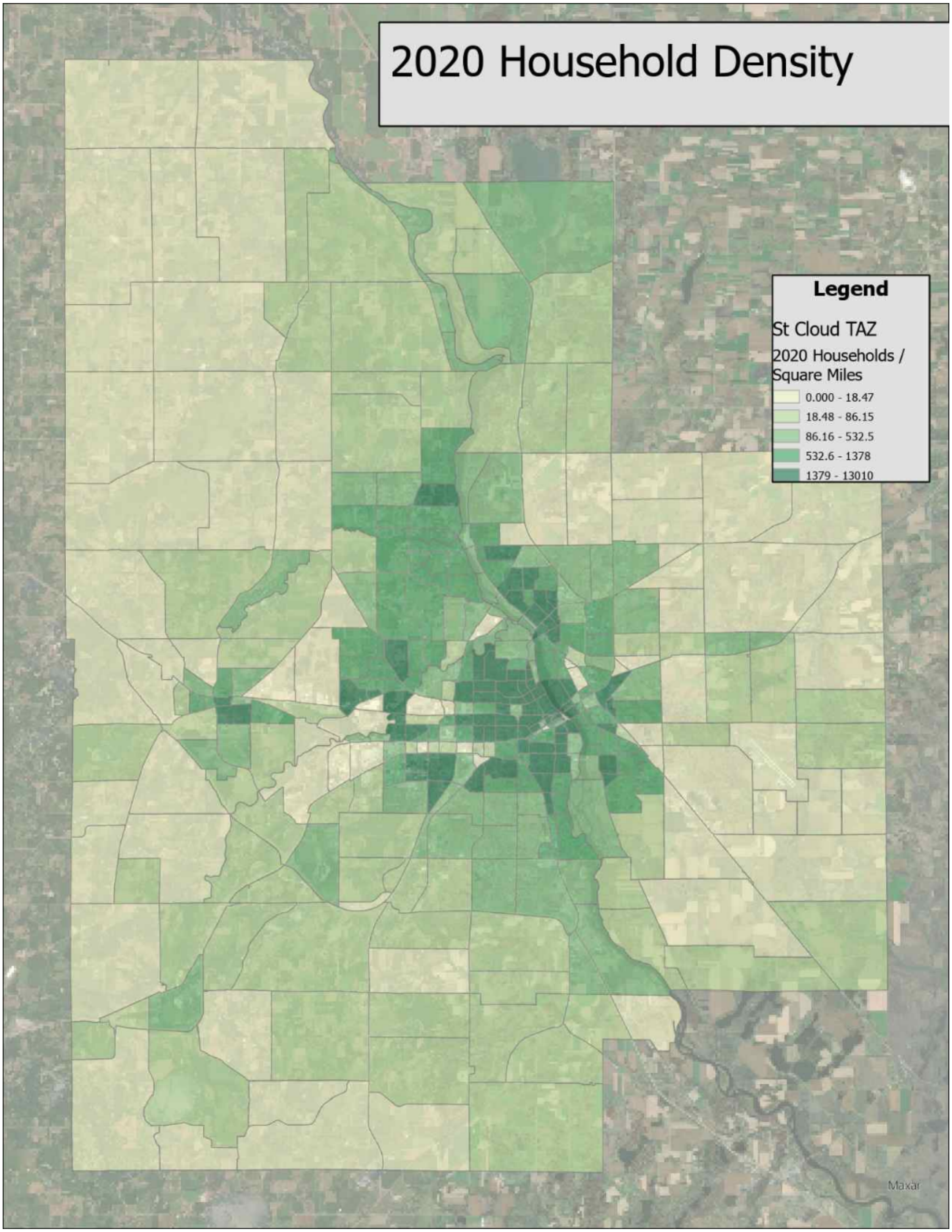
Table 36. VMT/VHT Comparisons (2050 No-Build v. 2020 Base)

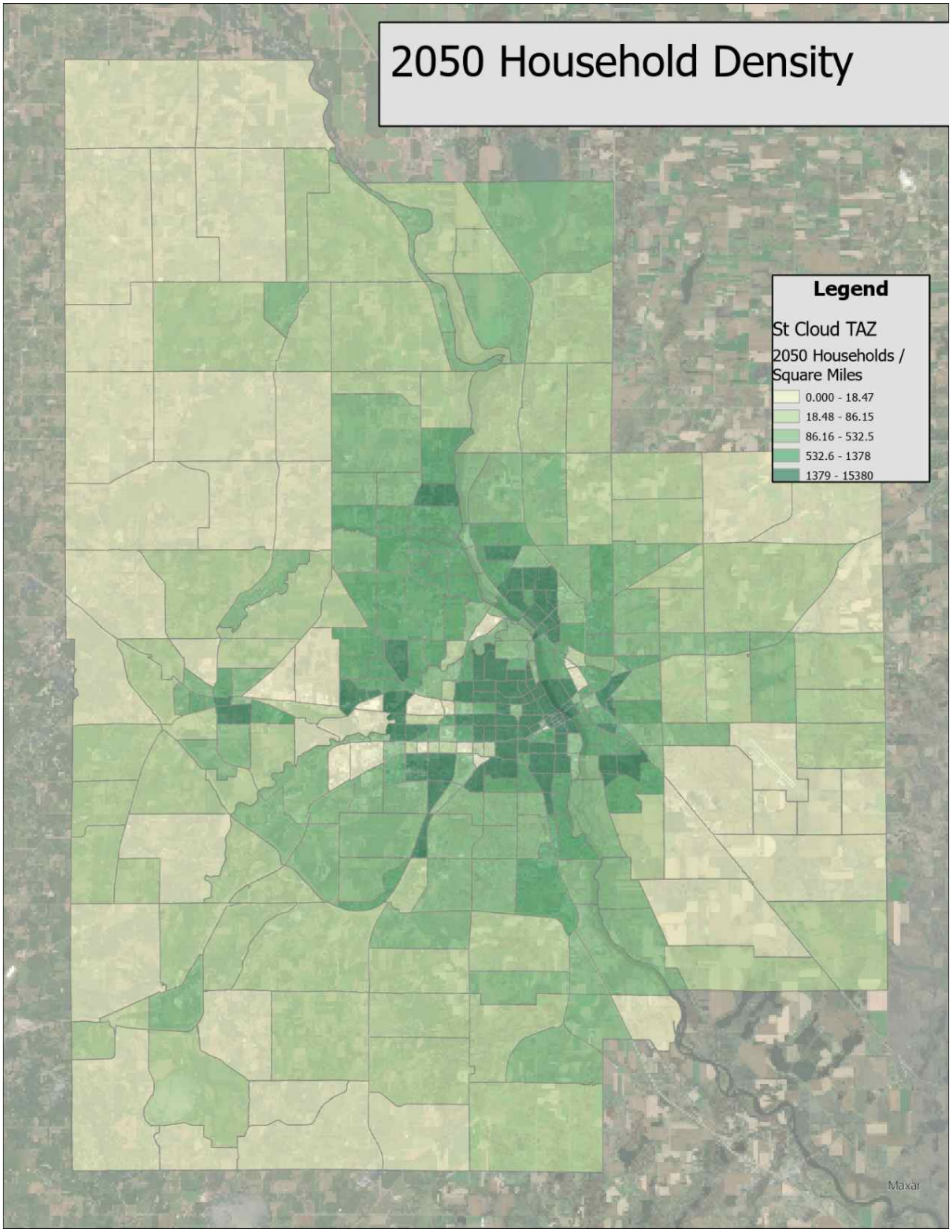
Time Period	VMT (miles)				VHT (hours)			
	Base (2020)	No-Build (2050)	CAGR	%Diff	Base (2020)	No-Build (2050)	CAGR	%Diff
AM	653,873	821,086	0.76%	25.6%	16,514	21,170	0.83%	28.2%
MD	1,193,131	1,494,499	0.75%	25.3%	30,153	38,615	0.83%	28.1%
PM	1,153,366	1,445,467	0.76%	25.3%	29,201	37,567	0.84%	28.7%
NT	614,766	770,874	0.76%	25.4%	15,523	19,873	0.83%	28.0%
Daily	3,615,136	4,531,925	0.76%	25.4%	91,391	117,225	0.83%	28.3%

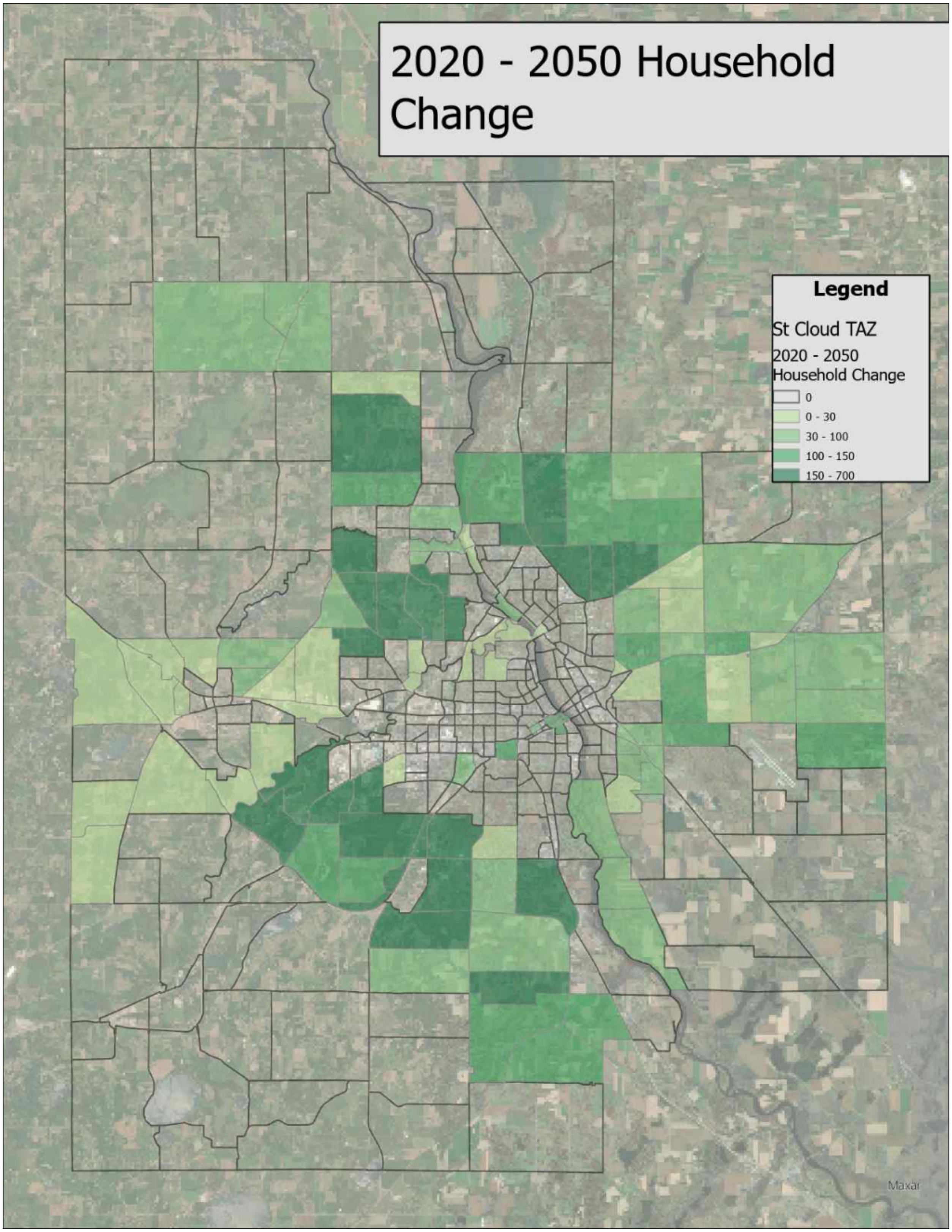
Table 37. Speed Comparisons (2050 No-Build v. 2020 Base)

