HEALTH AND ECONOMIC

VULNERABILITIES TO COVID-19

CLIENT: CITY OF MILWAUKEE - DEPARTMENT OF CITY DEVELOPMENT (DCD)

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INTRODUCTION

The COVID-19 Coronavirus pandemic has altered the lives of millions across the globe, subjecting those infected to a serious illness that many will not recover from. In addition to its impact on the health of those infected, the measures necessary to contain its spread have resulted in serious economic effects, shutting down businesses and forcing workers into unemployment. The speed at which the virus has spread and subjected communities to these severe health and economic outcomes, as well as the ever-changing information regarding its effects, have hindered the ability of governments to respond accordingly.

As of May 1, 2020, there have been 2,319 confirmed cases of COVID-19 coronavirus in the city of Milwaukee as well as 119 deaths with the virus as the confirmed cause (Milwaukee Health Department, 2020). While Milwaukee has not yet seen the level of infection of cities like New York, New Orleans or Detroit, its metro area rate of 205 cases per 100,000 does rank above the national average (Cortright, 2020). Within the city itself, however, there have been large discrepancies in both the areas and people most affected, with some neighborhoods and segments of the population experiencing higher concentrations of infections.

Statewide, nearly 400,000 residents have filed unemployment claims since business closures began in mid-March. Although official unemployment rates lag behind this dramatic increase, a preliminary analysis by the State Department of Workforce Development in early April estimated a rate of 27 percent (Daykin, 2020). Like the localized concentrations of infections, joblessness has struck certain types of employment and industries much harder than others. This disparity of economic and health effects among the population indicates both differences in the vulnerability within the population, and the need to target response by government bodies.

The purpose of the following analysis is to identify differences in vulnerability to health and economic impacts of the pandemic among the population of the city of Milwaukee. Through the use of GIS tools, variables associated with these vulnerabilities can be mapped to identify the neighborhoods and residents that may face the most severe effects of the ongoing crisis. Further analysis can also identify sociodemographic characteristics of these highly vulnerable areas and populations. Lastly, by examining the locations of businesses in the city and their characteristics as they relate to the effects of the pandemic, an attempt at identifying the most vulnerable commercial districts can also be made.

With the outputs of this analysis, the goal of this project is to provide the Milwaukee Department of City Development with information to better inform their response to COVID-19. Through their development programs, along with emerging pandemic responses, the department provides social assistance in the areas of employment, housing, and business

investment. The analysis provided is focused towards these areas and will allow for more targeted applications of these programs during and in the aftermath of COVID-19.

EXISTING RESEARCH

The health and economic vulnerabilities to COVID-19 are specific forms of the broader concept of social vulnerability. Social vulnerability is defined in various ways, but generally refers to "the inability of people, organizations, and societies to withstand adverse impacts from multiple stressors to which they are exposed (Warner, 2007)." This concept is studied both academically and by governmental bodies to aid in their preparation and response to stressors such as natural disasters, climate change, pandemics, and economic turmoil.

In studying this concept, attempts have been made to quantify and map social vulnerability. The most notable of these is the Social Vulnerability Index produced by the Centers for Disease Control and Prevention (CDC). The CDC's Social Vulnerability Index uses Census tract data on 15 factors related to general social vulnerability and ranks each tract across the county based on their relative score in these variables (Centers for Disease Control and Prevention, 2018). Similar indices have been created covering smaller geographic areas, using different variables to measure social vulnerability, or tailored to vulnerability to specific hazards (Vermont Department of Health, 2015) (Carvalhaes & Omitaomu, 2017).

These variations of the Social Vulnerability Index were all used to inform the creation of a model that would be specific to the health and economic vulnerabilities to COVID-19 in the city of Milwaukee. Variables were chosen based on their association with general social vulnerability as determined by existing SVI models, their association with pandemic-specific responses (Hutchins, 2009), and by researching the emerging reporting on COVID-19 and its effects. Because of the rapidly developing nature of information specific to COVID-19, the variables included in the model represent a snapshot of the information available at the time. As further research on COVID-19 develops these variables could be updated correspondingly.

DATA

Following the CDC's Social Vulnerability Index model, the data for this analysis was taken primarily from Census data tables at the Census tract level. This Census data included American Community Survey 5-year Estimates and Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics. Data on pre-existing health conditions was sourced from the CDC's 500 Cities Project. An additional part of the analysis looking at affected businesses used data from Esri's Business Analyst resources.

The collected data was further organized by subgroupings according to each variable's relation to COVID-19 vulnerability. Under the broader grouping of Health Vulnerabilities, the Pre-Existing Conditions subgroup contains five variables associated with increased fatality rates; the Demographic Contributors subgroup contains four additional demographic variables associated

with worse general health and COVID-19 specific outcomes; and the Increased Exposure Risk subgroup contains two variables potentially associated with a greater chance of contracting the virus. Under the broader grouping of Economic Vulnerabilities, the Job in Highly Affected Industry subgroup captures workers who are most likely to suffer job loss from COVID-19; the Existing Economic Vulnerabilities contains two variables associated with general inability to cope with income loss; and the Employment Accessibility subgroup contains three variables associated with difficulty in finding employment.

