CHAPTER 2:

NATIONAL & REGIONAL TRENDS AND FORECASTS

- Introduction
- Demographics
- Economics
- Land Use and Development
- Commuting Patterns
- Emerging Technologies

INTRODUCTION

National and regional trends and forecasts such as shifting demographics and growth provide insight into how best to invest in the transportation system to meet future needs while accommodating present needs. Demographic changes, commuting patterns, economic shifts, land use development patterns, and emerging technologies all influence the type, location, and amount of demand on transportation facilities and services and also pose potential equity considerations. The need to account for these changes is especially true in the greater Madison region – the fastest growing and fastest changing region in the state. The Madison area is out-pacing the rest of the state in all key economic indicators, including job creation, business growth, and construction activity.[1] The area's population growth is out-pacing the rest of the state and at the same time the population is becoming increasingly diverse.

DEMOGRAPHICS

Demographic projections have an impact on the type of solutions planned for the future transportation network. When coupled with commuting patterns, economic forecasts, and land use development patterns it is possible to prepare forecasts for future travel demand and identify issues and needs.

Population

The country's population continues to grow, with a majority of this growth occurring in the southern and western states. Wisconsin is growing at a slower pace than other states due to high out-migration without comparable in-migration of either domestic or foreign-born immigrants. However, Dane County and the City of Madison have deviated from that trend and are projected to continue to do so in the future with population continuing at a moderate rate. Dane County added nearly 100,000 new residents, while the City of Madison added nearly 41,000, between 2000 and 2015. This growth accounted for nearly ¼ of the state's growth over that time frame.

The population growth rate of Dane County as a whole outpaced the City of Madison's growth from 1990-2010 continuing a historical trend. As a result, the city's share of county population has decreased from 52.0% to 47.8%. This

Figure 2-1

Population Growth in Dane County and Madison

	Total Population			Change	
	1990	2000	2010	1990-2000	2000-2010
Dane County	367,085	426,526	488,073	16.2%	14.4%
City of Madison	190,766	208,054	233,209	9.1%	12.1%
City as % of County	52.0%	48.8%	47.8%		

Figure 2-2

Population Growth in Selected Communities

	Total Population			Change	
Community	**1990**	**2000**	**2010**	**1990-2000**	**2000-2010**
Cottage Grove, Village	1,131	4,059	6,192	258.9%	52.5%
Fitchburg, City	15,648	20,501	25,260	31.0%	23.2%
Madison, City	190,776	208,054	233,209	9.1%	12.1%
Madison, Town	6,442	7,005	6,279	8.7%	-10.4%
Maple Bluff, Village	1,352	1,358	1,313	0.4%	-3.3%
Middleton, City	13,785	15,770	17,442	14.4%	10.6%
Monona, City	8,637	8,018	7,533	-7.2%	-6.0%
McFarland, Village	5,232	6,416	7,808	22.6%	21.7%
Shorewood Hills, Village	1,680	1,732	1,565	3.1%	-9.6%
Stoughton, City	8,786	12,354	12,611	40.6%	2.1%
Sun Prairie, City	15,352	20,369	29,364	32.7%	44.2%
Verona, City	5,374	7,052	10,619	31.2%	50.6%
Waunakee, Village	5,897	8,995	12,097	52.5%	34.5%
Westport, Town	2,732	3,586	3,950	31.3%	10.2%

[1] Connect Madison, City of Madison Economic Development Strategy (Dec. 2016).

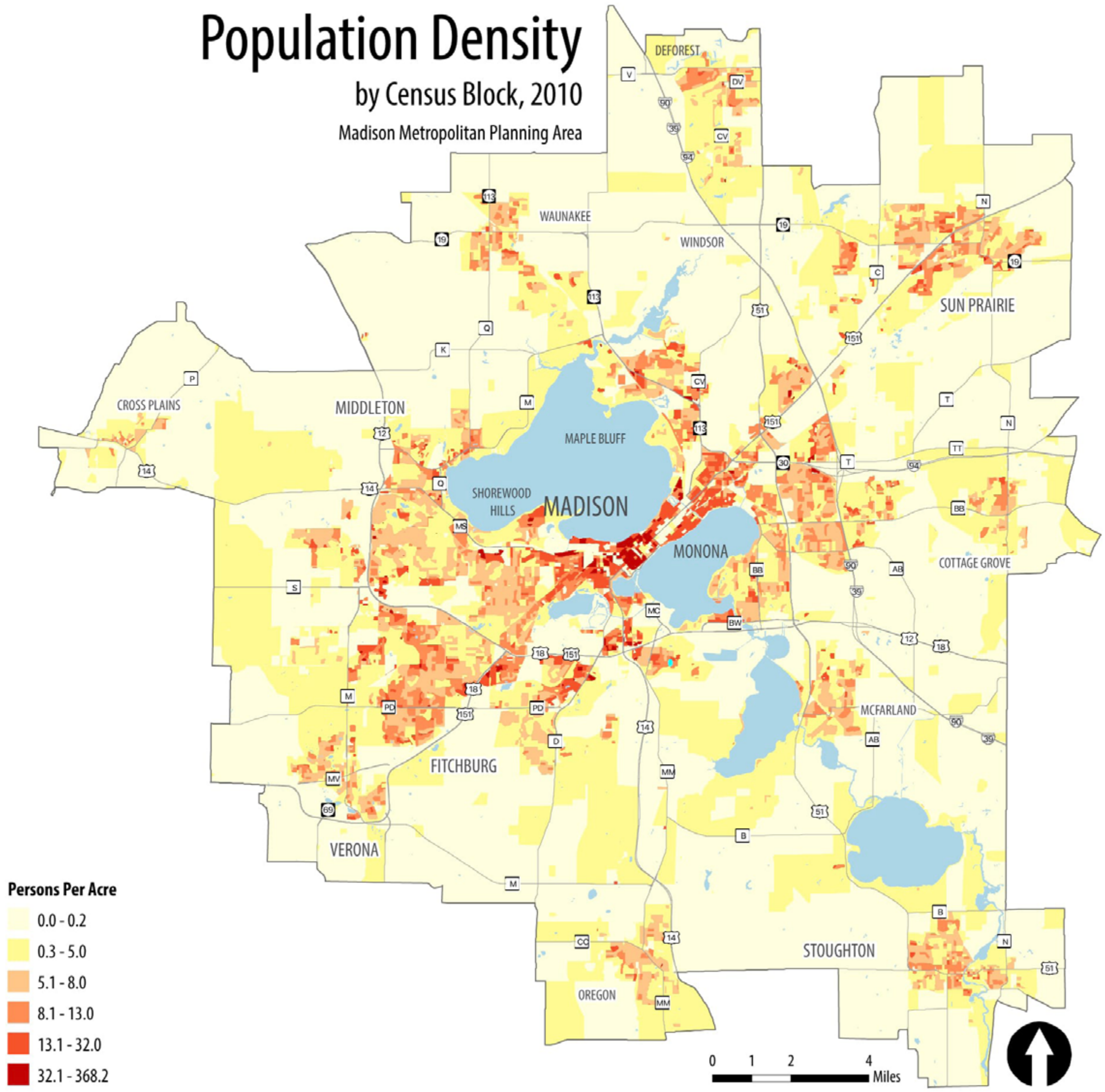


Figure 2-3: Population Density by Census Block, 2010

trend is expected to continue. Suburban cities and villages with the highest percentage growth rates over the past 25 years include Cottage Grove, Waunakee, Verona, and Sun Prairie. Paced by these communities and the DeForest/Windsor area, the larger outer urbanized areas are projected to grow by 59%, adding 55,000 new residents from 2010-2050. The population of the central urbanized area, including Madison, Fitchburg, Middleton, and McFarland, is projected to grow by 25% or 77,000 residents. The projected population growth in smaller urbanized and rural areas outside the Madison Metropolitan Planning Area is only expected to be about 17,000.

Figure 2-4

Madison Metropolitan Area Population

2010 Census and 2050 Forecast

	2010 Census		2050 Forecast		Change	
Municipality	Population	% of County	Population	% of County	Number	Percent
Central Urbanized Area Total	302,224	62%	379,118	60%	76,894	25%
City of Madison	234,618	48%	292,522	46%	57,904	25%
City of Fitchburg	25,413	5%	34,370	5%	8,957	35%
City of Middleton	17,548	4%	24,571	4%	7,023	40%
Village of McFarland	7,855	2%	10,379	2%	2,524	32%
Larger Outer Urbanized Area Total	93,111	19%	148,375	23%	55,264	59%
City of Sun Prairie	29,364	6%	50,883	8%	21,519	73%
City of Stoughton	12,611	3%	14,366	2%	1,755	14%
City of Verona	10,619	2%	18,840	3%	8,221	77%
Village of Cottage Grove	6,192	1%	10,594	2%	4,402	71%
Village of Waunakee	12,097	2%	19,279	3%	7,182	59%
Northern (DeForest/Windsor)	12,997	3%	20,794	3%	7,797	60%
Village of Oregon	9,231	2%	13,619	2%	4,388	48%
Smaller USAs Total	26,740	5%	36,151	5%	9,411	35%
Rural Total	65,998	14%	73,785	12%	7,787	12%
County Total	488,073		637,429		149,356	31%