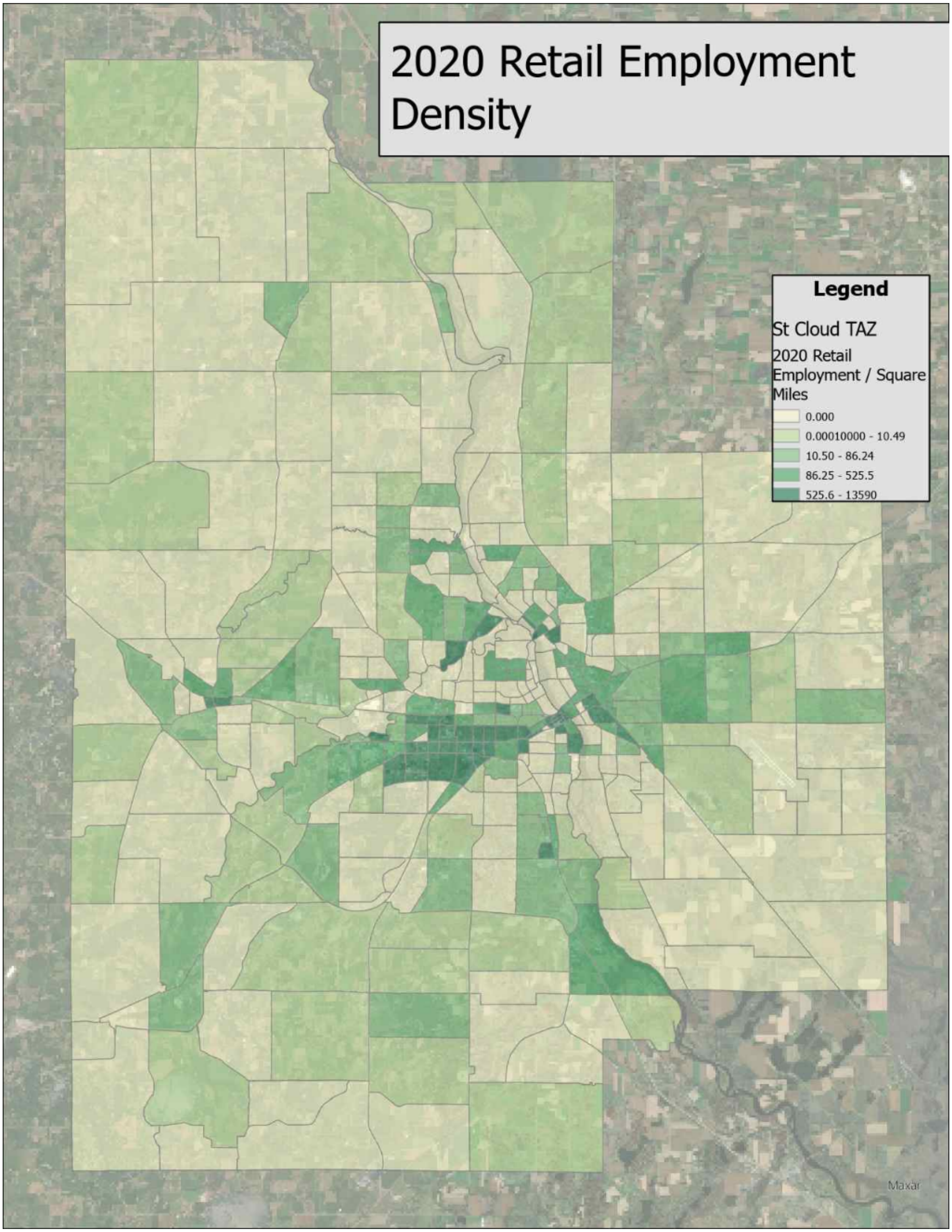
Time Period	Speed (miles per hour)		
	Base (2020)	No-Build (2050)	%Diff
AM	39.6	38.8	-2.0%
MD	39.6	38.7	-2.2%
PM	39.5	38.5	-2.6%
NT	39.6	38.8	-2.1%
Daily	39.6	38.7	-2.3%

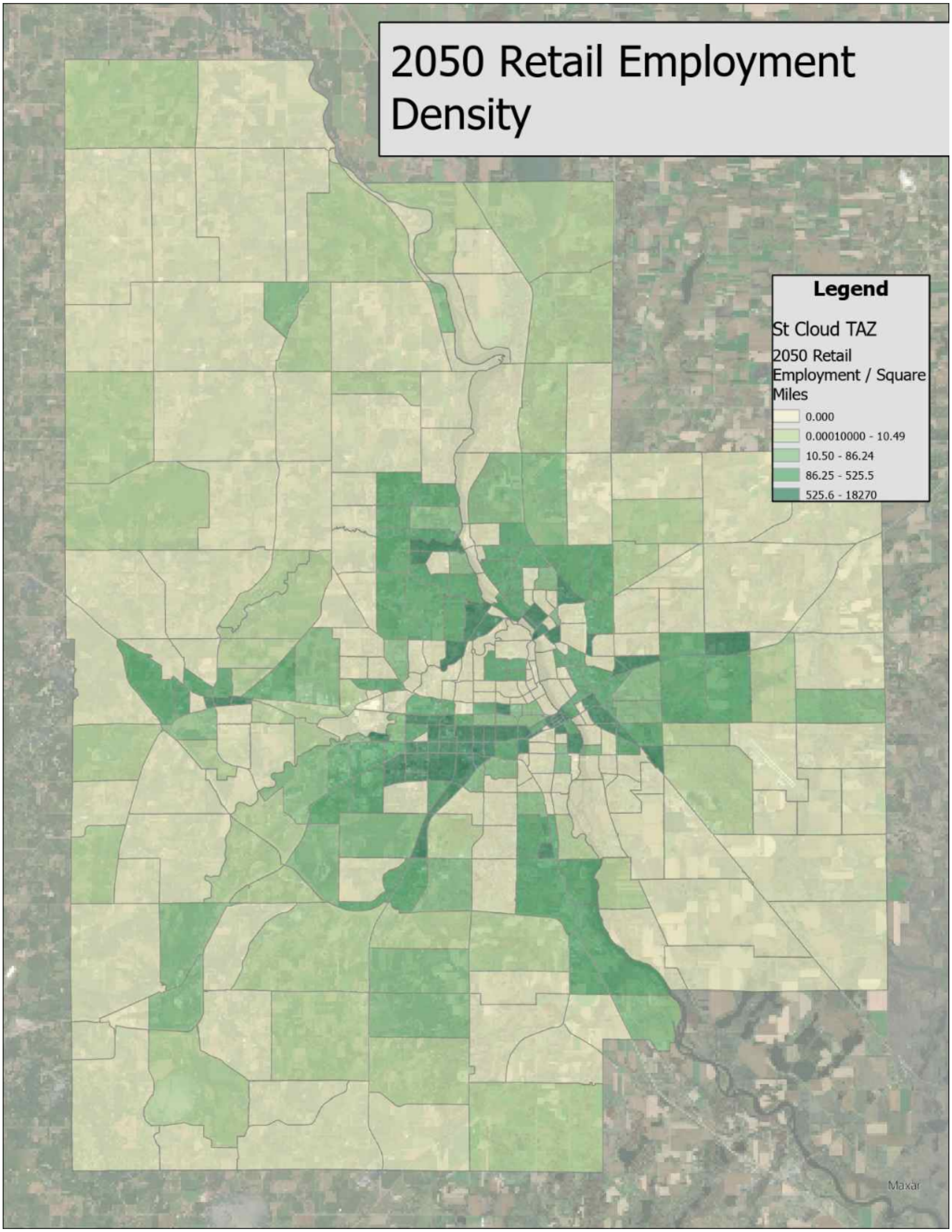
APPENDIX A: Socioeconomic Mapping

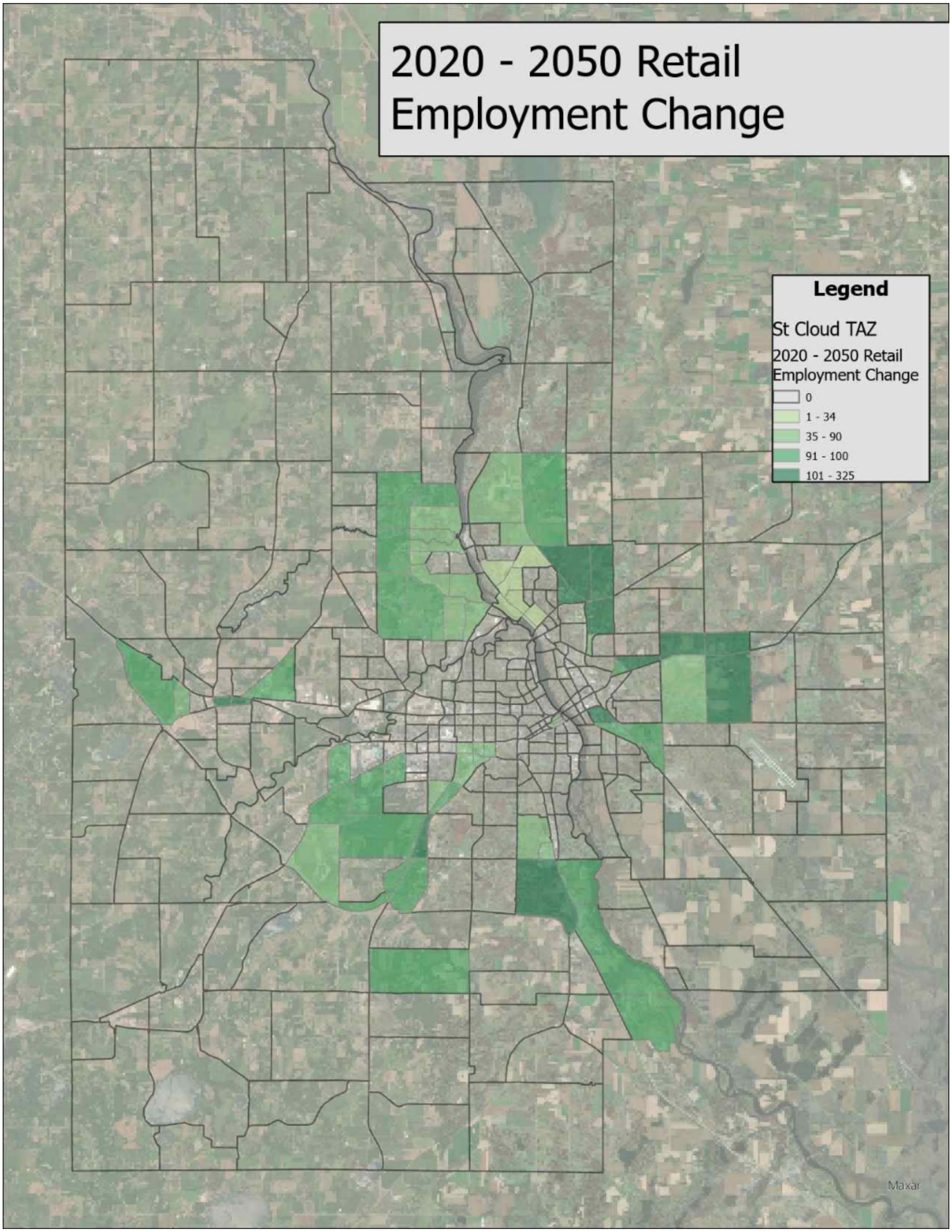

2020 Household Density
Legend
St Cloud TAZ
2020 Households /
Square Miles
0.000 - 18.47
18.48 - 86.15
86.16 - 532.5
532.6 - 1378
1379 - 13010
Maxar