An additional group of sociodemographic variables were also captured to identify characteristics of vulnerable populations beyond those which directly increase their vulnerability.

Classification	Grouping	Variable
Health Vulnerabilities	Pre-Existing Conditions	Obesity
		Diagnosed Diabetes
		COPD
		Coronary Heart Disease
		Kidney Disease
	Demographic Contributors	Age Over 65
		Male
		Disabilities
		No Health Insurance
	Increased Exposure Risk	Job in Health Care and Social Assistance
		Population Density

Figure 1. Variables identified as contributing to health vulnerability to COVID-19.

Classification	Grouping	Variable
Economic Vulnerabilities	Works in Highly Affected Industry	Job in Retail Trade
		Job in Arts, Entertainment, and Recreation
		Job in Accommodation and Food Services
	Existing Economic Vunerabilities	Housing Cost Burdened
		Median Income
	Employment Accessibility	No Access to Vehicle
		No Internet Access
		No High School Diploma

Figure 2. Variables identified as contributing to economic vulnerability to COVID-19.

	Variable
Demographic Profile Characteristics	Race and Ethnicity
	English Proficiency
	Households with Elderly
	Households with Children
	Occupants per Room
	Poverty
	Public/Private Health Insurance
	Owner or Renter

Figure 3. Variables identified as playing a role in distribution of reported COVID-19 cases.

METHODS

The data which reports pre-existing health conditions was gathered from the Center for Disease Control's 500 Cities dataset. The data uses the boundaries of the City of Milwaukee as the extent and are reported at the Census Tract level. These data are reported as population data and are from 2019.

Job sector data was gathered from the US Census 'On The Map' web tool. Data comes from the Longitudinal Employer-Household Dynamics (LEHD) Origin Destination Employment Statistics and is from 2017. The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in classifying business establishments. The following NAICS codes were examined as industries which are reported to be highly affected by the Coronavirus crisis:

- 44-45: Retail Trade
- 62: Health Care & Social Assistance
- 71: Arts, Entertainment & Recreation
- 72: Accommodation & Food Services

Many of the variables which were examined as part of this analysis were gathered from the American Community Survey 5-year estimates ending in 2018. These data were downloaded from the ACS data download platform using Milwaukee County as the extent. Data is reported at the Census Tract level.

The following variables are reported by ACS as population data:

- Age Over 65
- Male
- Disabilities
- No High School Diploma
- Race

The following variables are reported by ACS as household or housing unit data:

- No Health Insurance
- Jobs by Industry
- Housing Cost Burden
- Median Income
- No Access to Vehicle
- No Access to Internet
- English Proficiency
- Households with Elderly
- Households with Children
- Occupants per Room
- Owner or Renter Occupancy
- High Poverty

Population Density was calculated from the total population reported in the ACS 5-year estimates ending in 2018 divided by the area of the Census Tract.

The number of reported cases of COVID-19 was gathered from the Milwaukee County COVID-19 tracking dashboard. The COVID-19 case data was current as of approximately 1:30 PM on April 22, 2020. Case counts were provided in CSV format containing a simple count of number of cases per US Census Tract.

All examined variables were isolated from their source tables and cleaned into individual CSV files. Individual CSV files were then joined to shapefiles of Census Tracts based on the GEO_ID field. Three final shapefiles were created. One for each of the three main components of the analysis. New field name codes were generated for each variable in the attribute tables.

1. HEALTH VULNERABILITY INDEX (HVI)

Variables examined as part of the Health Vulnerability analysis were categorized together to create an index. The extent of the index analysis is limited to the City of Milwaukee boundary. The data which reports the pre-existing conditions is available only at this extent; The data from the US Census and ACS was clipped down to the boundary of the City of Milwaukee. Data which is available at the Milwaukee County extent is examined as well and will be displayed adjacent to the Census Tracts which comprise the City but are not included in the index.

For each variable, a new attribute field was calculated to report the percentage of the total population or total household. The normalized range of percentages was then examined; Census Tracts which had a percentage value above the 90th percentile were assigned a 'flag'. Another new field was calculated for each variable to denote the flag which is expressed in binary form. Those Census Tracts which fall in the top 10% of the distribution are assigned a value of 1. The remaining 90% of the Census Tracts are assigned a value of 0. Variables

contributing to the index are weighted equally. The index is created by adding up the flags in each Census Tract. The Census Tracts with the highest number of flags are then identified as those which have a higher health vulnerability to COVID-19.

2. ECONOMIC VULNERABILITY INDEX (EVI)

Variables which contributed to the economic vulnerability analysis were classified together in the same way as the previous analysis to create another index. As with the HVI, the extent of the Economic Vulnerability Index was limited to the City of Milwaukee boundary. Data to be included in the index was clipped to the extent of the City. Data available at the County extent is displayed on the map series for comparison but is not included in the index.

A new attribute field was again calculated for each variable which normalized raw count values by total households or total population. From this new range of percentages, the top 10% are assigned a 'flag' in the same process as the previous analysis. Variables contributing to the index are weighted equally. The Economic Vulnerability Index was then created by summing the number of flags in each Census Tract to determine those which have a higher economic vulnerability to COVID-19.