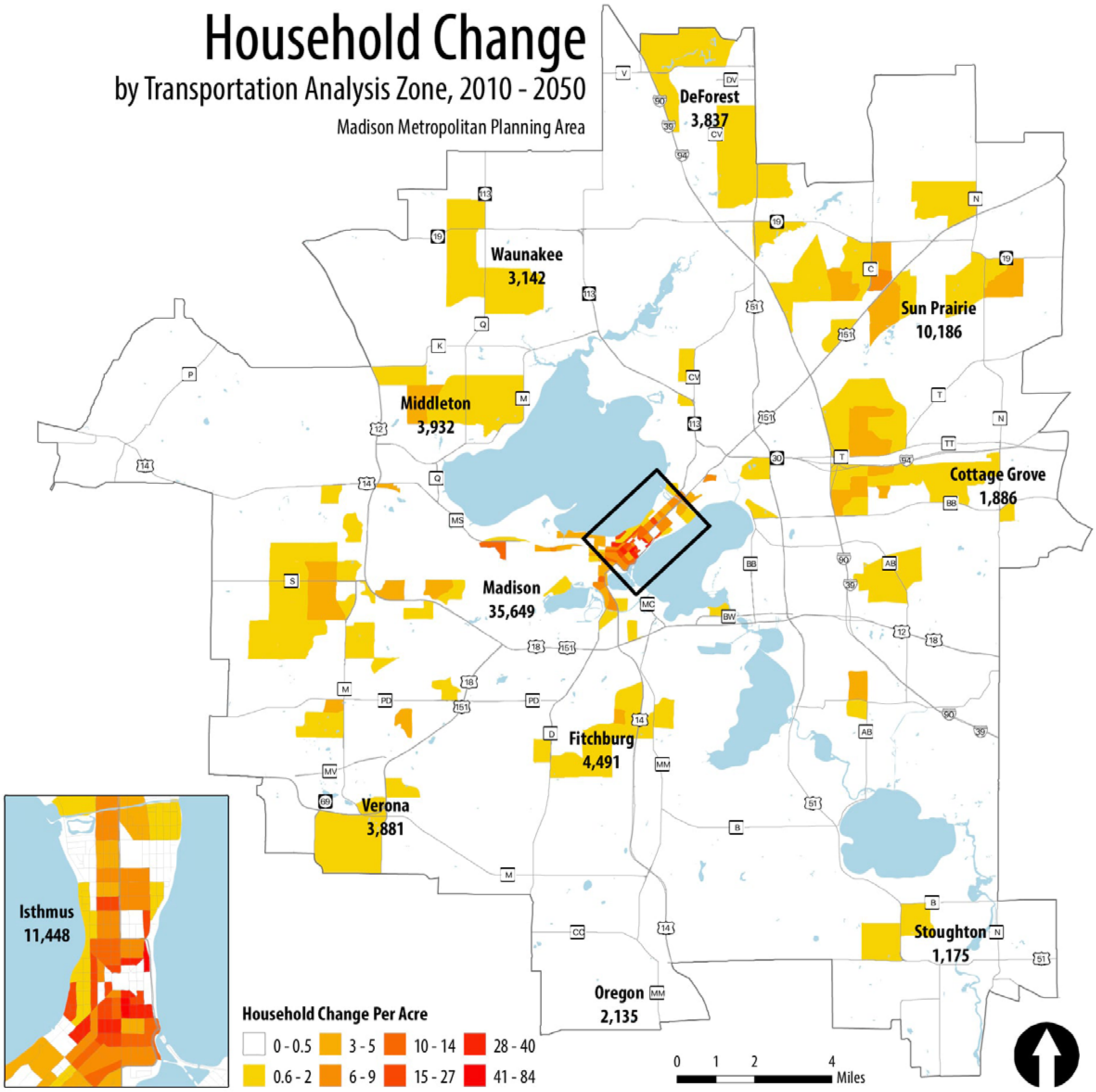


Figure 2-5: Change by Transportation Analysis Zone, 2010-2050

Households

While the population has continued to grow nationally and within the Madison region, the average size of a household has been in a decline. This decline has occurred for a number of reasons, including changing cultural norms, an increase in the percentage of single-person and two-person households, a reduction in the number of children each family is having, and an increase in elderly with the aging of the baby boomers. The US Census Bureau defines a household as "all the persons who occupy a housing unit as their usual place of residence. A housing unit is a house, an apartment, a mobile home, a group

Figure 2-6

Madison Metropolitan Area Households

2010 Census and 2050 Forecast

	2010 Census		2050 Forecast		Change	
Municipality	Households	% of County	Households	% of County	Number	Percent
Central Urbanized Area Total	132,172	65%	177,828	62%	45,656	35%
City of Madison	103,132	51%	138,781	49%	35,649	35%
City of Fitchburg	10,015	5%	14,506	5%	4,491	45%
City of Middleton	8,085	4%	12,017	4%	3,932	49%
Village of McFarland	3,097	2%	4,268	2%	1,171	38%
Larger Outer Urbanized Area Total	36,164	18%	62,406	22%	26,242	73%
City of Sun Prairie	11,636	6%	21,822	8%	10,186	88%
City of Stoughton	5,133	3%	6,308	2%	1,175	23%
City of Verona	4,223	2%	8,104	3%	3,881	92%
Village of Cottage Grove	2,210	1%	4,096	1%	1,886	85%
Village of Waunakee	4,344	2%	7,486	3%	3,142	72%
Northern (DeForest/Windsor)	5,029	2%	8,866	3%	3,837	76%
Village of Oregon	3,589	2%	5,724	2%	2,135	59%
Smaller USAs Total	10,497	5%	15,850	6%	5,353	51%
Rural Total	24,917	12%	29,100	10%	4,183	17%
County Total	203,750		285,184		81,434	40%

of rooms, or a single room that is occupied as separate living quarters. The occupants may be a single family, one person living alone, two or more families living together, or any other group of related or unrelated persons who share living arrangements."

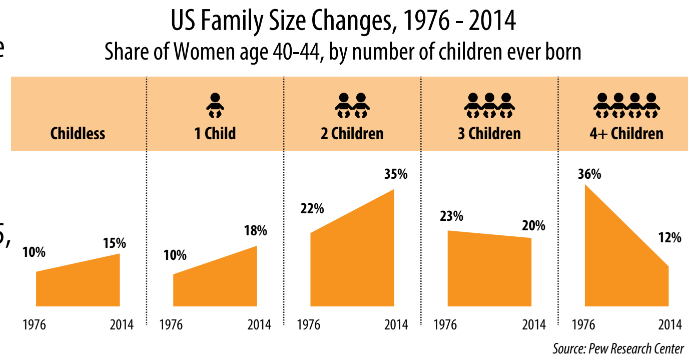


Figure 2-7: US Family Size Changes, 1976 - 2014

In 1970, the average US household size was 3.14. By 2015, the average US household size had fallen to 2.59. Here the trends have been similar – the average Dane County household size was 3.09 in 1970 and had dropped to 2.33 by 2010. Housing and household sizes are correlated with average house and household sizes larger in villages and towns, smaller in suburban cities, and the smallest in the City of Madison. The historic trend of shrinking household sizes is projected to continue in the future, with the City of Madison reaching an average household size of 2.03 by 2040, nearly 1 person less than 1970.

Average Household Size in Dane County Communities
Historical Census Data and Forecasts

	1970	1980	1990	2000	2010	Projections 2020	2030	2040
Towns	3.73	3.01	2.8	2.59	2.57	2.5	2.46	2.43
Villages	3.17	2.85	2.74	2.72	2.61	2.53	2.49	2.46
Small Cities	3.26	2.54	2.29	2.35	2.37	2.31	2.17	2.24
Madison	2.88	2.38	2.3	2.19	2.17	2.11	2.07	2.03
Dane County	3.09	2.56	2.46	2.37	2.33	2.27	2.23	2.2

Source: DOA

Figure 2-8: Average Household Size in Dane County Communities

Understanding trends in average household size along with other household characteristics is important because the makeup of households affects the demand for different types of housing and the location of that housing. For example, if the City of Madison has an average household size of 2.17 in 2010 and a population of 234,618, it can be surmised that over 108,000 housing units are needed to accommodate those residents. One of the ways that the City of Madison plans to accommodate future housing needs is through infill and redevelopment in existing and planning activity centers and in the downtown and Isthmus areas. In fact, infill and redevelopment areas such as the East Washington Avenue corridor are projected to accommodate well over 50% of all new households in the City of Madison between 2010 and 2050. Of those, around 11,500 are forecast to be located within the greater Isthmus area, more than even the City of Sun Prairie, the largest suburb. This is consistent with the trend over the past fifteen years and city policy.

Figure 2-5 on page 2-4 illustrates the areas with a large projected increase in households. While the City of Madison's percentage share of households and population is projected to continue to slowly decline, close to 36,000 or 50% of all future new households within the Metropolitan Planning Area are projected to be located within the central city.