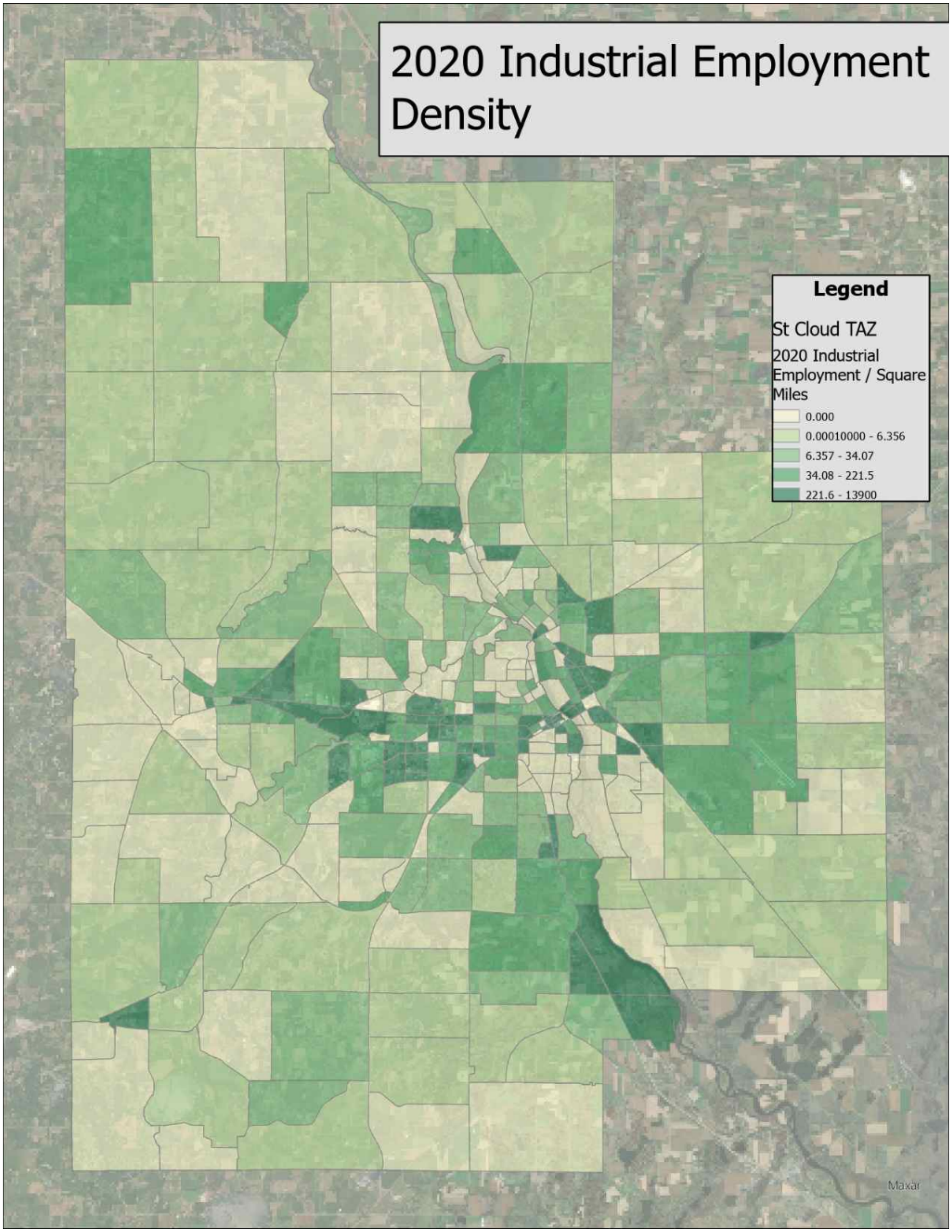

2050 Household Density
Legend
St Cloud TAZ
2050 Households /
Square Miles
0.000 - 18.47
18.48 - 86.15
86.16 - 532.5
532.6 - 1378
1379 - 15380
Maxar

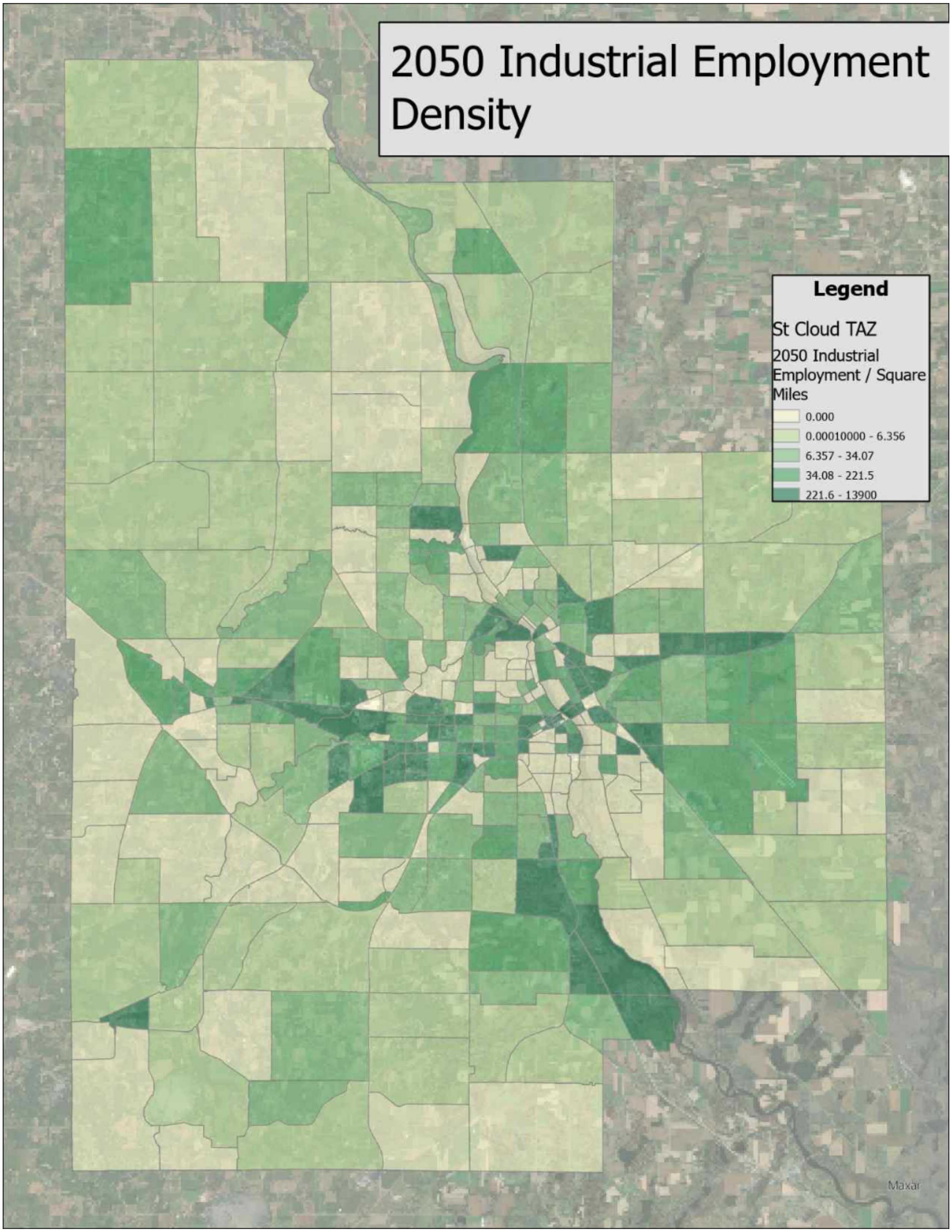

2020 - 2050 Household Change
Legend
St Cloud TAZ
2020 - 2050
Household Change
0
0 - 30
30 - 100
100 - 150
150 - 700
Maxar


2020 Retail Employment Density
Legend
St Cloud TAZ
2020 Retail Employment / Square Miles
0.000
0.00010000 - 10.49
10.50 - 86.24
86.25 - 525.5
525.6 - 13590
Maxar

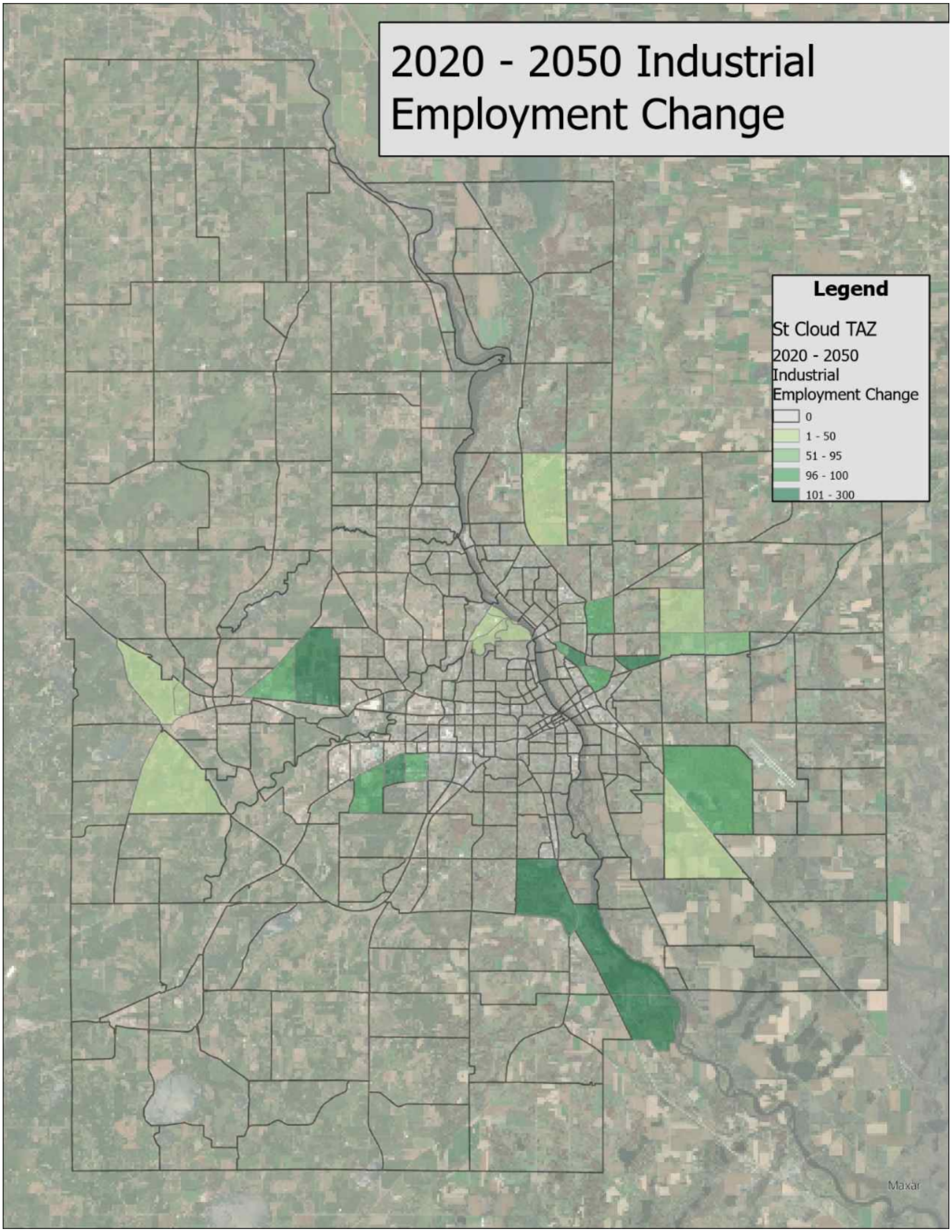

2050 Retail Employment Density
Legend
St Cloud TAZ
2050 Retail Employment / Square Miles
0.000
0.00010000 - 10.49
10.50 - 86.24
86.25 - 525.5
525.6 - 18270
Maxar