3. TOTAL VULNERABILITY INDEX (TVI)

The flags from both the health vulnerability index and the economic vulnerability index were combined together to yield a total vulnerability index. These Census Tracts are identified as those which have a higher overall vulnerability to the effects of the COVID-19 crisis.

4. COMPARISON TO REPORTED COVID-19 CASES

Reported COVID-19 case data was acquired from the Milwaukee County COVID-19 tracking dashboard. The dashboard is managed by the Milwaukee County Office of Emergency Management. The data which populates the dashboard is sourced from the Wisconsin Electronic Disease Surveillance System (WEDSS) and was current as of approximately 1:30 PM on April 22, 2020. Though there are several other attributes associated with the WEDSS dataset, due to HIPAA restrictions, data provided to this project was limited to a simple count of reported COVID-19 cases per US Census Tract. This data is displayed using graduated colors to identify 'hotspots' within Milwaukee County. A comparison was made to the Health Vulnerability Index (HVI) to identify any correlation between our calculated vulnerability to COVID-19 and actual reported cases.

5. SOCIODEMOGRAPHIC CHARACTERISTICS

Secondary to the individual and combined indices, an additional exploration of sociodemographic characteristics was conducted. These variables were chosen for examination

after an extensive review of existing research. The populations which these characteristics describe have been found to be disproportionately affected by the Coronavirus in preliminary studies. These variables were determined to not be a contributor to specifically health vulnerability or economic vulnerability but have been found to play a role either in the effect on individuals or households during the global pandemic or in the distribution of reported COVID-19 cases.

A new attribute field was calculated for these variables which normalizes the raw counts by the total population or household. These values were then displayed using graduated colors in Symbology to highlight those Census Tracts which have higher percentages of each individual characteristic. These characteristics are then cross referenced to both the reported COVID-19 case data as well as the results of the index analyses to determine correlation. As the Coronavirus crisis unfolds, the growth of reported cases of COVID-19 can be tracked and compared to the findings of the sociodemographic characteristics analysis to better understand the distribution among the population in the City of Milwaukee.

6. ESRI BUSINESS ANALYST – WISCONSIN BUSINESSES (2018)

A case study identifying businesses which have been most affected by the Coronavirus pandemic was conducted in addition to the index analyses. The dataset comes from the ESRI Business Analyst extension in ArcGIS and is from 2018. The dataset contains point data of all businesses in the state of Wisconsin. For this case study, data was clipped to the boundary of Milwaukee County. Businesses which are likely considered essential and to remain in business throughout COVID-19 were identified based on their North American Industry Classification System (NAICS) code (See Appendix). These results were excluded from the rest of the analysis. This determined which businesses were most likely forced to close during Wisconsin's 'Safer at Home' executive order. These businesses were then grouped together by Business Improvement District (BID) to better understand specific areas within Milwaukee which might be more economically impacted by COVID-19 business closures. Businesses which do not lie within a BID are displayed as well for comparison.

A kernel density analysis was conducted to further the understanding of specific businesses which will be most affected by the Coronavirus. The field 'Employee Number' was used to conduct the kernel density analysis which identifies areas of high job density. Additionally, it locates areas which contain small businesses with few employees which are more likely to be adversely affected by COVID-19 business closures.

RESULTS & DISCUSSION

1. HEALTH VULNERABILITY INDEX (HVI)

To determine health vulnerability in the City of Milwaukee to COVID-19, three groupings comprising a total of eleven variables (Table 1) were examined, using normalized variable values by total population/household. The HVI was created by adding all 'flags' in each Census Tract, where each flag denoted the top 10% (or 90th percentile and above) of values for each variable analyzed. As noted previously, while the spatial extent of the HVI is geographically confined to the boundaries of the City of Milwaukee denoted in dark black, and is heavily reliant upon the CDC 500 Cities dataset, use of ACS 5-year estimates (2018) resulted in the availability of data for certain variables (e.g. Age Over 65) for the entirety of Milwaukee County.

Classification	Grouping	Variable
Health Vulnerabilities	Pre-Existing Conditions	Obesity
		Diagnosed Diabetes
		COPD
		Coronary Heart Disease
		Kidney Disease
	Demographic Contributors	Age Over 65
		Male
		No Health Insurance
		Disabilities
	Increased Exposure Risk	Job in Health Care and Social Assistance
		Population Density

Table 1. List of all groupings and variables for the Health Vulnerability Index (HVI).

Figure 4 presents the geographical distribution of health vulnerability for the City of Milwaukee. Of the 212 census tracts in the city, 104 were flagged as having health vulnerabilities. 8 census tracts had between 6-7 flags, 14 census tracts had between 4-5 flags, 82 census tracts had between 1-3 flags, and 108 census tracts had 0 flags. While health vulnerability (1 or more EVI