Age

Much like the rest of the state, Dane County has a large elderly population that is projected to grow in the future. The percentage of Dane county's population aged 65 and older is expected to double from 10% to 20% between 2010 and 2040. This growth is partially due to the aging of the Baby Boomers generation as well as advances in medicine that have increased life expectancies. The growth of this population cohort comes at a time in which aging in place – living in one's own home and community, independently regardless of age, income, and ability – has become not only an expected consideration but a norm. A growing

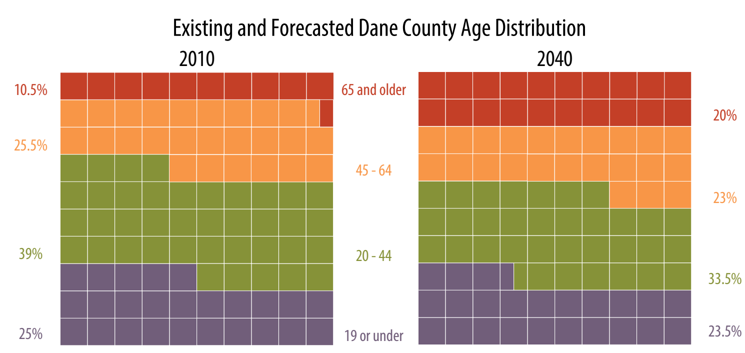


Figure 2-9: Existing and Forecasted Dane County Age Distribution

aging population, some of whom will not have the ability to transport themselves, will require a transportation network that will allow for safe and convenient transportation to grocery stores and other shopping destinations, entertainment, healthcare facilities, places of worship, and other destinations. Existing accommodations will have to be reinforced and future technologies explored to ensure adequate mobility and accessibility for all.

Race and Ethnicity

The United State has become and is projected to continue becoming more diverse. In fact, the Pew Research Center projects that more than 80% of population growth between 2010 and 2050 will be attributable to immigrants and their US-born descendants. This, in combination with higher fertility rates among African American, Hispanic American, and Asian American populations compared to the non-Hispanic white population, is driving the trend of growing diversity.

In the Madison region these trends have been evident as well. Between 2000 and 2010, the white population grew at a rate of 9% while the African American population grew at 49%, Asian American population grew at 56%, mixed races population at 59%, and other minority groups grew at 82%. Further, the Hispanic population grew at a rate of 101% compared to the Non-Hispanic population growth rate of 11%. This is important because of the different travel habits and residence location decisions of the minority versus white population. Of course, these choices may change in the future. See the Environmental Justice Analysis in Appendix B for more detailed information on the distribution of the minority population within the region and an analysis related to the equitable distribution of transportation resources.

Demographics of Dane County, 2010

Race

Race	Number 2010	Percent of Total 2010	Increase 2000 -2010
White	413,631	85%	9%
Black/African American	25,347	5%	49%
Asian	23,035	5%	56%
Other Minority	13,960	3%	82%
Two or More Races	12,100	3%	59%
Total Population	**488,073**	**100%**	**14%**

Ethnicity

Ethnicity	Number 2010	Percent Total 2010	Increase 2000-2010
Hispanic	28,925	6%	101%
Non Hispanic	459,148	94%	11%
Total Population	**488,073**	**100%**	**14%**

Figure 2-10: Demographics of Dane County, 2010

ECONOMICS

The location, density, and distribution of employment in relation to where employees live are some of the primary factors influencing travel demand. Though work trips make up less than 20% of all trips, they are generally the longest trip of the day and most occur during peak use times, driving the capacity needs of the transportation system. Often non-work trips are combined with work trips, contributing to congestion during the peak travel periods.

Dane County is home to the State's flagship university, the seat of state government, and to numerous biotechnology firms. Additionally, the region boasts strong healthcare, health and information technology, agribusiness/food, insurance, financial, and precision manufacturing industries. The regional economy is becoming increasingly private-sector driven. The diversity and concentration of employers within the county has led to the county having one of the lowest unemployment rates in Wisconsin, and being a net importer of employees. Within the County, the cities of Madison and Middleton have more jobs than workers living in the community. According to US Census data estimates, around 40,000 workers travel into Dane County per day from surrounding counties, while around 10,000 travel from Dane County to surrounding counties for work.

In the future, it is anticipated that Dane County will continue to import an increasing number of employees from surrounding counties. Between 2010 and 2050, Dane County's employment is forecast to increase from 314,000 to 398,700, while the

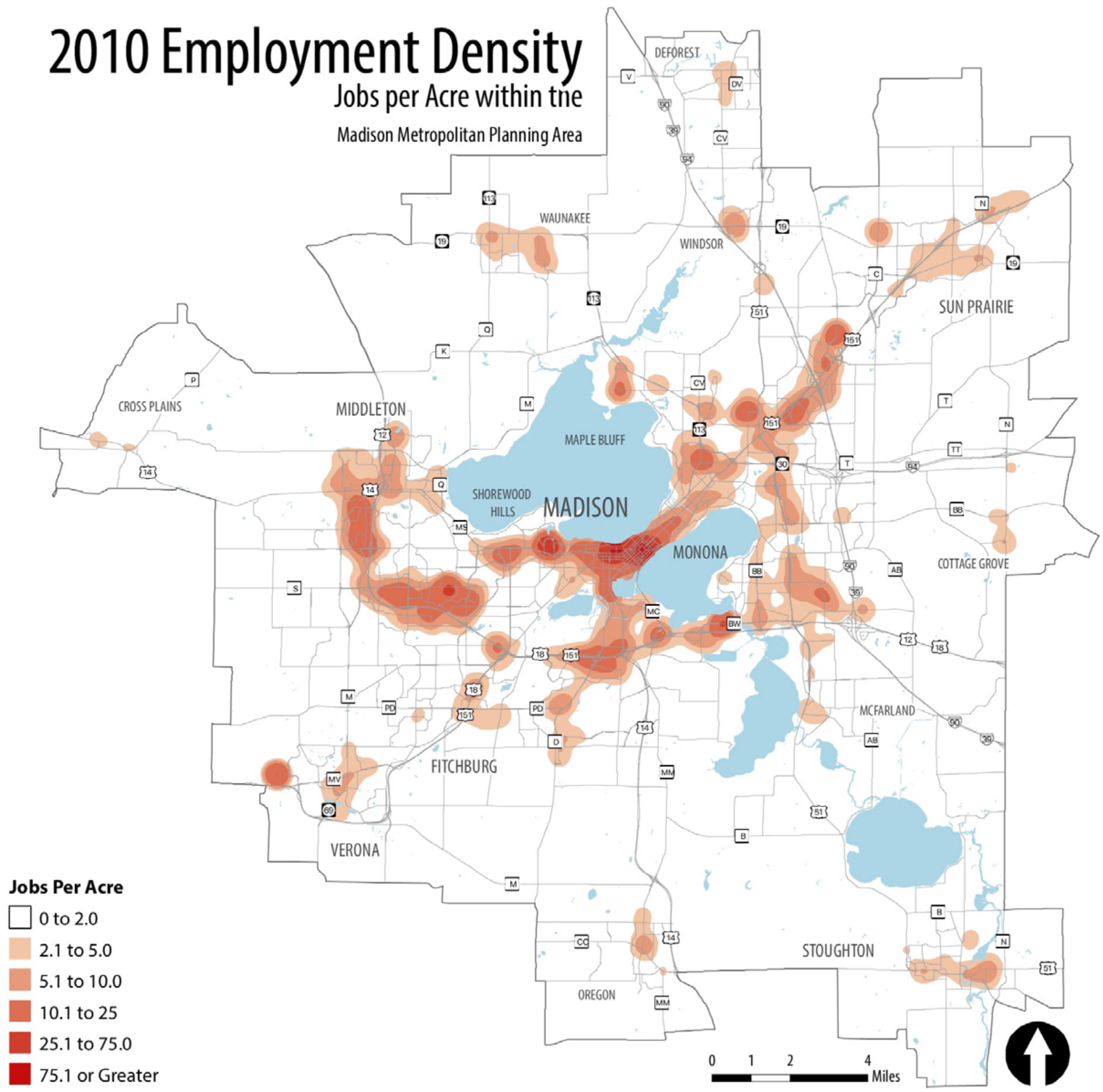


Figure 2-12: 2010 Employment Density

2050 resident employed labor force working in the county is projected to be 316,100. Assuming the percentage of Dane County workers working in other counties remains at 5.3%, the number of workers commuting into the county from other counties would increase to 99,300, a 136% increase from today's numbers.