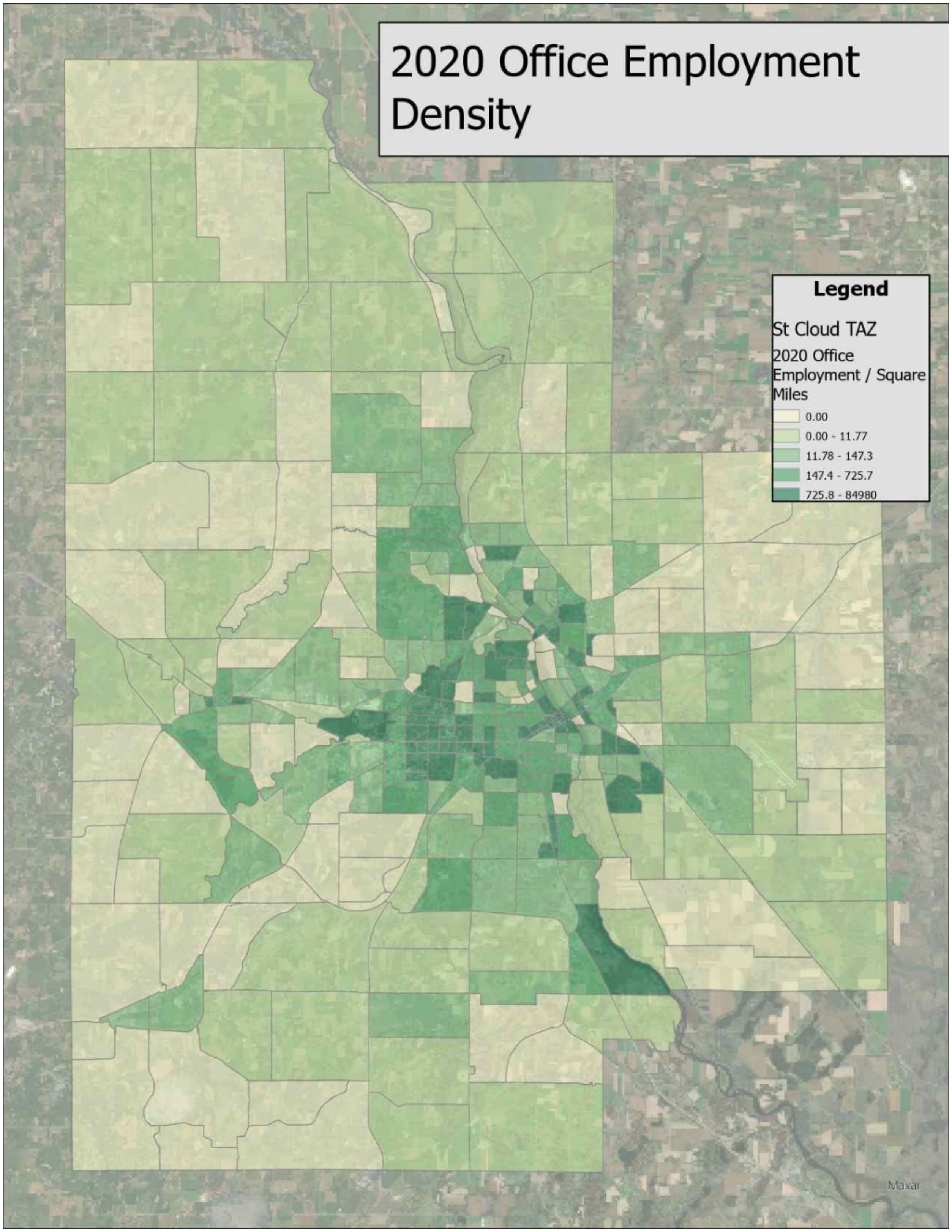

2020 - 2050 Retail
Employment Change
Legend
St Cloud TAZ
2020 - 2050 Retail
Employment Change
0
1 - 34
35 - 90
91 - 100
101 - 325
Maxar

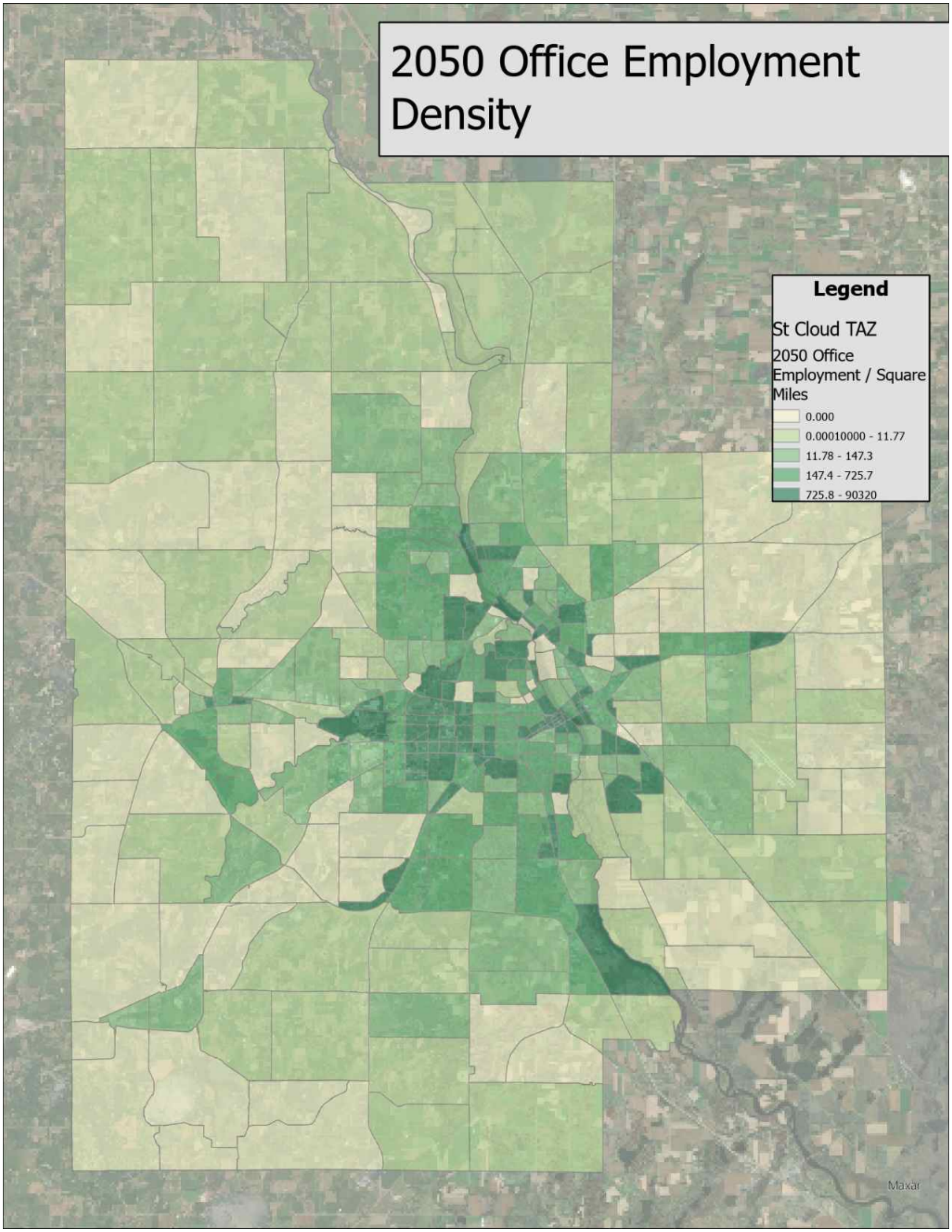

2020 Industrial Employment Density
Legend
St Cloud TAZ
2020 Industrial Employment / Square Miles
0.000
0.00010000 - 6.356
6.357 - 34.07
34.08 - 221.5
221.6 - 13900
Maxar

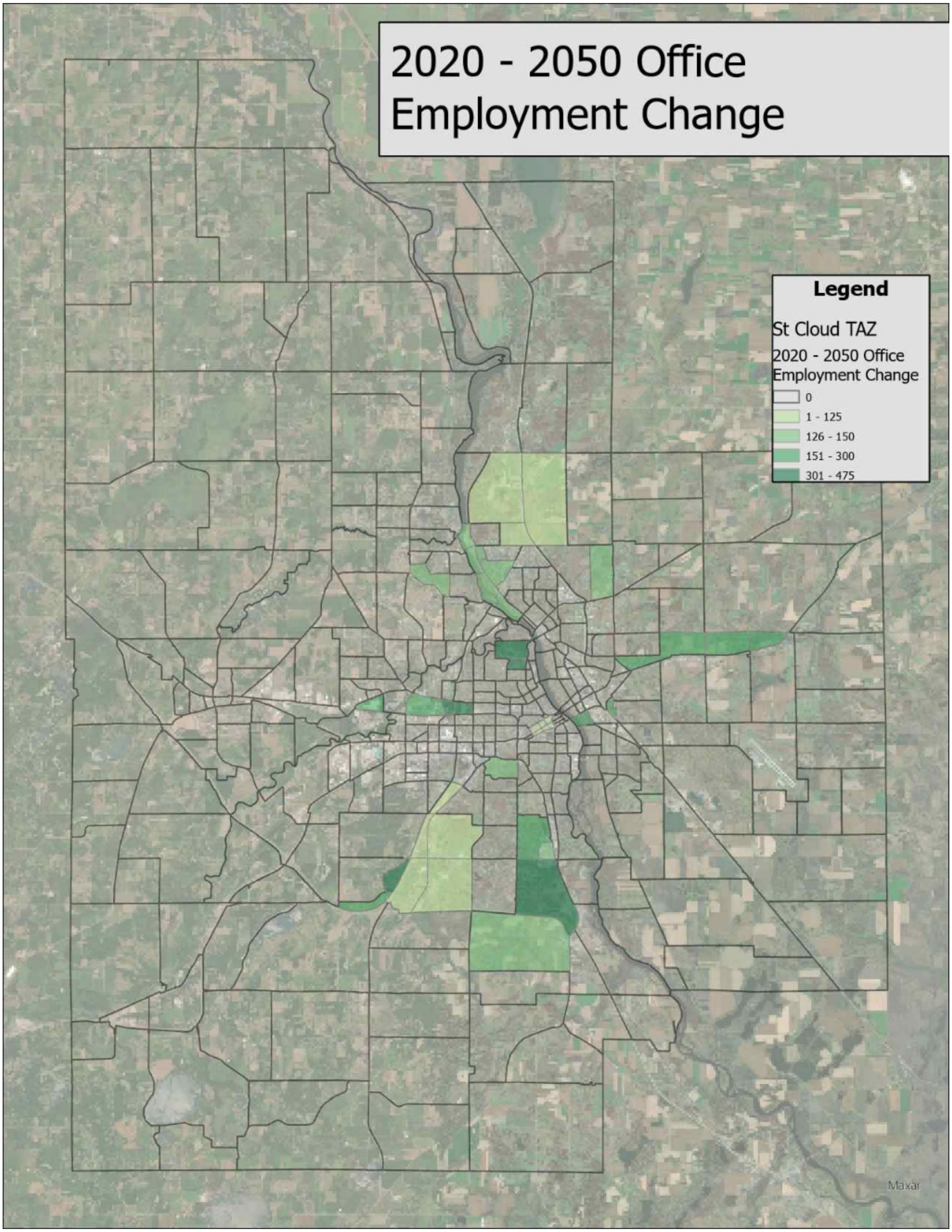


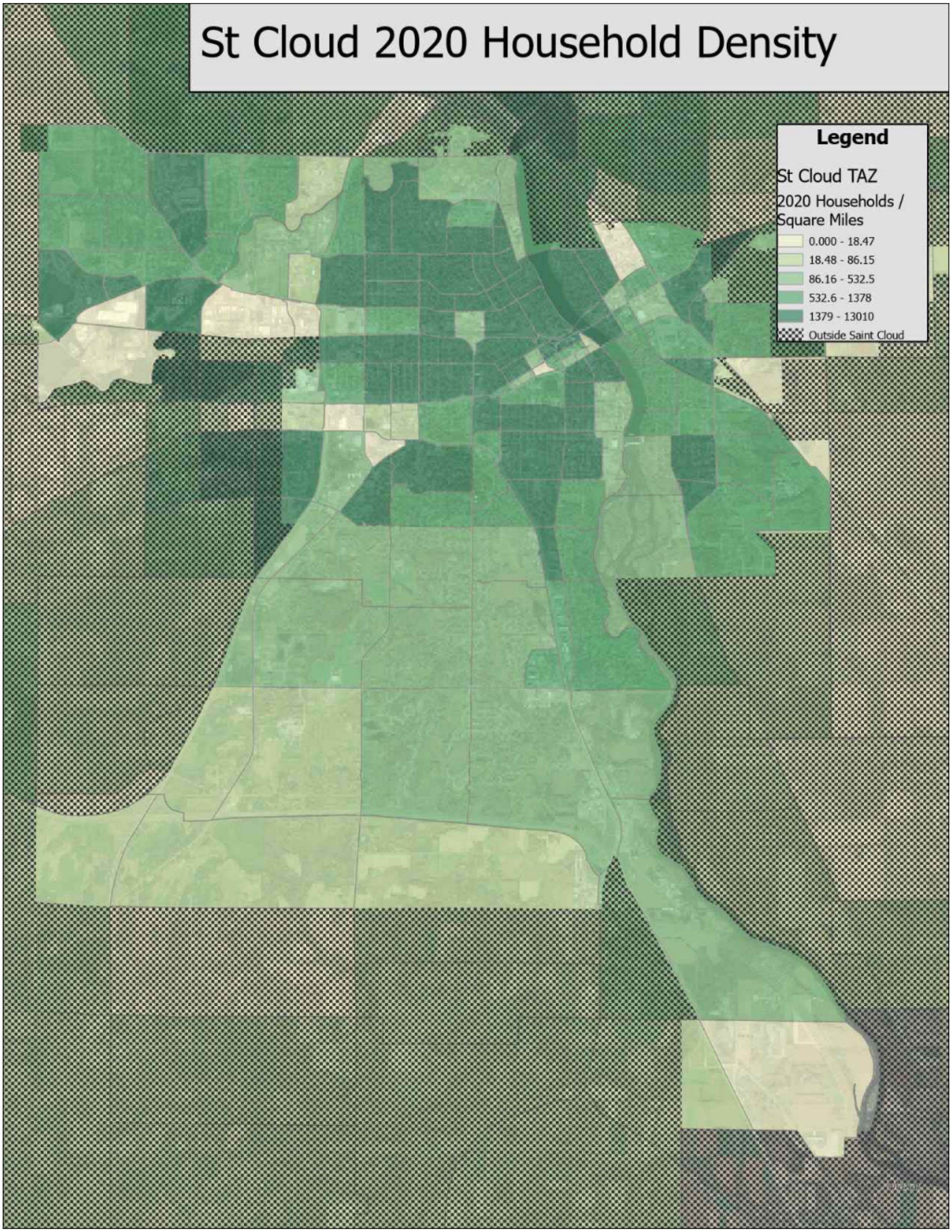
2050 Industrial Employment Density
Legend
St Cloud TAZ
2050 Industrial Employment / Square Miles
0.000
0.00010000 - 6.356
6.357 - 34.07
34.08 - 221.5
221.6 - 13900
Maxar