flags) is geographically distributed across the city, the census tracts with relatively higher health vulnerabilities (4 to 7 HVI flags) generally occur in the city's center and south. More specifically, census tracts with the highest health vulnerabilities (6 to 7 HVI flags) occur in three primary locations—northwest of Milwaukee's downtown (4600, 4700, 6500, and 8800), the Menominee River Valley and its northern environs (13600, 186000, 186800), and further southwest along Milwaukee's shared boundary with the City of Greenfield (120202). By focusing on individual variables and groupings of variables outlined in Table 1, the geographic extent and character of health vulnerability in the City of Milwaukee can be further explored.
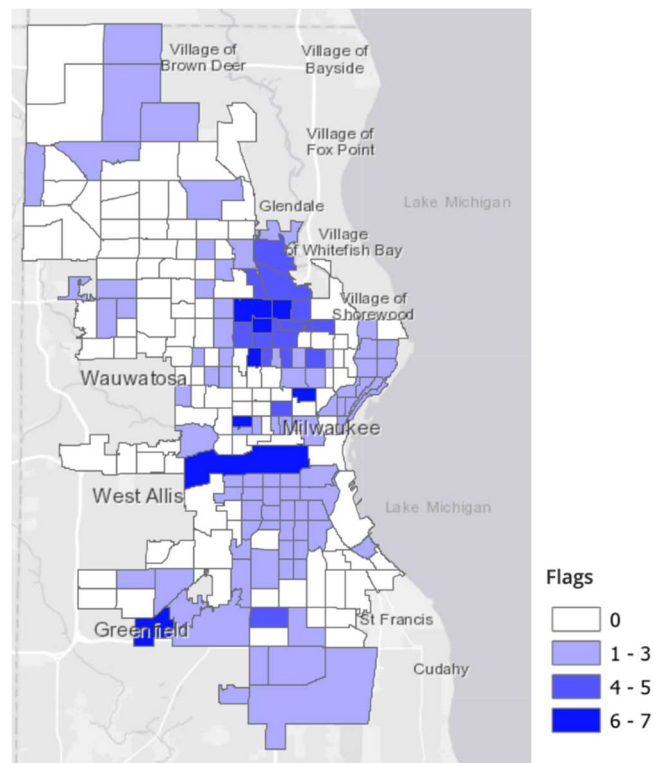

Figure 4. Health Vulnerability Index (HVI) for the City of Milwaukee using normalized variable values by total population/household. Index created by adding all 'flags' in each Census Tract, where each flag denotes the top 10% (or 90th percentile and above) of values for each variable.

1.1   Pre-Existing Conditions

According to the Centers for Disease Control and Prevention, older adults and people of any age with serious underlying medical conditions are most likely at higher risk for COVID-19 (CDC, 2020). However, information regarding the cases and impacts of the disease is changing rapidly. For instance, a suspected relationship between asthma and other chronic respiratory diseases and COVID-19 has been reevaluated (Hakim, 2020). Given these considerations, five pre-

existing conditions shown to be correlated with COVID-19 imp—*obesity*, *diagnosed diabetes*, *COPD*, *coronary heart disease*, and *kidney disease*—were selected.
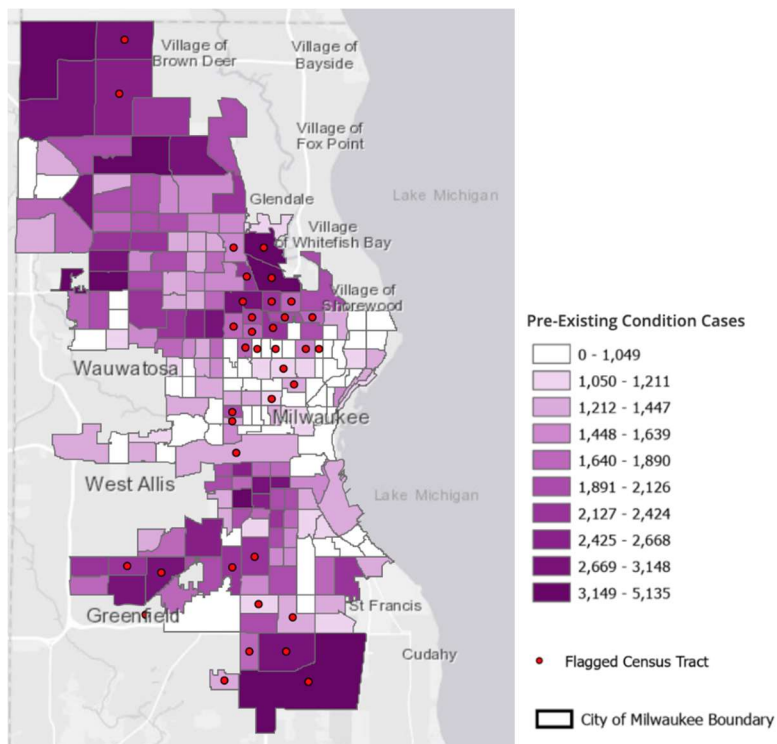

Figure 5. Geographic distribution of pre-existing conditions for City of Milwaukee. Census tracts with 'flags' highlighted represent 90th percentile or higher values based on all variables.

Based on data obtained from the CDC 500 Cities Project (2013-2017), in the City of Milwaukee there were 328,624 reported pre-existing conditions amongst the five conditions examined in this study (Figure 5), obesity (54.1%), diagnosed diabetes (18.6%), COPD (11.1%), coronary heart disease (10.0%), and kidney disease (6.1%). Flagged census tracts, representing census tracts with the highest number of flags across the five pre-existing condition variables, are concentrated northwest of downtown Milwaukee—an area comprising Milwaukee's 53205, 53206, 53209, 53212, and 53216 zip codes and stretching south toward Milwaukee's Menominee River Valley. A secondary area of high pre-existing conditions can be seen in Milwaukee's south adjacent to the municipalities of Greenfield, Franklin, and Oak Creek. Two census tracts in the city's far northwest (101 and 102) were also flagged as highly vulnerable.