While the City of Madison's share of employment is forecast to decline somewhat, total employment within the city is projected to grow by 46,000, accounting for over 50% of new employment within the Metropolitan Planning Area. Of that,

Figure 2-13

Madison Metropolitan Area Employment

2010 InfoUSA and 2050 Forecast

	2010 InfoUSA		2050 Forecast		Change	
Municipality	Employment	% of County	Employment	% of County	Number	Percent
Central Urbanized Area Total	249,579	80%	307,366	77%	57,787	23%
City of Madison	195,888	62%	241,093	60%	45,205	23%
City of Fitchburg	12,165	4%	17,967	5%	5,802	48%
City of Middleton	19,104	6%	22,941	6%	3,837	20%
Village of McFarland	1,943	1%	2,511	1%	568	29%
Larger Outer Urbanized Area Total	45,094	14%	70,545	18%	25,451	56%
City of Sun Prairie	11,362	4%	15,168	4%	3,806	34%
City of Stoughton	6,445	2%	6,625	2%	180	3%
City of Verona	9,315	3%	22,280	6%	12,965	139%
Village of Cottage Grove	2,625	1%	4,287	1%	1,662	63%
Village of Waunakee	5,901	1%	8,406	2%	2,505	42%
Northern (DeForest/Windsor)	6,054	2%	9,737	2%	3,683	61%
Village of Oregon	3,392	1%	4,042	1%	650	19.16%
Smaller USAs Total	9,567	3%	11,267	3%	1,700	18%
Rural Total	9,478	3%	9,480	2%	2	0%
County Total	313,718		398,658		84,940	27%

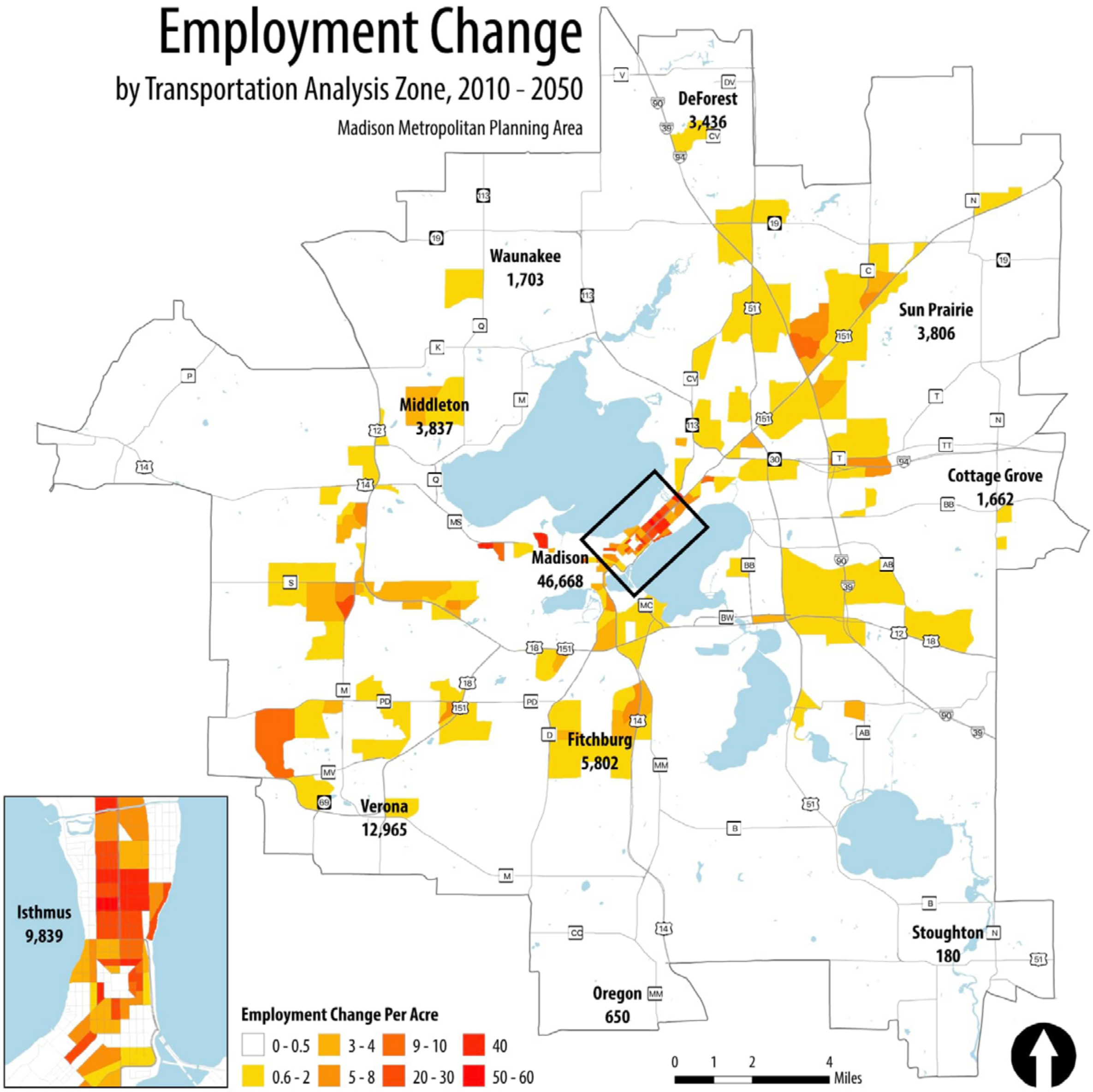
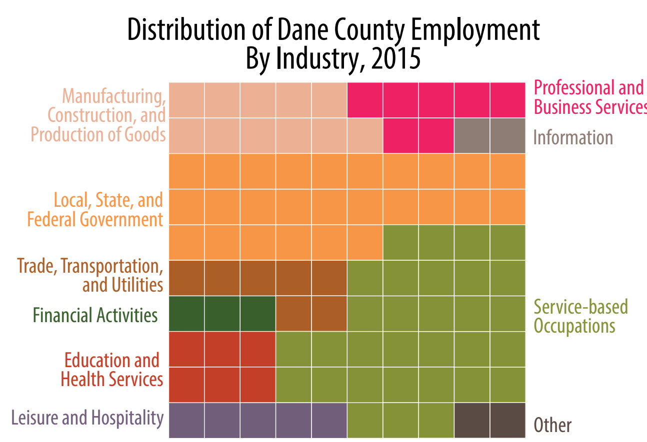


Figure 2-14: Employment Change 2010 - 2050

around 10,000 new jobs are forecast within the Isthmus area. This is largely based on projections for the Capitol East District, developed to assess future parking demand and other necessary improvements. Among suburban communities, the City of Verona's employment is expected to grow by far the most, largely due to Epic Systems, the county's largest private employer. However, Fitchburg, Sun Prairie, Middleton, DeForest, and Cottage Grove are all expected to have a healthy increase in employment.



2015 Annual BLS County-level QCEW Data

Figure 2-15: Distribution of Dane County Employment by Industry, 2015

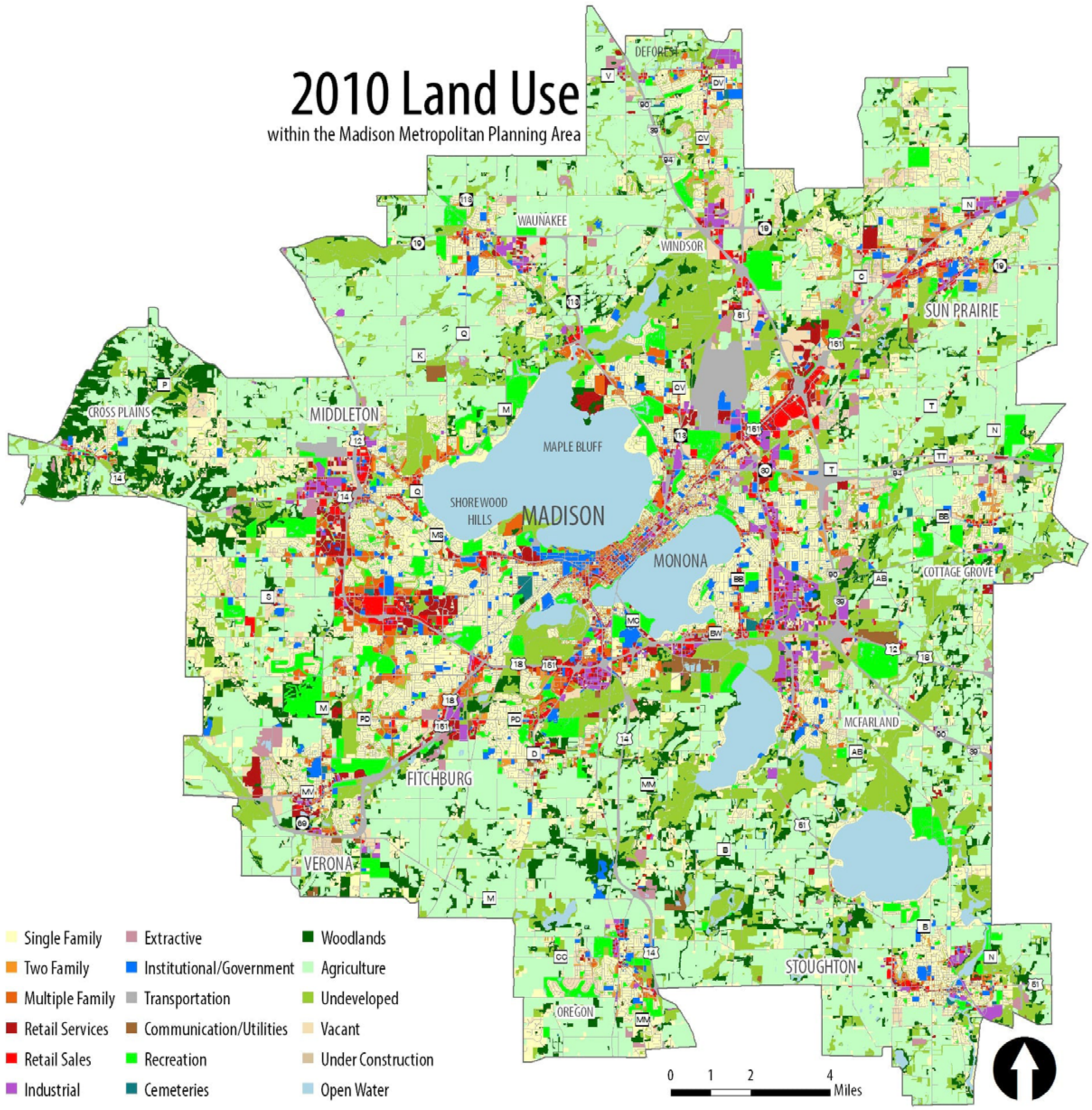


Figure 2-16: 2010 Land Use

LAND USE

The mix, location, and density of land uses determines travel demand. This means that land use and site configuration have a direct impact on the types of transportation facilities and services that are needed in an area. For example, residential land uses must have access to places of employment, stores, schools, and entertainment; therefore, it is imperative that there are roadway, transit, bicycle, and pedestrian connections between land uses. The distance between and density of the land uses influences the type of transportation one may use for a specific trip and whether the trip will be made as an individual trip or in a chain of trips.