2020 - 2050 Industrial
Employment Change
Legend
St Cloud TAZ
2020 - 2050
Industrial
Employment Change
0
1 - 50
51 - 95
96 - 100
101 - 300
Maxar

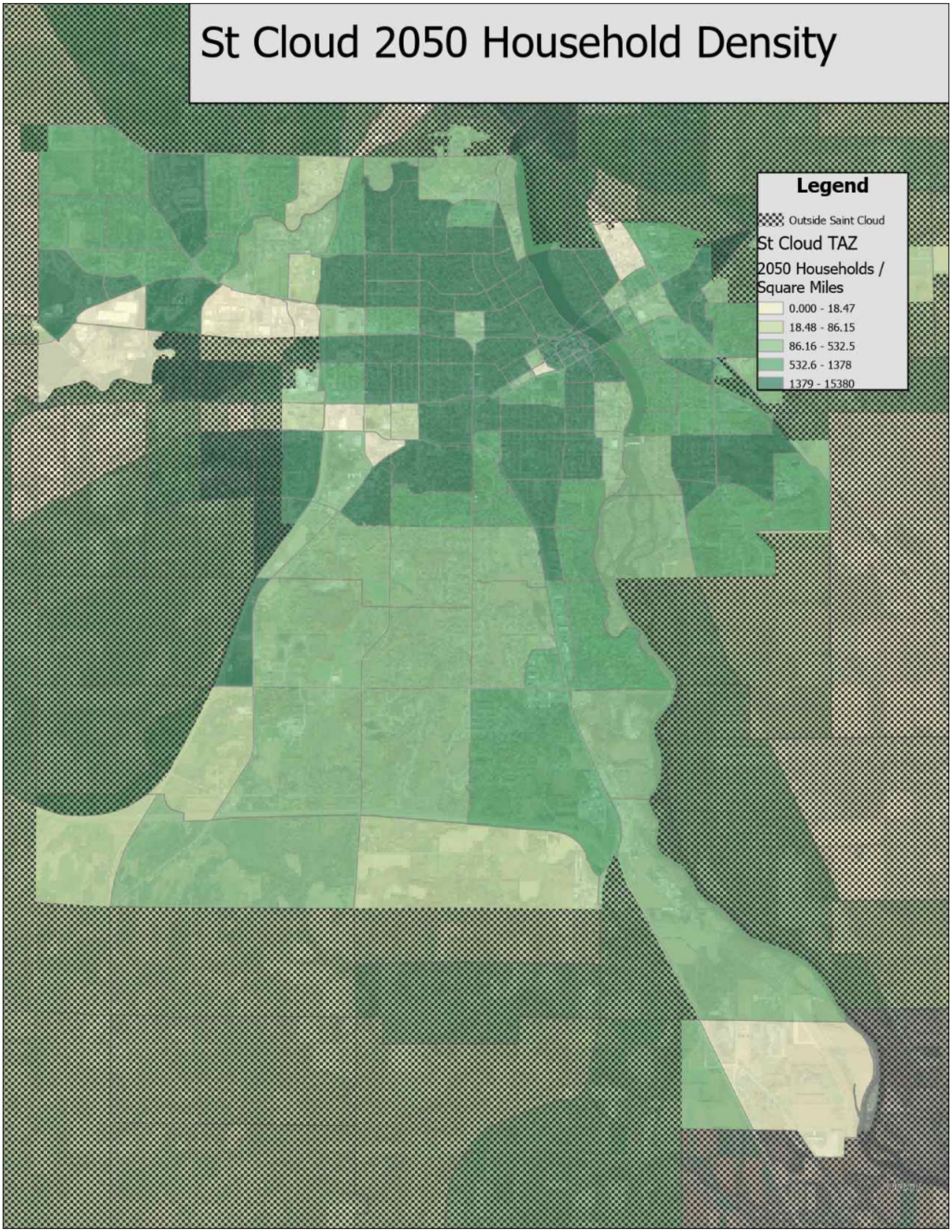

2020 Office Employment Density
Legend
St Cloud TAZ
2020 Office Employment / Square Miles
0.00
0.00 - 11.77
11.78 - 147.3
147.4 - 725.7
725.8 - 84980
Maxar

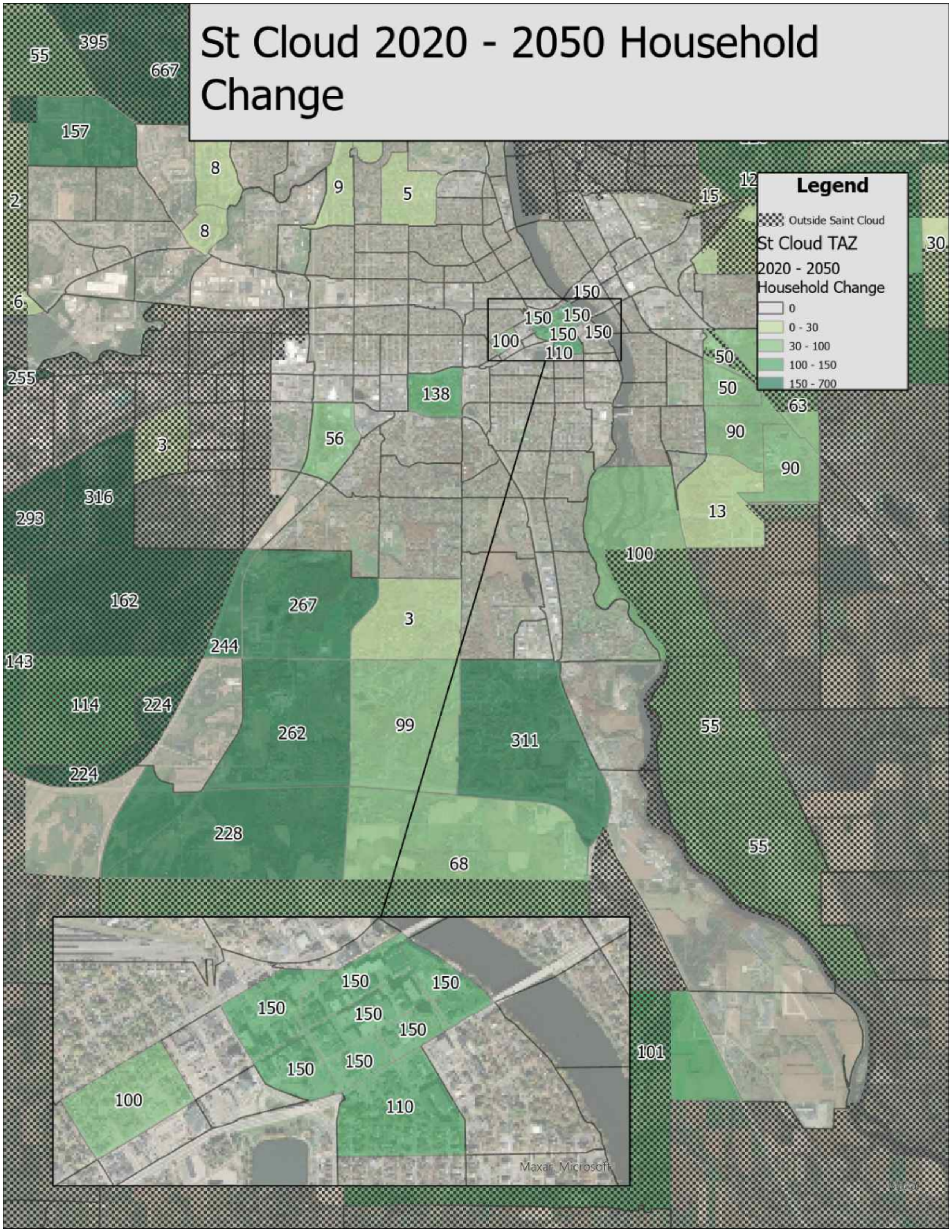

2050 Office Employment Density
Legend
St Cloud TAZ
2050 Office Employment / Square Miles
0.000
0.00010000 - 11.77
11.78 - 147.3
147.4 - 725.7
725.8 - 90320
Maxar


2020 - 2050 Office
Employment Change
Legend
St Cloud TAZ
2020 - 2050 Office
Employment Change
0
1 - 125
126 - 150
151 - 300
301 - 475
Maxar



St Cloud 2020 Household Density
Legend
St Cloud TAZ
2020 Households / Square Miles
0.000 - 18.47
18.48 - 86.15
86.16 - 532.5
532.6 - 1378
1379 - 13010
Outside Saint Cloud


St Cloud 2050 Household Density
Legend
Outside Saint Cloud
St Cloud TAZ
2050 Households / Square Miles
0.000 - 18.47
18.48 - 86.15
86.16 - 532.5
532.6 - 1378
1379 - 15380