1.2   Demographic Contributors

While the full range of demographic contributors impacting health vulnerability to COVID-19 are beyond the scope of this analysis, currently available information and clinical reports suggest that four demographic contributors are highly associated with health vulnerability to COVID-19: *Age Over 65*; *Male*; *No Health Insurance*; and *Disabilities* (CDC, 2020). Figure 6 and Figure 7 presents the geographic distribution of each of these variables across the City/County of Milwaukee.
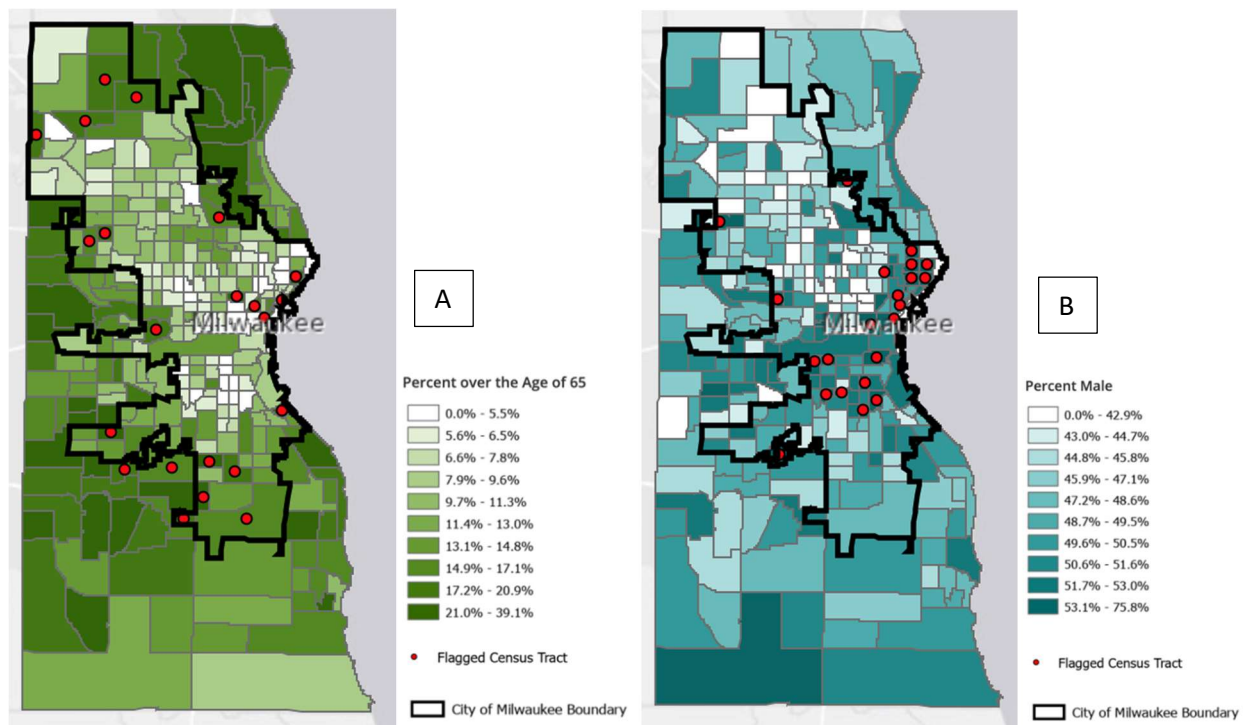

Figure 6. Geographic distribution of (A) *Age Over 65* and (B) *Male* for City/County of Milwaukee. Census tracts with 'flags' highlighted represent 90th percentile or higher values.

Of the 954,209 people in Milwaukee County, 12.9% are over the age of 65 (123,013 people). Noticeably, flagged census tracts within the City of Milwaukee lie on the outer edges of the city, with the lowest number of people over the age of 65 residing in the city's center. Where Milwaukee's male population reaches above 53.6% (the 90th percentile), flag concentrations are visible along Milwaukee eastside and south of the Menominee River Valley. The geographic distribution of people with no health insurance coverage is particularly conspicuous, as all but one flagged census tract lies in an area immediately south of the Menominee River Valley. In this area, 18.5% of people do not have health insurance—a figure ten percent higher than the national average in 2018 (Berchick, Barnett, & Upton, 2019). Flagged census tracts where over 19% of people reported a disability, in comparison, is arguably the most evenly distributed of the four demographic contributors impacting health vulnerability across the City of Milwaukee,