Conversely, the availability of transportation facilities may influence whether a development is viable or not. For example, without convenient highway access, large retailers on the urban periphery may not be able to attract customers. Similarly, industrial areas are less likely to succeed without easy access to interstate highways or other major freight corridors. Land use

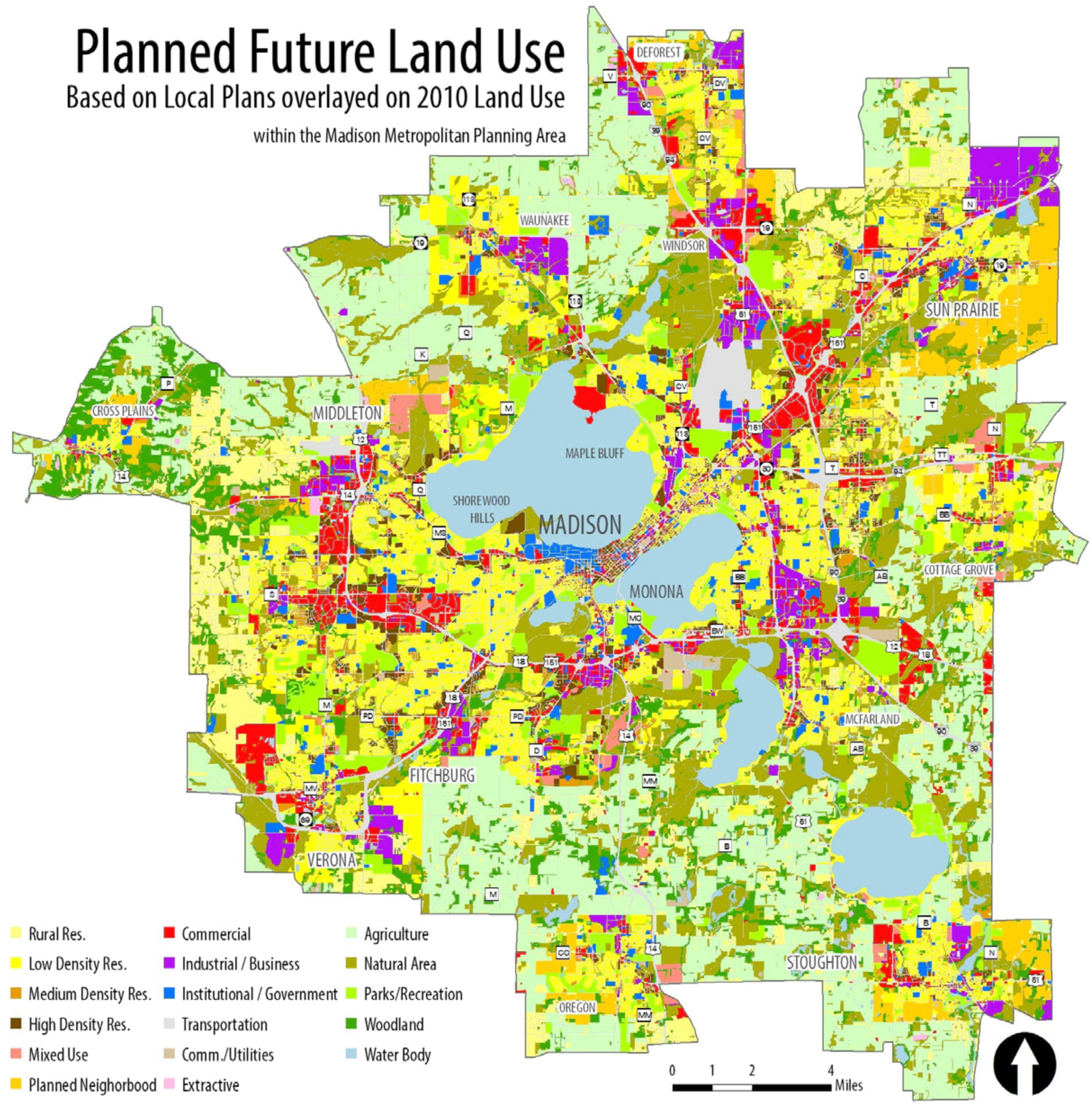


Figure 2-17: Planned Future Land Use

and transportation facilities are inextricably linked.

Figure 2-16 shows the location of existing land uses in the Madison Metropolitan Planning area. Some of the most intense or dense uses include two and multifamily residences, commercial, and institutional/governmental. These uses tend to be concentrated in downtown Madison, the Isthmus, and along major transportation corridors in communities throughout the area. Trip generating uses, such as retail sales/services and industrial uses, agglomerate near one another in areas with strong access to regional or interstate facilities. Less intense uses, such as single family homes, tend to locate within, at a minimum, driving distance to major regional transportation corridors and away from intense or trip generating uses.

A number of urban planning models have been developed to determine how land use, transportation facilities, and density interact. One prominent contemporary model, the Rural-to-Urban Transect, suggests that urbanism occurs in symbiotic transects. The Transect describes levels of urbanization that range from a natural rural preserve to a dense urban core. Each of these typologies is symbolic of different development patterns and requires different transportation facilities. One of the benefits of this model is that it demonstrates the similarity between zones that may not appear to be similar, but have similar characteristics and require similar transportation treatments.

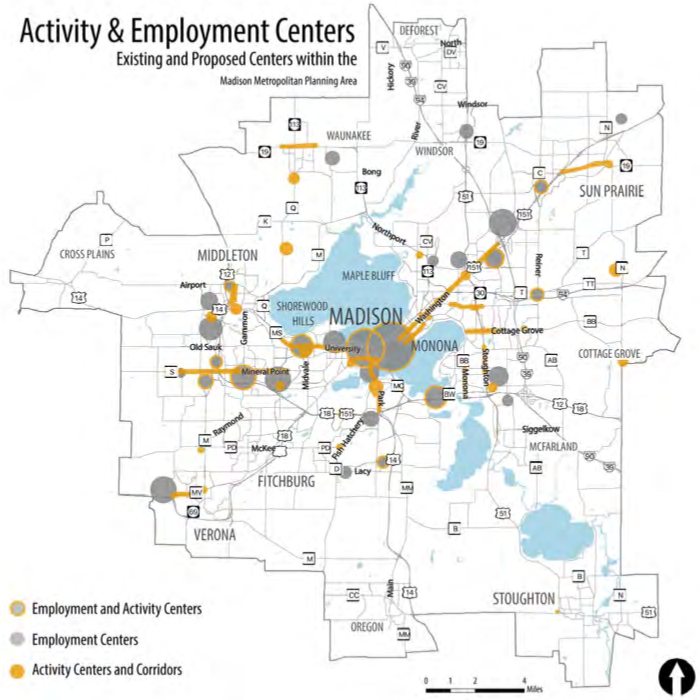


Figure 2-18: Activity and Employment Centers

For instance, the Madison neighborhood of Hill Farms near University Avenue has similar transportation needs to that of the Schenk-Atwood-Starkweather-Yahara (SASY) neighborhood. Though the densest portion of Hill Farms would be viewed a contemporary, transit-oriented development and SASY is an older neighborhood built around a defunct streetcar line, both require high-quality transit service, quality pedestrian and bicycle facilities, and regional transportation for moving residents, workers, shoppers, and freight. The Transect would identify them both as "urban center" zones, and require similar facilities.

In the past, communities did not deviate from the gradient shown in the Transect – an urban core buoyed a community, with urbanity dissipating into suburban and then rural form gradually as one moves away from the core. This configuration encourages driving in the periphery and forces traffic into one dense core. Contemporary configurations retrofit dense activity centers into areas that have been traditionally home to suburban or general urban development or build them as part of new developments. This configuration change increases pedestrian and bicycle activity, while making transit more viable. The development of high-density, mixed-use activity centers, primarily along existing and planned major transit corridors is a central recommendation of the City of Madison's Madison in Motion Transportation Plan and this RTP. The development of these centers, illustrated in Figure 2-18, is reflected in the land use growth forecast for the RTP.

Figure 2-17 on page 2-10 shows planned future land use based on local land use plans. The map, along with input from local planners and officials, served as a guide for the growth forecasts used to estimate future travel demand for the RTP using the regional travel model. It should be noted that the growth forecast for the RTP constituted far less than the complete build out of plans reflected in the map due to differences in the timeframe of local plans, and the need for the RTP growth scenario to adhere to county forecast control totals for households, population, and employment.