St Cloud 2020 - 2050 Household Change
Legend
Outside Saint Cloud
St Cloud TAZ
2020 - 2050
Household Change
0
0 - 30
30 - 100
100 - 150
150 - 700
55
395
667
157
8
9
5
8
2
15
12
30
6
150
150
150
150
100
150
110
50
255
138
50
63
56
90
3
90
316
13
293
100
162
267
3
244
143
114
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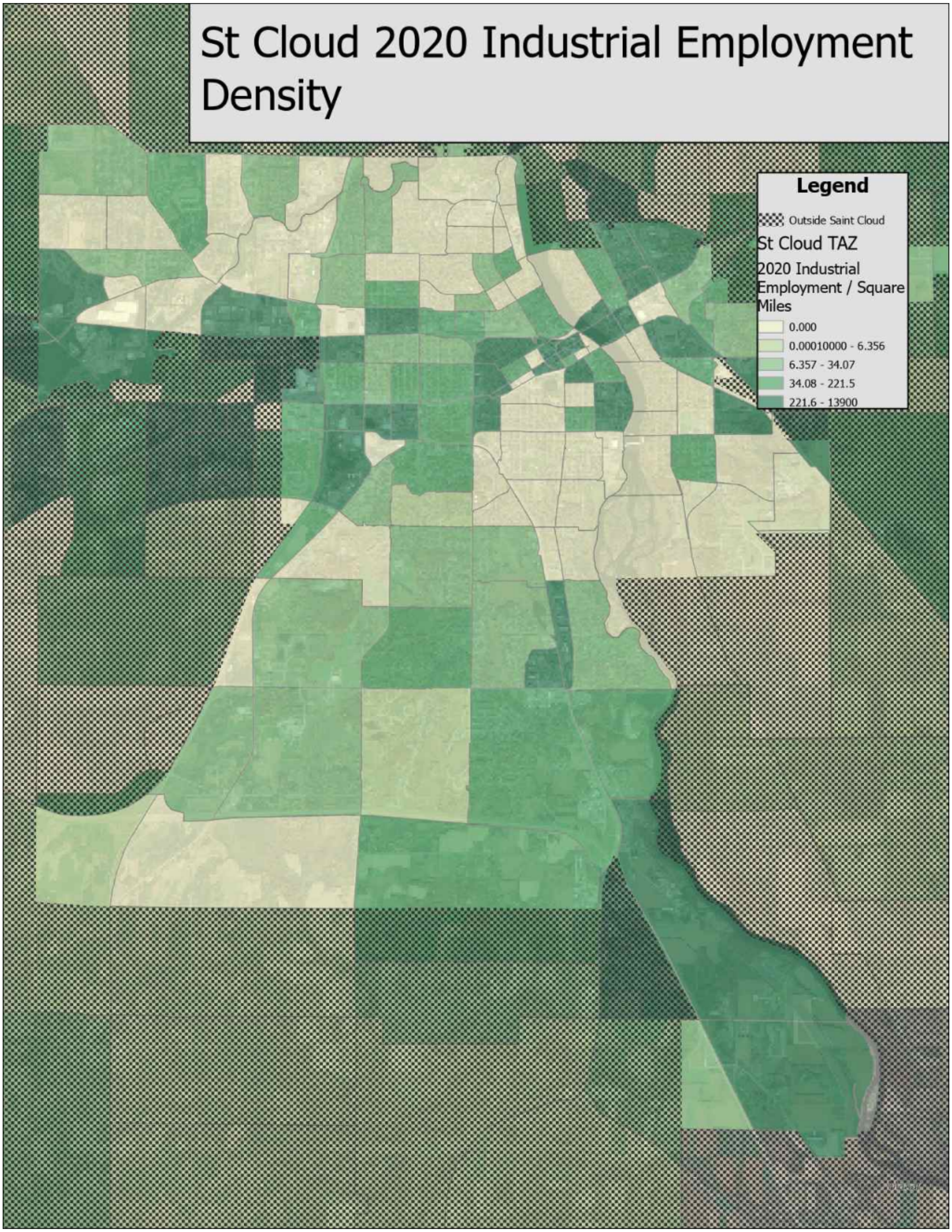
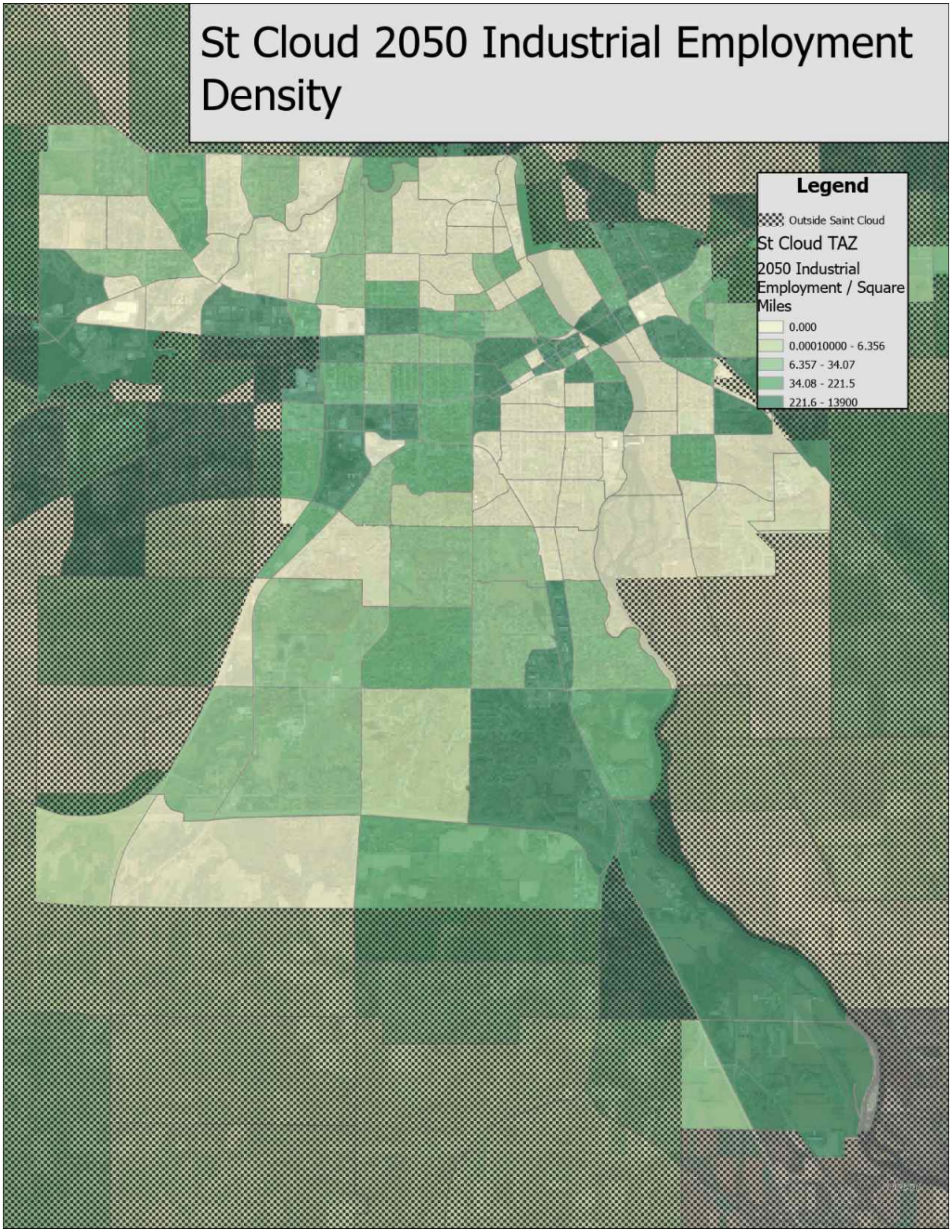
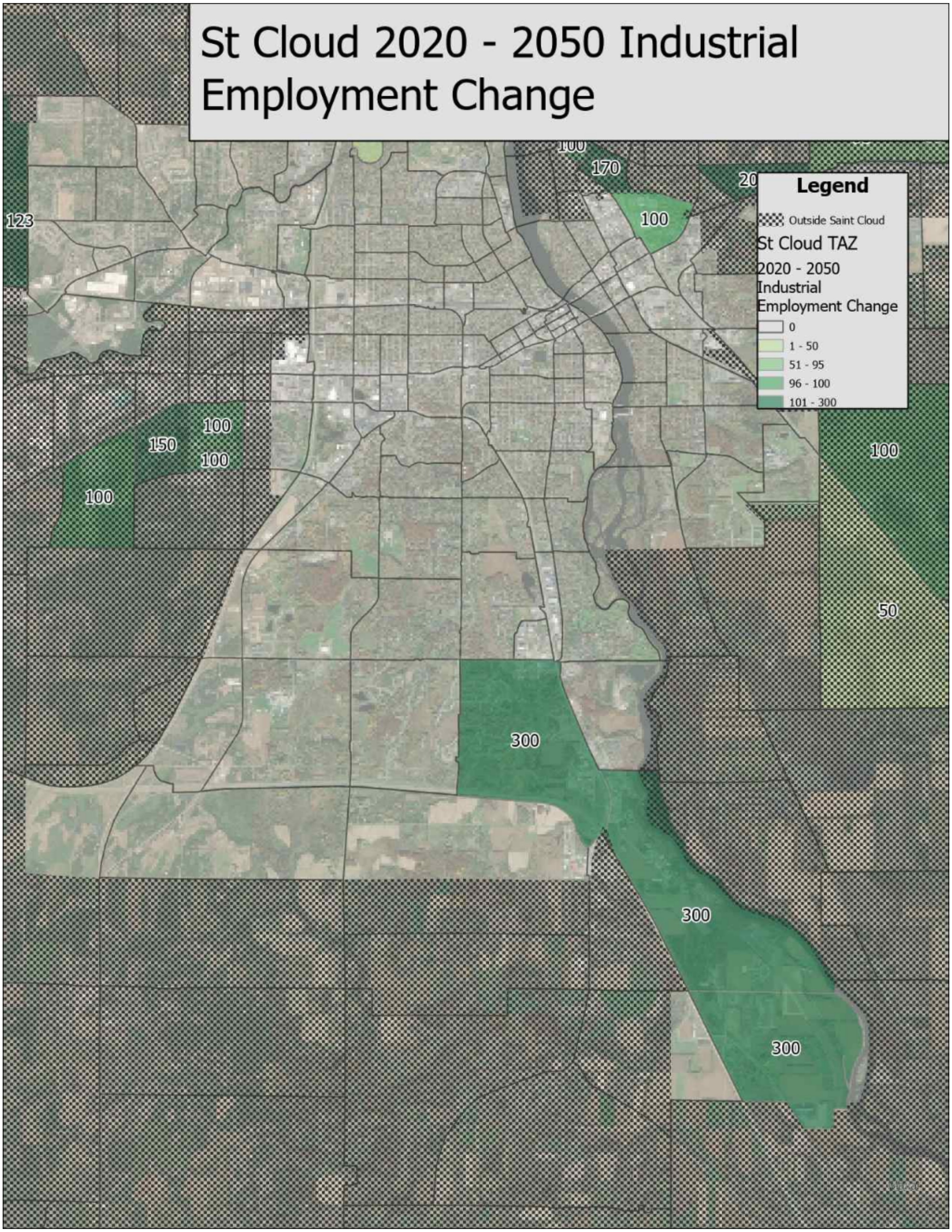
150
100
110
Maxar, Microsoft


St Cloud 2020 Industrial Employment Density
Legend
Outside Saint Cloud
St Cloud TAZ
2020 Industrial Employment / Square Miles
0.000
0.00010000 - 6.356
6.357 - 34.07
34.08 - 221.5
221.6 - 13900


St Cloud 2050 Industrial Employment Density
Legend
Outside Saint Cloud
St Cloud TAZ
2050 Industrial Employment / Square Miles
0.000
0.00010000 - 6.356
6.357 - 34.07
34.08 - 221.5
221.6 - 13900