although a concentration of flags can be found northwest of Milwaukee's downtown coinciding with zip codes 52206 and 53212.
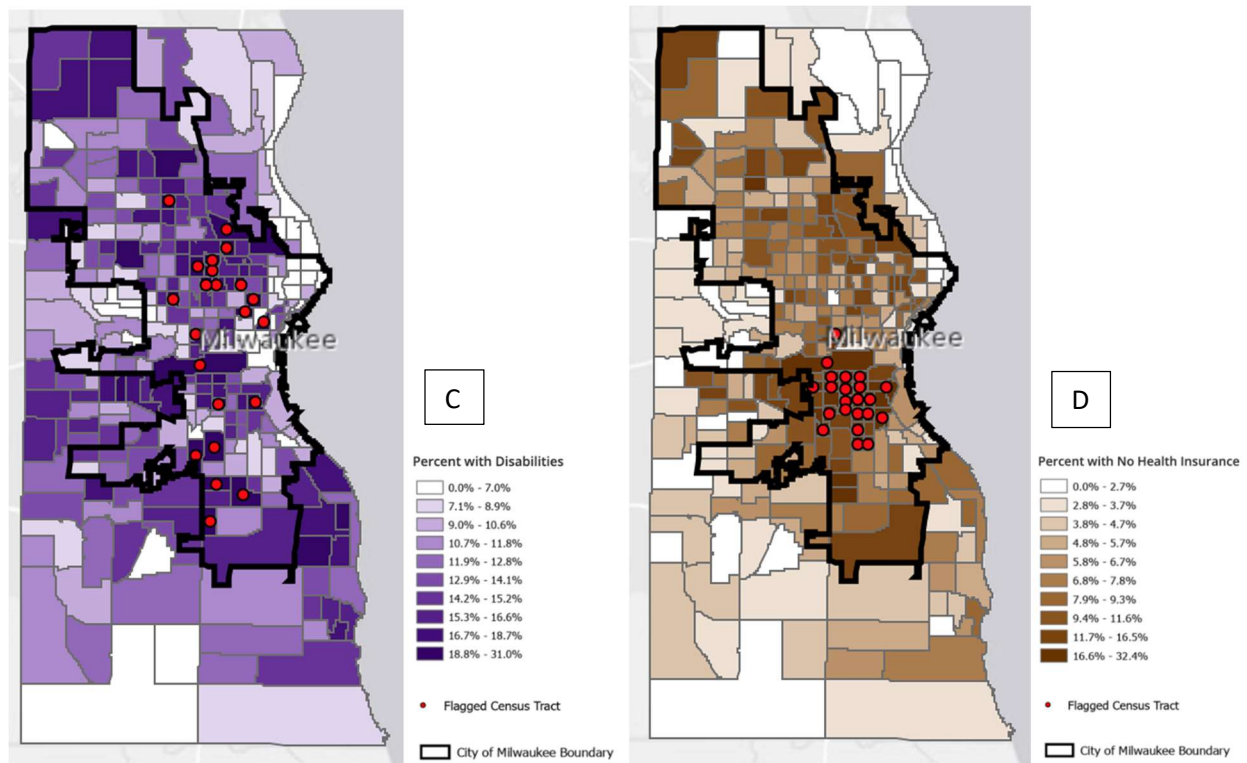

Figure 7. Geographic distribution of (C) *No Health Insurance* and (D) *Disabilities* for City/County of Milwaukee. Census tracts with 'flags' highlighted represent 90th percentile or higher values.

It is important to note that range of potential demographic contributors to health vulnerability to COVID-19 is not known conclusively. For instance, while reports indicate that amongst confirmed cases of COVID-19 men have a higher rate of mortality than women, medical professionals are currently examining a range of behavioral, social, and biological to understand that particular disparity (Devlin, 2020). Moreover, sex-disaggregated data is not yet available for all countries reporting COVID-19 cases, hospitalization, and mortality, making early reporting suggestive if not inconclusive. Other researchers have drawn particular parallels to HIV/AIDS epidemic and the potential dangers of excluding certain groups from COVID-19 research. As Susan Blumenthal contends, "Initially, the research community failed to recognize women as an important group to study. As a consequence, clinical trials of HIV/AIDs medications and preventive interventions excluded them. We continue to pay the price for this public health oversight: women now represent nearly 52% of people living with HIV globally" (Blumenthal, 2020). As such, understanding of the myriad and complex ways in which demographic contributors could potentially affect personal and collective vulnerability to COVID-19 remains ongoing.