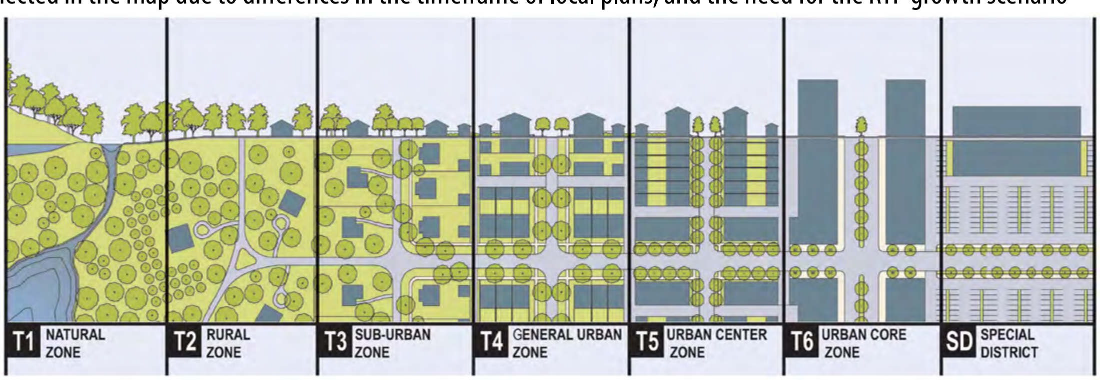


Figure 2-19: Rural to Urban Transect

COMMUTING PATTERNS

Commuting describes travel that is made to and from a place of employment. In the Madison area, the most dense concentration of employment is in the downtown Madison/UW Campus area; however, over the last few decades most of the new employment growth has occurred in peripheral Madison and suburban job centers, such as the American Center, Old Sauk Trails, UW Research Park, Middleton Business Park, Fitchburg Center, and Epic campus. As a result, travel patterns are becoming more disbursed throughout the region.

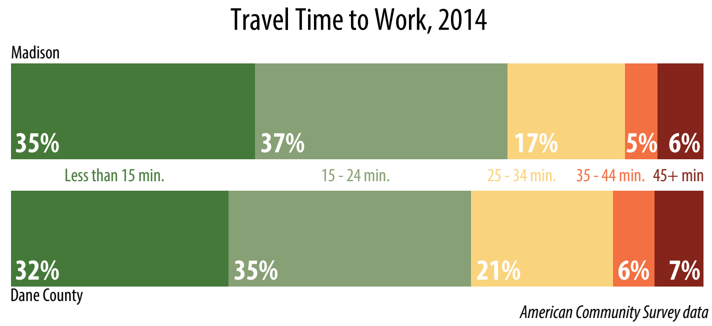


Figure 2-20: Travel Time to Work, 2014

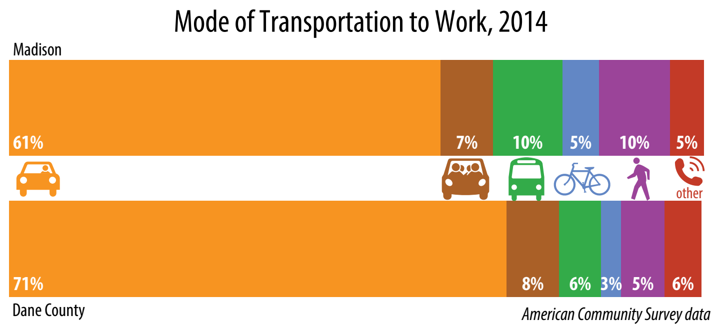


Figure 2-21: Mode of Transportation to Work, 2014

The mode and time it takes for someone to get to work are directly related to where people live. People who live in urban environments generally have shorter commutes than their rural counterparts and more modal options available for their commute. In Dane County, 71% of all residents drive alone to get to work, compared to 61% in the City of Madison. City residents were also more likely to take transit, walk, and bike to work. County residents were more likely to carpool to work or utilize other commuting methods, such as telecommuting.

Over the last five years, a number of new apartment buildings have been constructed in downtown Madison and on the Isthmus. These new buildings have attracted a residential population of young professionals. While many of these new residents may be moving to downtown to be closer to work, others are doing so in an effort to live a more urban lifestyle while working in the periphery of the region. This results in so called "reverse commuting."

One particularly popular reverse commute is between downtown Madison and the Epic campus on the western edge of the City of Verona. In 2012, Epic employed more than 6,200 employees. Understanding that many Epic employees were commuting from Madison to Verona, Metro Transit, the City of Verona, and Epic worked to add two new bus routes – one connecting the campus to downtown Madison and the other connecting to the West Transfer point. Ridership has been so strong on the routes that buses were added in 2015. As of 2015, Epic had grown to more than 9,000 employees.

As mentioned previously, Dane County is a net importer of workers due to having a surplus of jobs and stronger economy than surrounding counties. Figure 2-21 on page 2-13 shows county-to-county average daily commuter flows based on 2009 - 2013 American Community Survey data. The counties supplying Dane County with the most workers per day (all over 4,000) include


The large Epic Systems corporate campus in western Verona.

Columbia, Rock, Green, Jefferson, and Sauk. More than 1,000 workers per day leave Dane County for work in each of the following counties: Rock, Columbia, Sauk, and Jefferson Counties.

As the major employment hub, the City of Madison experiences a large influx of workers from other communities within the county as well as from outside the county. It is estimated that about 63,000 workers commuted to the city from other communities in Dane County in 2014. Figure 2-23 shows the percentage of residents within each community that are commuting to the City of Madison for work. Incorporated communities with the most workers commuting to Madison were some of its closest neighbors, including the Village of Shorewood Hills (68%), Village of Maple Bluff (62%), Town of Madison (60%), City of Fitchburg (58%), City of Monona (54%), and Village of Brooklyn (51%). Many unincorporated towns had more than 45% of all workers commuting to the City of Madison including the Towns of Dane, Vermont, Vienna, Bristol, Cottage Grove, Madison, Blooming Grove, and Middleton.

One way that the region mitigates the traffic impact of regional commuting is the Wisconsin Department of Administration (DOA) run State of Wisconsin Vanpool Program. The Vanpool Program allows groups of 8 to 15 commuters from various parts of southern Wisconsin ride to work each day together. Vanpools are more formally structured than carpools, due to the cost of operating and insuring the vans. DOA provides this structure, collecting a biweekly fee from all van riders to cover gasoline, vehicle maintenance, and insurance for all participants. Emergency guaranteed rides home are provided through MATPB's Rideshare etc. program up to three times per year.

There are currently over 900 riders utilizing 80 vans originating in communities all across southern Wisconsin. Some vanpool participants come from communities as close to Madison as McFarland, while others travel as far away as Milwaukee and Racine. Some of the more popular vanpools origins include Janesville, Milwaukee, Waukesha, and Portage.