St Cloud 2020 - 2050 Industrial Employment Change
Legend
Outside Saint Cloud
St Cloud TAZ
2020 - 2050 Industrial Employment Change
0
1 - 50
51 - 95
96 - 100
101 - 300
100
170
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150
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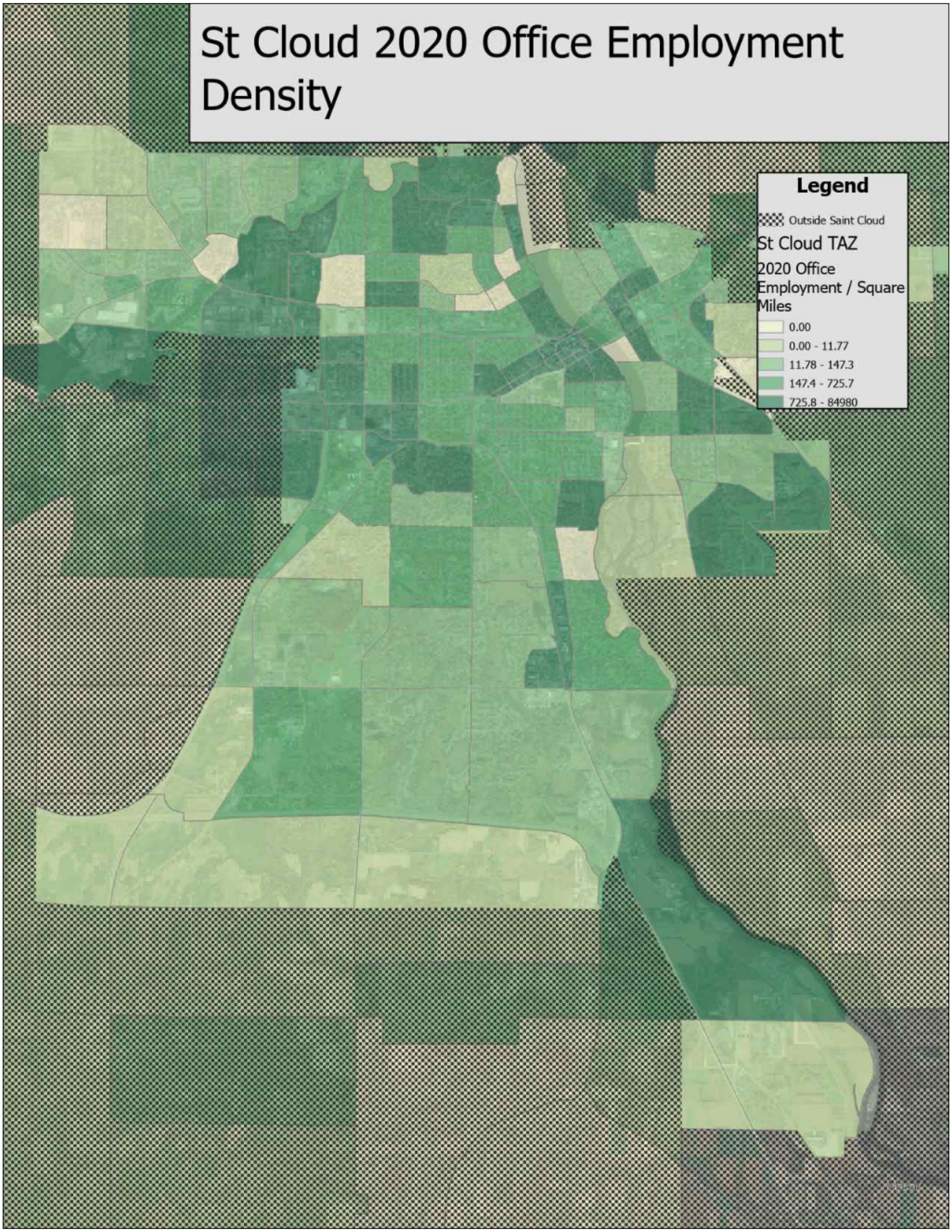
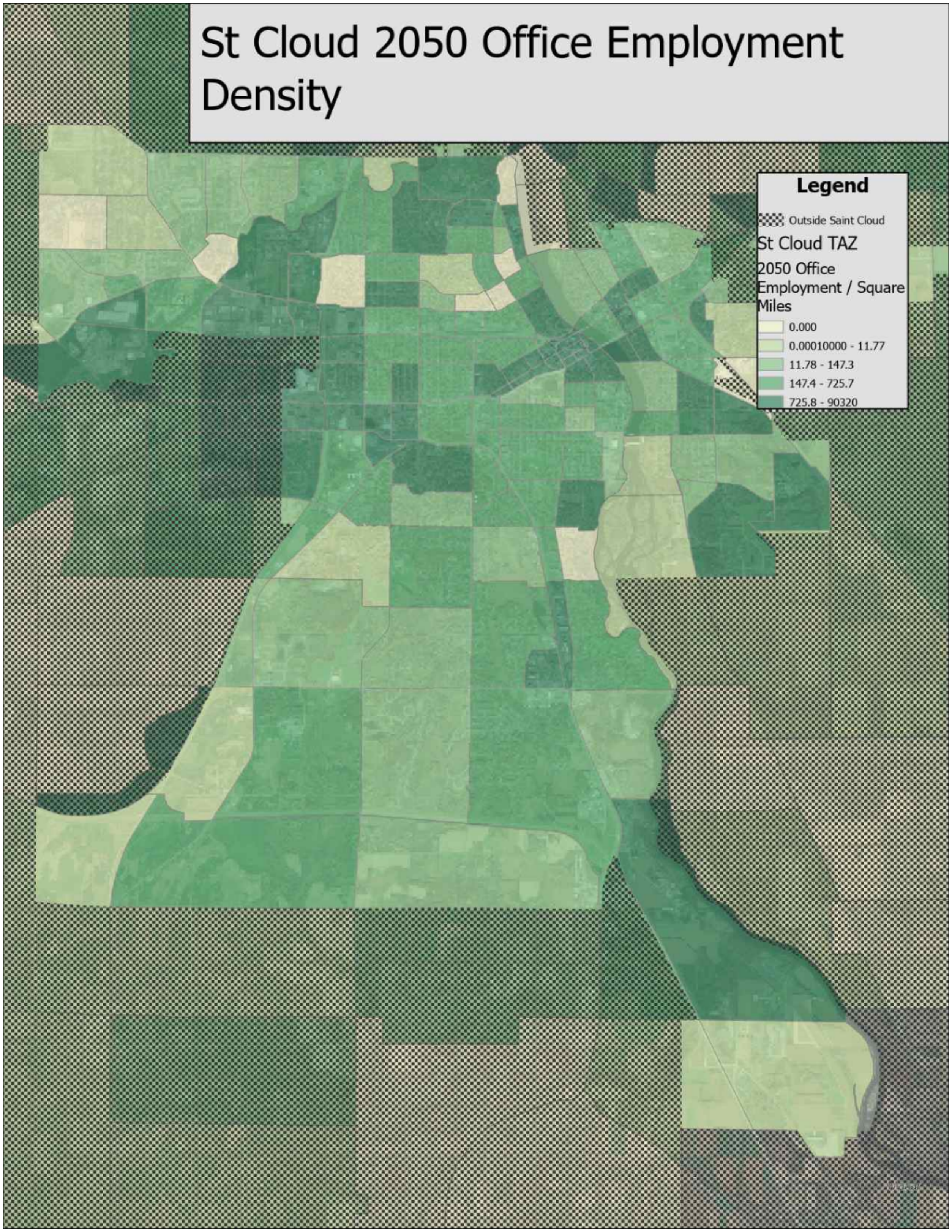
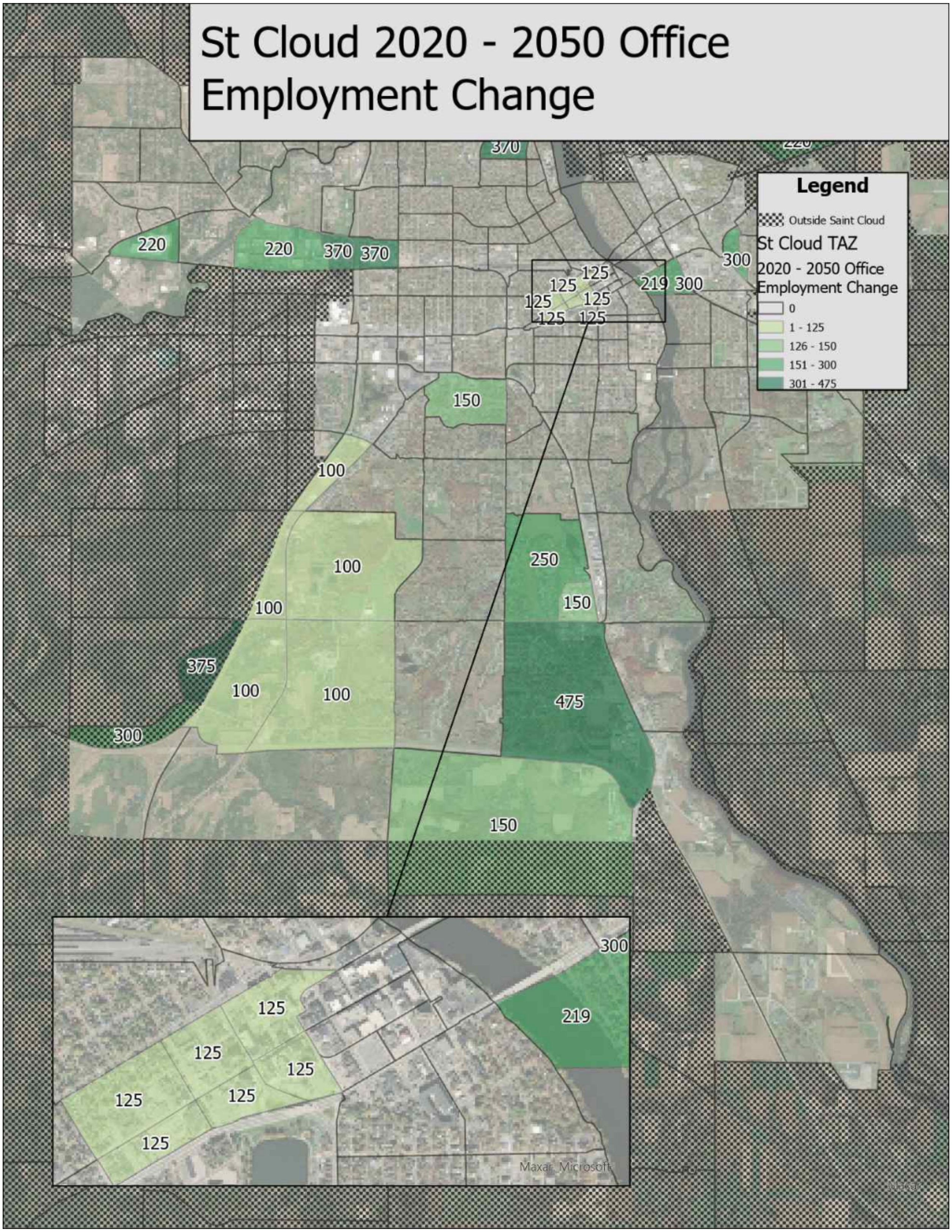
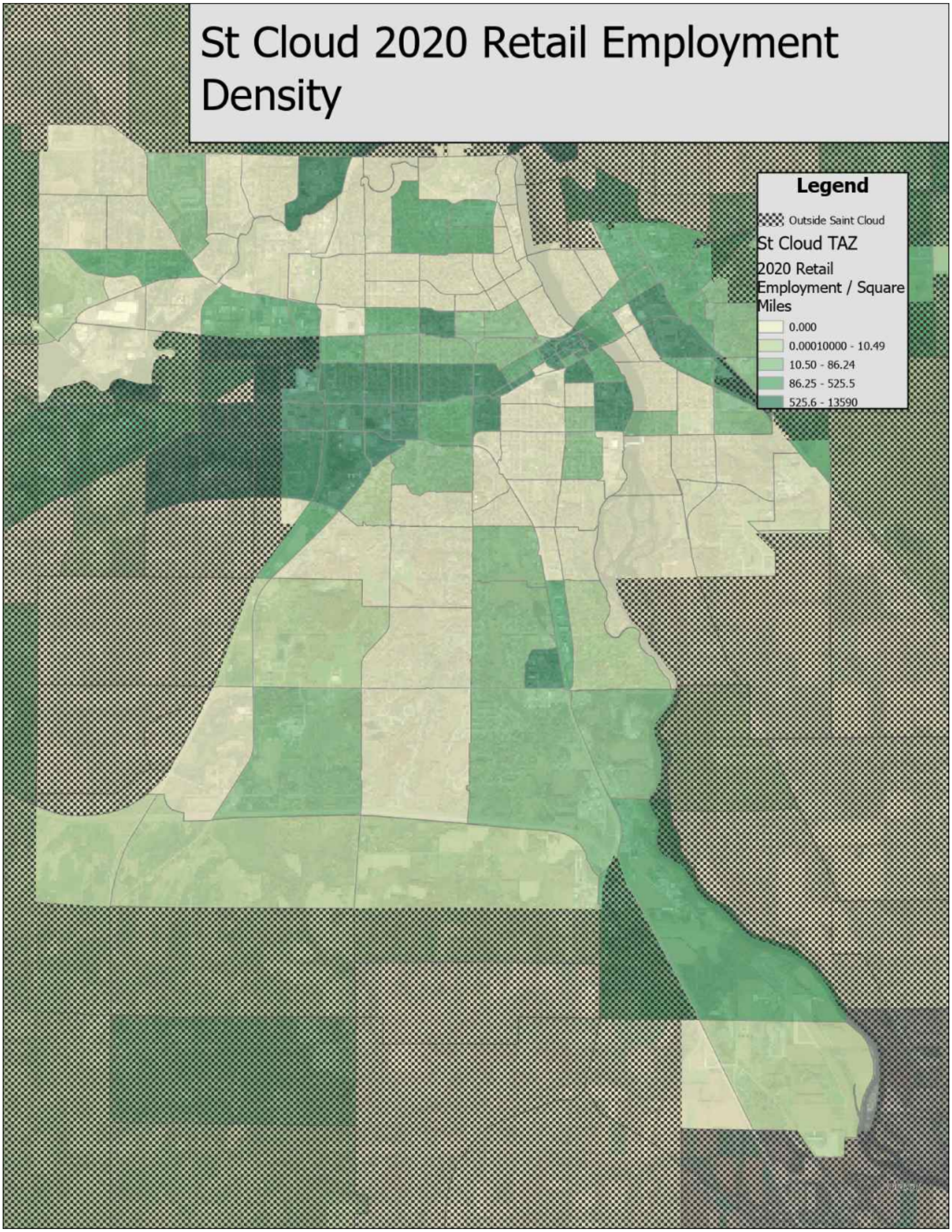
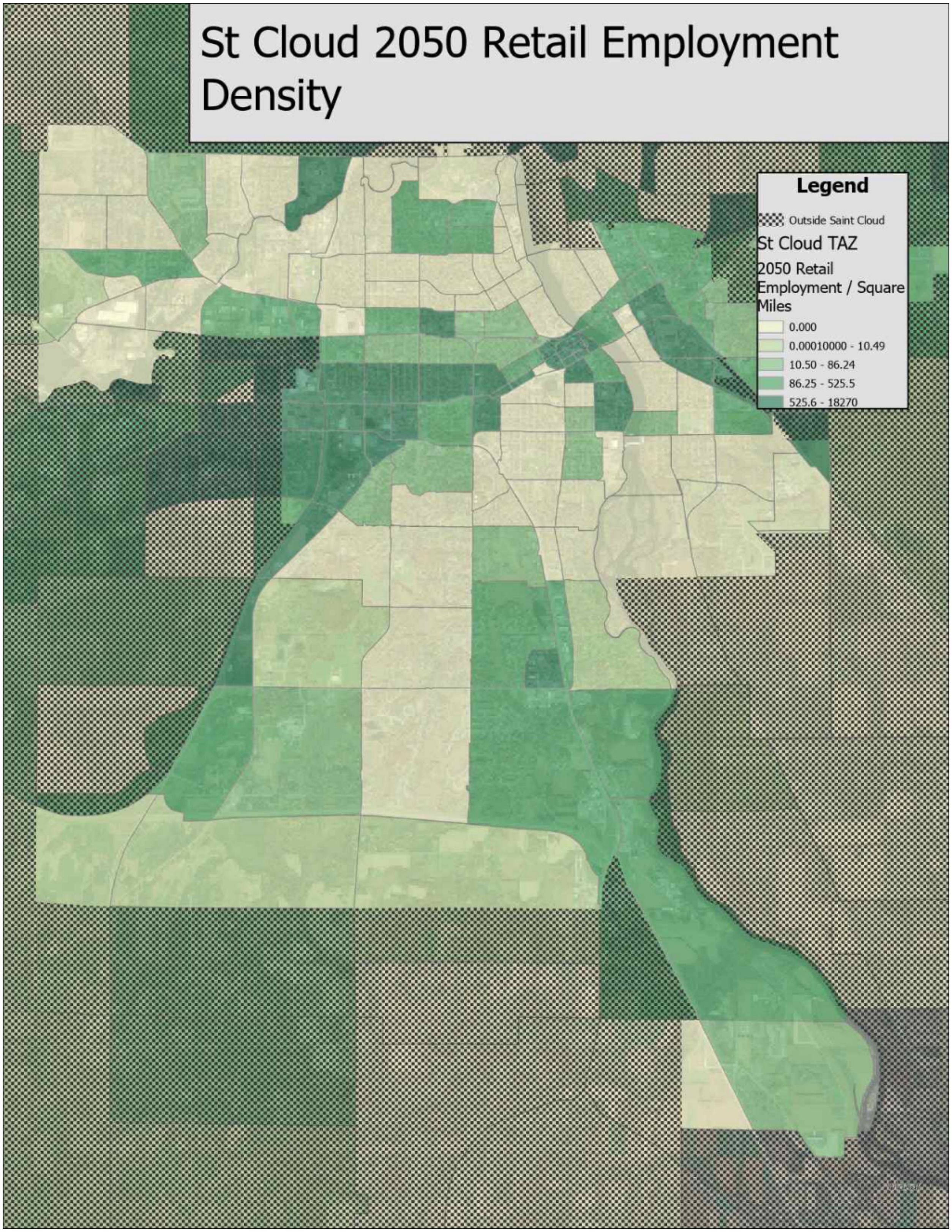
100
100
50
300
300
300