1.3   Increased Exposure Risk

At the level of individual variables, results from "Jobs in Health Care and Social Assistance" is particularly striking. According to the *New York Times* (Gamio, 2020), which analyzed risk levels using the U.S. Department of Labor's O*NET database, jobs in health and social assistance are particularly vulnerable based on the physicality of those professions as well as the frequency of exposure. Dentists, paramedics, nurses, and flight attendants were found to be jobs were proximity to others and frequency of exposure is particularly high, thereby suggesting that these professions may potentially a have particularly high degree of exposure to diseases such as COVID-19. In Milwaukee County, 17.6% of jobs are considered in a health care and social assistance industry, totally approximately 79,570 jobs according to the U.S. Census in 2017.
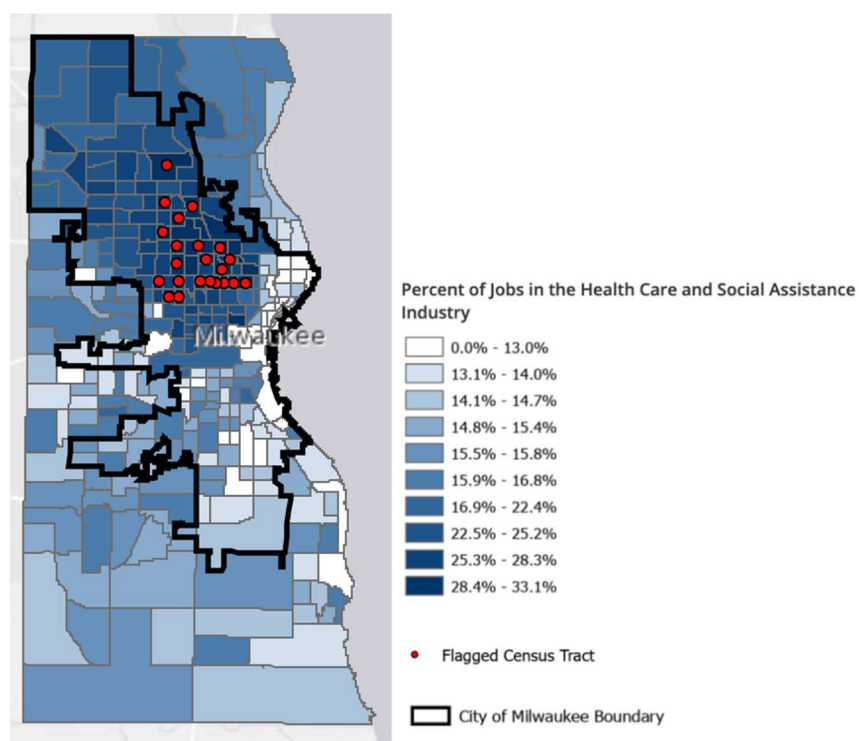

Figure 8. Geographic distribution of *Jobs in Health Care and Social Assistance* in City/County of Milwaukee. Census tracts with 'flags' highlighted represent 90th percentile or higher values.

Focusing on the City of Milwaukee, flags associated with these professions are concentrated almost entirely in Milwaukee's north and far northwest sides, where the percentage of jobs in this industry can be more than 30% of the population. Flagged census tracts within the city of Milwaukee, representing populations where more than 28% work in a health care or social assistance industry, are abundant northwest of Milwaukee's downtown, coinciding with an area covered by zip codes 53206, 53209, and 53212. The ubiquity and breadth of this particular industry, however, should not be overlooked. Markedly, despite geographic concentration in

certain areas, at least 10% of workers in the majority of census tracts in both the City of Milwaukee and Milwaukee County are classified under health care and social assistance.
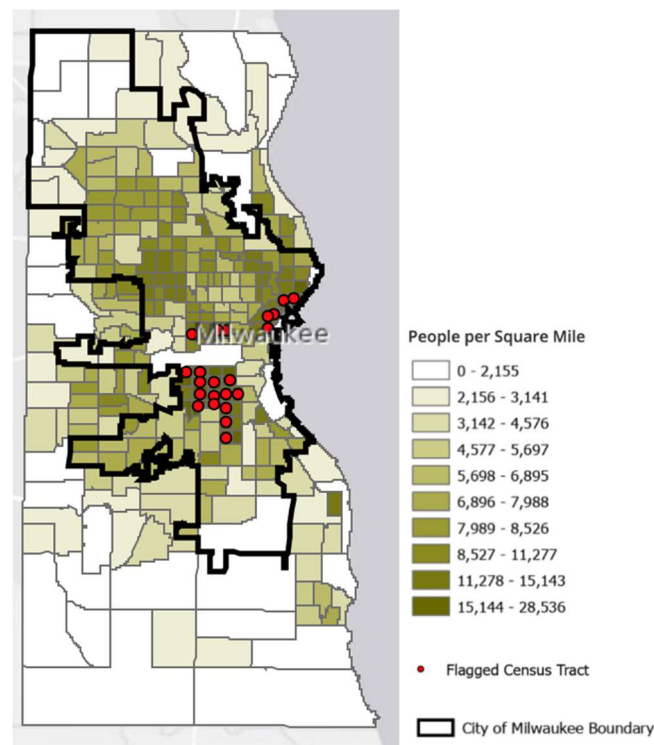

Figure 9. Geographic distribution of *Population Density* in City/County of Milwaukee. Census tracts with 'flags' highlighted represent 90th percentile or higher values.

Population density (Figure 9) is a second variable routinely associated with increased exposure risk to COVID-19. According to the CDC, "because COVID-19 is primarily transmitted by respiratory droplets, population density might also play a significant role in the acceleration of transmission" (Citation). While Milwaukee County has a much lower level of population density than urban areas like New York City that has reported the highest number of COVID-19 cases in the U.S., there are approximately 954,209 people and 248 miles of squared area in Milwaukee County. Notably, the average population density of all census tracts in Milwaukee County is 7,802 people per square mile. Flags indicating high health vulnerability due to population density are concentrated in downtown Milwaukee and immediately north and south of the Menominee River Valley, representing census tracts with over 17,161 persons (90th percentile).