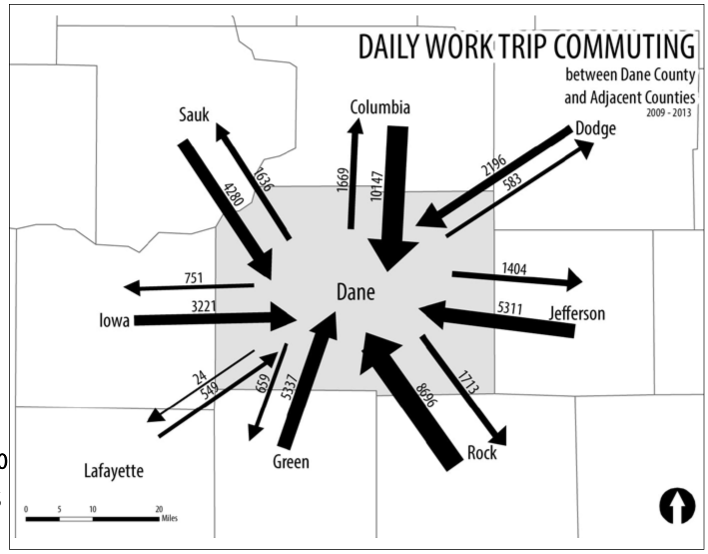


Figure 2-22: Daily Work Trip Commuting between Dane and Adjacent Counties

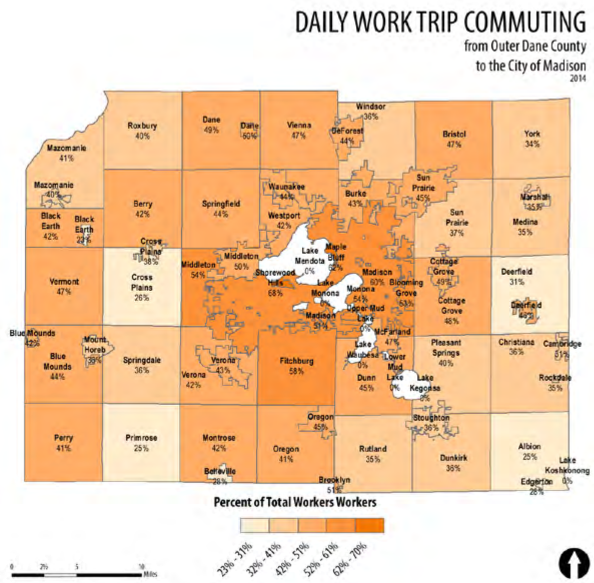


Figure 2-23: Daily Work Trip Commuting from Dane County to the City of Madison

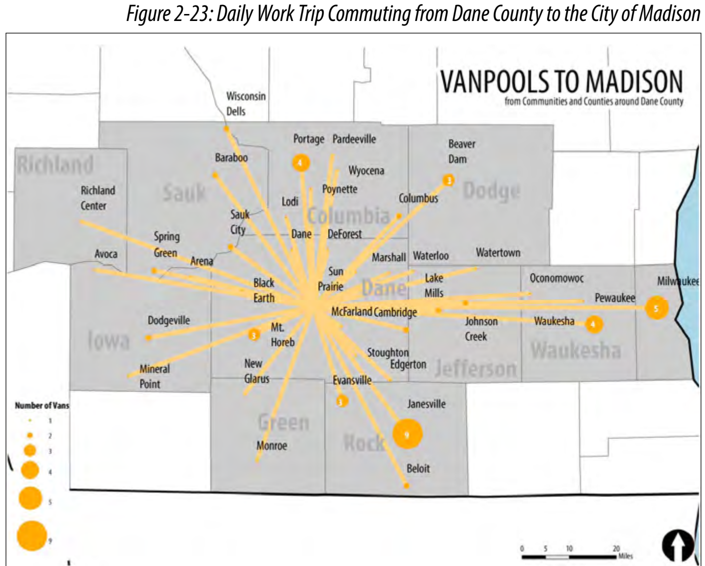


Figure 2-24: Vanpools to Madison

EMERGING TECHNOLOGIES

Transportation is currently experiencing a rapid change not seen since the early 20th century. Some of this change is due to changes in personal preferences, such as the increase in freight going directly to home due to the rise of online shopping, while other changes are due to the advent of new technologies. In the 2015 report [Transportation Technology Scan: A Look-Ahead](), the US DOT identified 11 technological advances and innovative concepts that could fundamentally alter the transportation landscape and their potential benefits, challenges, and potential issues. These technologies include:

Additive manufacturing (3D printing) is a technology that allows for three-dimensional objects to be created using an extruder or laser layer by layer. This technology has the potential to upend the manufacturing process by replacing the transfer of parts with the transfer of designs over the internet, allowing parts to be printed on-site. This could reduce the need for warehouses and shipping services – lessening the number of heavy vehicles on roadways.

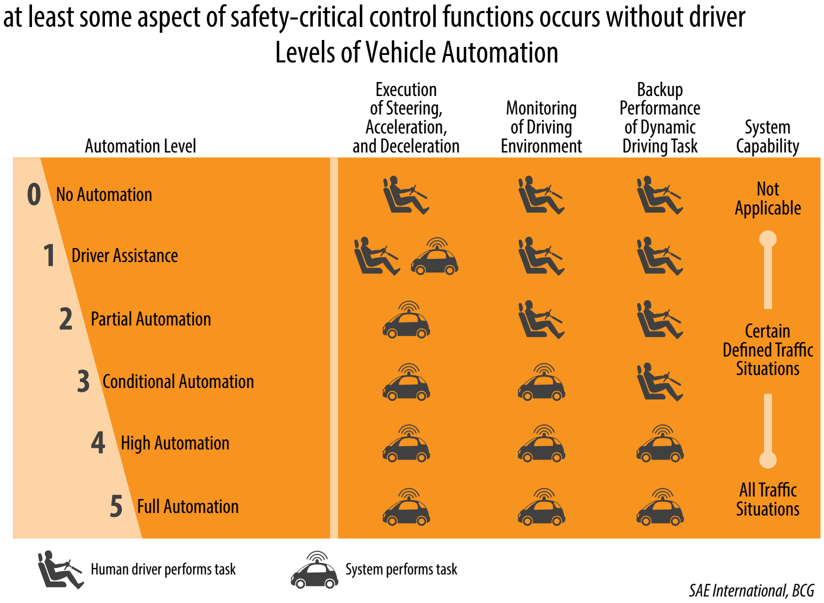
- Benefits of this technology include more localized production of goods, reducing regional roadway infrastructure needs – some of the most expensive roadways in the transportation system. This may reduce the cost of low-volume vehicle parts, including the cost of transit vehicle replacement parts and allow for the purchase of hard to find/procure parts.
- Potential downsides with this technology include an increased need for high-quality local infrastructure due to the nature of more goods being produced locally.

Advanced analytics and machine learning are technologies that provide computers with the ability to learn without explicitly being programmed, particularly when being inputted with "big data."

- Example programs are being created with the capability of using big data to identify patterns that can be used to make well-informed predictions such as traffic models. Some traffic operations centers have automated traffic operations systems that automatically adapt signalization during periods of high traffic or alert operators of potential traffic accidents. An adaptive signal system was installed in the McKee Road and Fish Hatchery Road corridors as part of the Beltline/Verona Road construction project and a similar system is planned for the University Avenue corridor.
- Benefits include increased efficiency of existing roadways through predictive analytics and pre-trip guidance for travelers and increased safety due to automatic dispatching of 911 services through a mixture of this technology and the "internet of things."

Automated vehicles are vehicles in which at least some aspect of safety-critical control functions occurs without driver input. Over time, it is anticipated that vehicles will gradually gain more autonomy. Because of this continuum of automation, "levels of vehicle automation" have been developed to quantify levels of driver reliance. A vehicle with a rating of 0 has no automation and requires the driver to manage all control functions, while a rating of 5 is completely automated and requires not human management during the trip.

- Examples of vehicle automation are becoming more mainstream each year. Many higher-end vehicles



SAE International, BCG

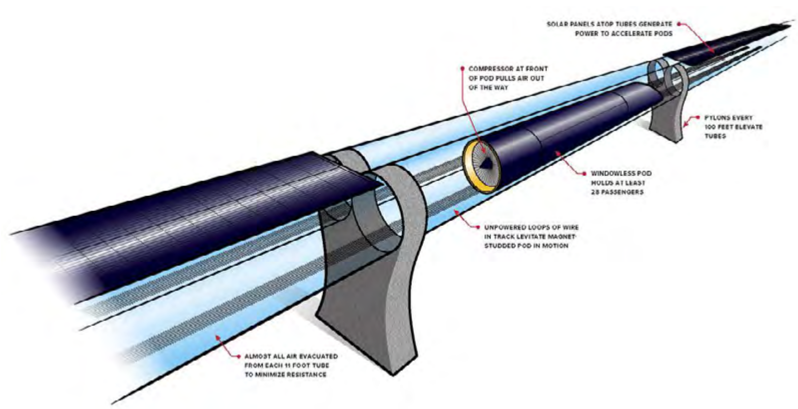
Figure 2-25: Levels of Vehicle Automation

currently come with automated features such as parking assist and crash avoidance. Some automakers, such as Tesla, have released highway autopilot features or are planning on releasing them in the near future.

- Benefits of this technology include improved safety, reduced travel times, reduced energy consumption, reduced vehicle emissions, improved reliability, increased roadway capacity (due to closer vehicle spacing), and increased transit accessibility. Vehicle sharing could become much more attractive since they would be able to provide door-to-door service for all riders. Work zone safety would be greatly improved. Transit service could be delivered at a reasonable cost in lower-density communities.
- Potential Issues of this technology include a dramatic increase in vehicle miles traveled due to "drivers" that would otherwise be unable to use the roadway. A reduction in driving stress may lead to an increase in discretionary travel and increased urban sprawl. The transition period from traditional cars to autonomous vehicles may be difficult due to low public acceptance of the vehicles and cost barriers for low-income or elderly traveler. Further, the unknowns of this technology make it difficult to determine whether capacity expansion is an appropriate treatment for congested or unreliable roadways. Parking lots and related facilities could be rendered obsolete because vehicles will have the ability to drop off passengers and return to their origin or pick up other passengers.

Hyperloop is an intercity travel concept in which patrons travel on a fixed route of paired bi-directional tubes on elevated pylons, traveling in capsules riding on low-friction air bearings within those tubes at speeds of up to 750 miles per hour.

- Benefits of this technology include the ability to reach far away destinations in a fraction of the time it would take to use conventional options – such as regional buses or airplanes. The technology could lead to economic



Hyperloop concept, CNET.com

development benefits for regions and cities it serves. It has the potential to save a great deal of energy, emissions, and time over existing transportation modes.

Infrastructure inspection robots can be used to assess the structural integrity of a variety of infrastructure using sensors and 3D imaging.

- Benefits of this technology include the ability for governmental agencies to examine and assess more infrastructure due to the speed of robots in comparison to humans; improved and more comprehensive inspections that result in improved reliability, safety, and infrastructure longevity; better assessment of infrastructure at disaster sites; and a reduction in inspection-related traffic disruptions.