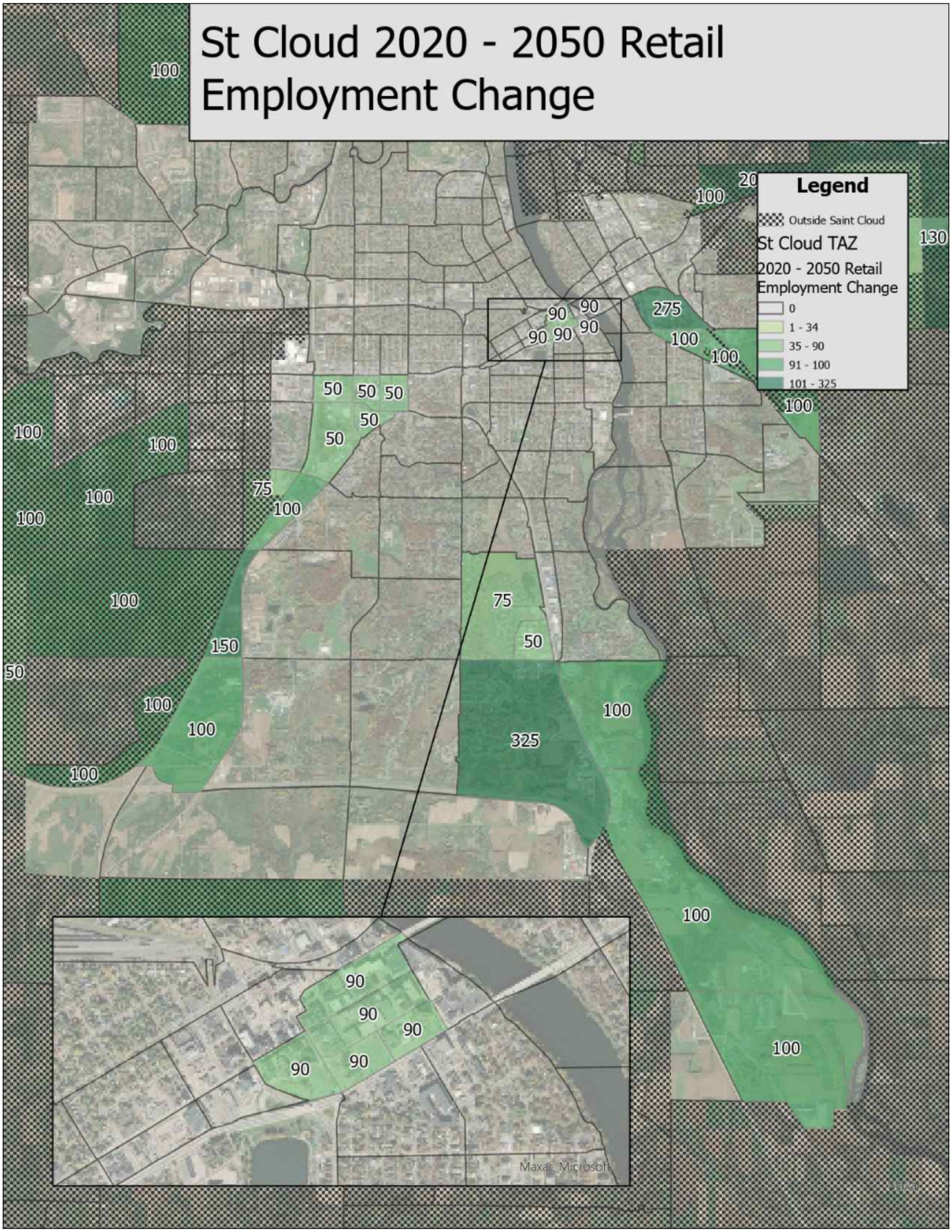

St Cloud 2020 Office Employment Density
Legend
Outside Saint Cloud
St Cloud TAZ
2020 Office Employment / Square Miles
0.00
0.00 - 11.77
11.78 - 147.3
147.4 - 725.7
725.8 - 84980


St Cloud 2050 Office Employment Density
Legend
Outside Saint Cloud
St Cloud TAZ
2050 Office Employment / Square Miles
0.000
0.00010000 - 11.77
11.78 - 147.3
147.4 - 725.7
725.8 - 90320


St Cloud 2020 - 2050 Office Employment Change
Legend
Outside Saint Cloud
St Cloud TAZ
2020 - 2050 Office Employment Change
0
1 - 125
126 - 150
151 - 300
301 - 475
370
220
220
370
370
125
125
125
125
125
125
219
300
300
150
100
100
100
250
150
375
100
100
475
300
150
125
125
125
125
125
125
300
219
Maxar, Microsoft


St Cloud 2020 Retail Employment Density
Legend
Outside Saint Cloud
St Cloud TAZ
2020 Retail Employment / Square Miles
0.000
0.00010000 - 10.49
10.50 - 86.24
86.25 - 525.5
525.6 - 13590


St Cloud 2050 Retail Employment Density
Legend
Outside Saint Cloud
St Cloud TAZ
2050 Retail Employment / Square Miles
0.000
0.00010000 - 10.49
10.50 - 86.24
86.25 - 525.5
525.6 - 18270


St Cloud 2020 - 2050 Retail Employment Change
Legend
Outside Saint Cloud
St Cloud TAZ
2020 - 2050 Retail Employment Change
0
1 - 34
35 - 90
91 - 100
101 - 325
100
130
275
90
50
75
150
325
Maxar, Microsoft

APPENDIX B: Unweighted Trip Rates

HBW Production Rates				
Workers	Vehicles			
	0	1	2	3+
0 Worker	0.2	0.4	0.6	0.7
1 Worker	0.4	0.8	1.1	1.6
2 Worker	0.7	1.1	1.7	2.5
3+ Worker	1.0	1.6	2.5	3.8

HBSC Production Rates				
HH Size	Vehicles			
	0	1	2	3+
1 Person	0.0	0.1	0.1	0.2
2 Person	0.0	0.3	0.5	0.8
3 Person	0.1	0.4	0.8	1.3
4 Person	0.1	0.6	1.2	2.0
5+ Person	0.2	0.9	1.6	2.8

HBO Production Rates				
HH Size	Vehicles			
	0	1	2	3+
1 Person	2.5	2.8	3.0	3.3
2 Person	3.6	4.1	4.6	5.3
3 Person	4.6	5.3	6.0	7.0
4 Person	5.7	6.6	7.6	9.1
5+ Person	7.2	8.4	9.7	11.8

NHB Production Rates				
HH Size	Vehicles			
	0	1	2	3+
1 Person	1.7	2.8	3.5	4.4
2 Person	2.0	3.1	4.1	5.6
3 Person	2.2	3.4	4.7	6.6
4 Person	2.5	3.8	5.4	7.8
5+ Person	2.8	4.2	6.3	9.4

APPENDIX C: Weighted Trip Rates

HBW Production Rates				
Workers	Vehicles			
	0	1	2	3+
0 Worker	0.1	0.4	0.6	0.8
1 Worker	0.3	0.6	0.9	1.3
2 Worker	0.5	0.8	1.2	1.7
3+ Worker	0.8	1.1	1.6	2.3

HBSC Production Rates				
HH Size	Vehicles			
	0	1	2	3+
1 Person	0.0	0.0	0.0	0.0
2 Person	0.0	0.1	0.3	0.4
3 Person	0.1	0.3	0.5	0.8
4 Person	0.2	0.5	0.8	1.3
5+ Person	0.2	0.7	1.2	2.0

HBO Production Rates				
HH Size	Vehicles			
	0	1	2	3+
1 Person	2.1	2.8	3.2	3.7
2 Person	2.4	3.7	4.9	6.6
3 Person	2.7	4.5	6.4	9.1
4 Person	3.0	5.4	8.1	12.0
5+ Person	3.4	6.6	10.4	15.9

NHB Production Rates				
HH Size	Vehicles			
	0	1	2	3+
1 Person	1.6	3.4	4.7	6.5
2 Person	1.9	3.7	5.2	7.5
3 Person	2.2	3.9	5.7	8.3
4 Person	2.6	4.2	6.2	9.3
5+ Person	3.1	4.6	6.9	10.6

APPENDIX D: Full Employment Regression Results

Daily Trip Attraction Regressions

	Dependent variable:			
	HBW	HBO	HBSC	NHB
Total Employment	0.57*			
	(0.22)			
Manufacturing/Indust.		0.98		0.65
		(0.55)		(0.59)
Retail/Trade		0.47		0.81*
		(0.49)		(0.34)
Service/Office		1.79		2.25*
		(0.98)		(0.85)
Households		2.35*		2.13*
		(0.92)		(0.91)
School Enrollment			2.10*	
			(0.64)	
Observations	11	34	4	44
R^2	0.41	0.59	0.78	0.70
Adjusted R^2	0.35	0.53	0.71	0.67
Residual Std. Error	787.59 ($d_f = 10$)	909.61 ($d_f = 30$)	898.19 ($d_f = 3$)	883.73 ($d_f = 40$)
F Statistic	6.93* ($d_f = 1; 10$)	10.76*** ($d_f = 4; 30$)	10.69* ($d_f = 1; 3$)	23.09*** ($d_f = 4; 40$)
Note:				*p<0.05; **p<0.01; ***p<0.001