US DOT

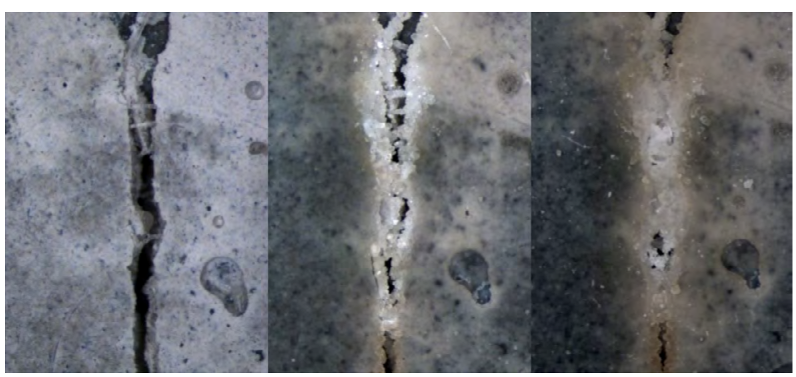
Innovative concepts for protecting pedestrians, bicyclists, and motorcyclists are improvements in traffic safety for "vulnerable road users." These improvements range from vehicle safety mechanisms such as sensor-based detection systems to pedestrian guards on freight trucks.

- Examples of this type of technology include advanced driver assistance systems (ADAD) that alert drivers of objects or people nearby using radar, sonar, or infrared signals; technologies that apply breaks to avoid crashes; and technologies that avoid collisions by cooperative communication between cell-phone signals of vulnerable users and vehicles to notify both parties of potential issues.
- Benefits of this technology include increased safety for all roadway users. Additionally, this could lead to an increase in multimodal activity (and thus lower VMT) due to increased confidence in safety by vulnerable users.

The **Internet of Things** is the network of interconnected, uniquely identifiable devices embedded in physical objects or "things."

- Examples of this technology include applications that monitor and control energy use, cloud-connected wearable devices that track physical conditions, and vehicle-to-infrastructure technology that is currently in development.
- Benefits of this technology include a better understanding of infrastructure utilization (more accurate tracking of usage patterns), safety improvements (tracking mental alertness for professional transportation operators and real-time monitoring of environmental hazards), and improved operations for freight (robotic loading and unloading) .

Materials science in infrastructure is technological advancements in the materials used to produce and repair physical infrastructures, such as roads and bridges. New materials such as self-healing roads have been shown to extend asphalt life by more than 50%. These pavements work by mixing organic matter into the pavement to produce limestone or other filling materials when exposed to water and heat, filling and seal cracks as they occur.



Bioconcrete though the healing process. Delft University.

- Benefits of this technology include increasing the lifespan, resilience, and safety of infrastructure while reducing maintenance needs, costs and environmental impact. Increased roadway lifespan will reduce traffic disruptions caused by roadway reconditioning and reconstruction. Improved roadway conditions will reduce driver and cyclist maintenance cost and improve the quality of travel. Reductions in road repair need will reduce CO_2 emissions from cement production and construction.
- Potential challenges associated with this technology include a need to train workers in new construction and maintenance techniques.

On-demand ride services (sometimes called ridesharing or transportation network companies) are services that use smartphone applications to connect passengers to drivers. In many ways this is not very different than traditional taxi service; however, the increased price transparency and availability of travel information (such as arrival times and GPS locations) have caused these services to increase in popularity.

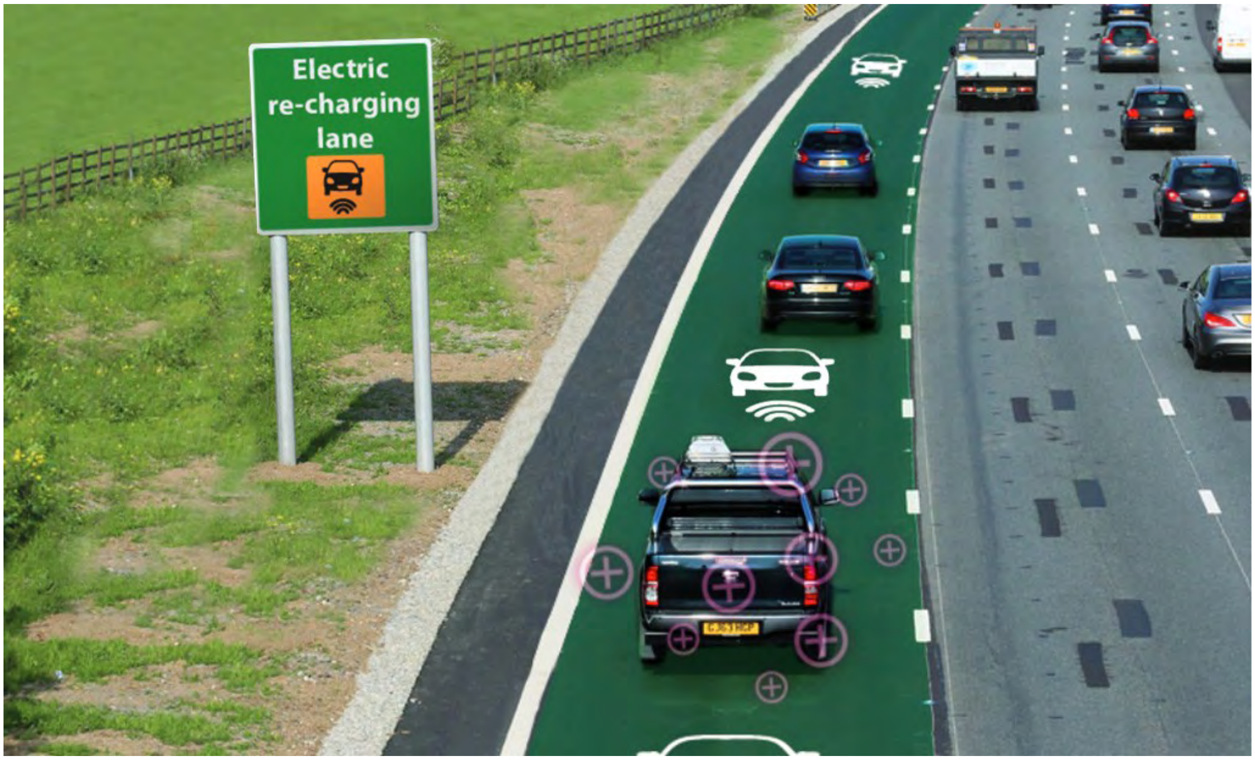
Self-Driving Uber in Pittsburgh, PA. Businessinsider.com

- Examples of this type of service include Lyft and Uber. Local services, such as Green Cab, also utilize similar functionality.
- Benefits of this technology include encouraging multimodal travel by making it possible to move away from automobile ownership when combined with other transportation options such as walking, bike sharing, and transit. If applied to transit, the technology could help agencies discover new fixed-routes that may not have otherwise been apparent and also address "first mile, last mile" connection problems. This technology could improve acceptance of autonomous vehicles by increasing the availability of automated vehicles and lowering entrance costs by allowing rental.
- Issues with this type of service include displacement of transit trips and/or active transportation trips if the services are too inexpensive or convenient, resulting in increased VMT and negative environmental impacts.

Unmanned aircraft systems (UAS) (also commonly called drones or unmanned aerial vehicles (UAV)) are aircraft without a human pilot aboard. While these vehicles are currently controlled by operators on the ground, future vehicles will have the ability to operate without a human operator. In fact, the US DOT estimated that the total number of UAS in operation could surpass the number of manned aircraft by 2035.


Delivery Drone Concept, Amazon.com

- This technology is currently used in military situations, law enforcement, firefighting, border patrol, disaster release, search and rescue, construction management, transportation facility inspection, and roadway condition inspection.
- Benefits of this technology include "find and deliver" capabilities that could find people or objects that are lost, reduction of roadway congestion due to drone-based package delivery, increased speed of package delivery, and the ability to solve first-and-last mile freight issues in congested urban environments.
- Potential challenges include reduced quality-of-life due to noise and visual intrusion, safety concerns due to recreational drones, and privacy concerns.



Wireless charging Concept, Intel Corporation

Wireless power transfer is a technology that allows for the recharging of electronic devices with chargers and cables. Initially, it is likely that electric buses and other vehicles traveling on high traffic corridors could be the first adopters of this technology to justify the capital investment cost. Once the technology becomes less expensive, light-duty and consumer vehicles are likely to follow. In addition to wireless power transfer, distributed fast charging has the potential to change the entire transit system. Developers of this technology claim that electric powered buses can be charged in as little as five minutes. This could allow for charging at places where transit vehicles taxi throughout the area, such as the Capitol Square and at transfer points.

- This technology is currently being used with some smartphones and has been used in pilot projects by transit providers in Utah, Texas, and Calfornia.[2]
- Benefits of this technology include limiting the need for individual consumers to have reliable access to charging stations. It would also extend the driving range of electric vehicles by providing charging capability on major roadways, a potential boon for automated vehicles. The technology also allows vehicles to have smaller batteries – reducing weight and improving efficiency. Further, the environmental benefits would be substantial. Smaller batteries reduce the environmental impact of electric vehicle batteries cannot currently be discarded in an environmentally cost-neutral way.

While many of these technologies on their own would be transformational, the confluence of a number of them into the transportation system at once poses more questions than answers for manufacturers, consumers, and planners. It will be important to determine quantifiable ways that the new technologies will impact planning – be it newfound capacity, cost savings, or a complete reimagining of the transportation system. It will be important, now more than ever, to recalibrate planning efforts based on these, and other, emerging technologies and remain flexible, nimble, and adaptable in the coming years.

[2] http://wave-ipt.com/projects