Although urban centers have reported a considerable proportion of COVID-19 cases, hospitalizations, and mortality, however, it is important to note that population density is not necessarily a factor that makes an individual place more susceptible to COVID-19. Health experts and affected communities have become increasing vocal over the need for the development of systematic and geographically responsive approaches to COVID-19 in rural areas and urban peripheries. Commentators across the U.S. and further afield have drawn

particular concern over the rapid movement of populations from cities to less densely populated communities following the implementation of "stay-at-home" orders, as well as to the potential impacts of returning migrant workers to rural communities (Ranscombe, 2020). For example, in South Carolina efforts have been made to compare data between counties, as early reports suggest that the least densely populated counties have accounted for the majority of COVID-19 cases (Harriot, 2020). Other researchers have begun to examine vulnerabilities that may be specific to or overly representation of rural areas, including but not limited to poor health infrastructure, rates of obesity, and a generally older population (Jilani, 2020). As urban centers have been the most proactive in reporting COVID-19 cases, it is likely that understanding of the relationship between population density and health vulnerability to COVID-19 will expand.

2. ECONOMIC VULNERABILITY INDEX (EVI)

To determine economic vulnerability in the City of Milwaukee to COVID-19, three groupings comprising a total of eight variables (Table 2) were examined, using normalized variable values by total population/household. The HVI was created by adding all 'flags' in each Census Tract, where each flag denoted the top 10% (or 90th percentile and above) of values for each economic variable analyzed. As noted previously, while the use of ACS 5-year estimates (2018) resulted in the availability of data for variables for the entirety of Milwaukee County, interest in integrating economic *and* health vulnerability led to the geographic restriction of vulnerability index for both classes to the City of Milwaukee. However, based on the methodology outlined and the availability of data, the creation of an EVI and HVI at the county level is conceivable.

Classification	Grouping	Variable
Economic Vulnerabilities	Works in Highly Affected Industry	Job in Retail Trade
		Job in Arts, Entertainment, and Recreation
		Job in Accommodation and Food Services
	Existing Economic Vulnerabilities	Housing Cost Burden
		Median Income
	Employment Accessibility	No Access to Vehicle
		No Internet Access
		No High School Diploma

Table 2. List of all groupings and variables for the Economic Vulnerability Index (EVI).

Figure 10 presents the geographical distribution of economic vulnerability for the City of Milwaukee. Of the 212 census tracts in the city, 90 were flagged as having economic vulnerability. Six census tracts had between 5-6 flags, 14 census tracts had between 3-4 flags, 70 census tracts had between 1-2 flags, and a total of 122 census tracts had 0 flags.
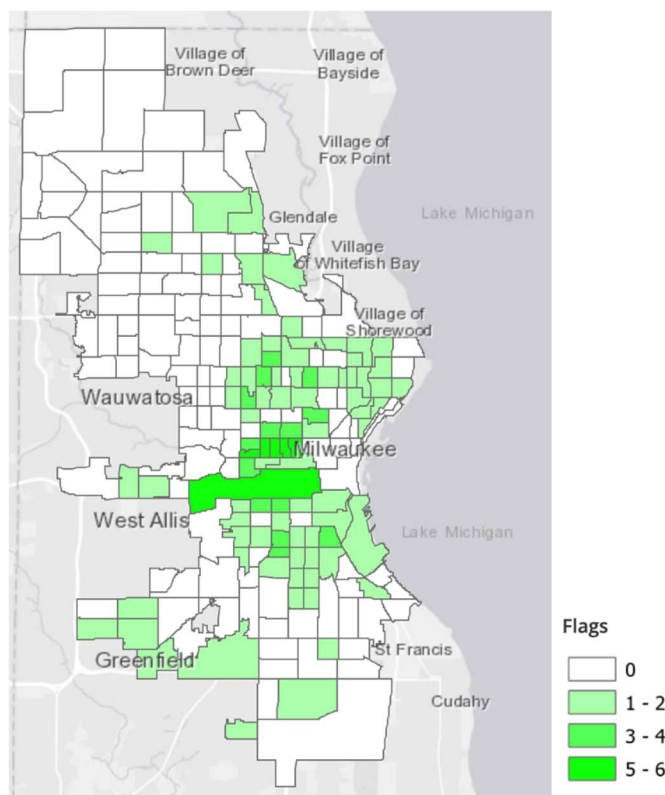

Figure 10. Economic Vulnerability Index (EVI) for the City of Milwaukee using normalized variable values by total population/household. Index created by adding all 'flags' in each Census Tract, where each flag denotes the top 10% (or 90th percentile and above) of values for each variable.

While economic vulnerability (1 or more EVI flags) is geographically distributed across the city, albeit except for Milwaukee's far northwest, the census tracts with the highest health vulnerability (5 to 6 EVI flags) occur in the city's center. More specifically, census tracts surrounding the Menominee River Valley are suggested to be particularly vulnerable, with census tracts 13700 and 14600 raising the most flags. By focusing on the variables (and groupings of variables) outlined in Table 2, the geographic extent and character of economic vulnerability in the City of Milwaukee can further explored.

2.1 Works in Highly Affected Industry

As understanding of the effects of COVID-19 expands across sectors, multiple industries in addition to the health care and social assistance have been identified as particularly vulnerable. In a recent study conducted by Marcus Lu using the U.S. Department of Labor's O*NET database (Lu, 2020), three physical job attributes—contact with others, physical proximity, and exposure to disease and infection—were explored. Figure 11 presents the results of this analysis.
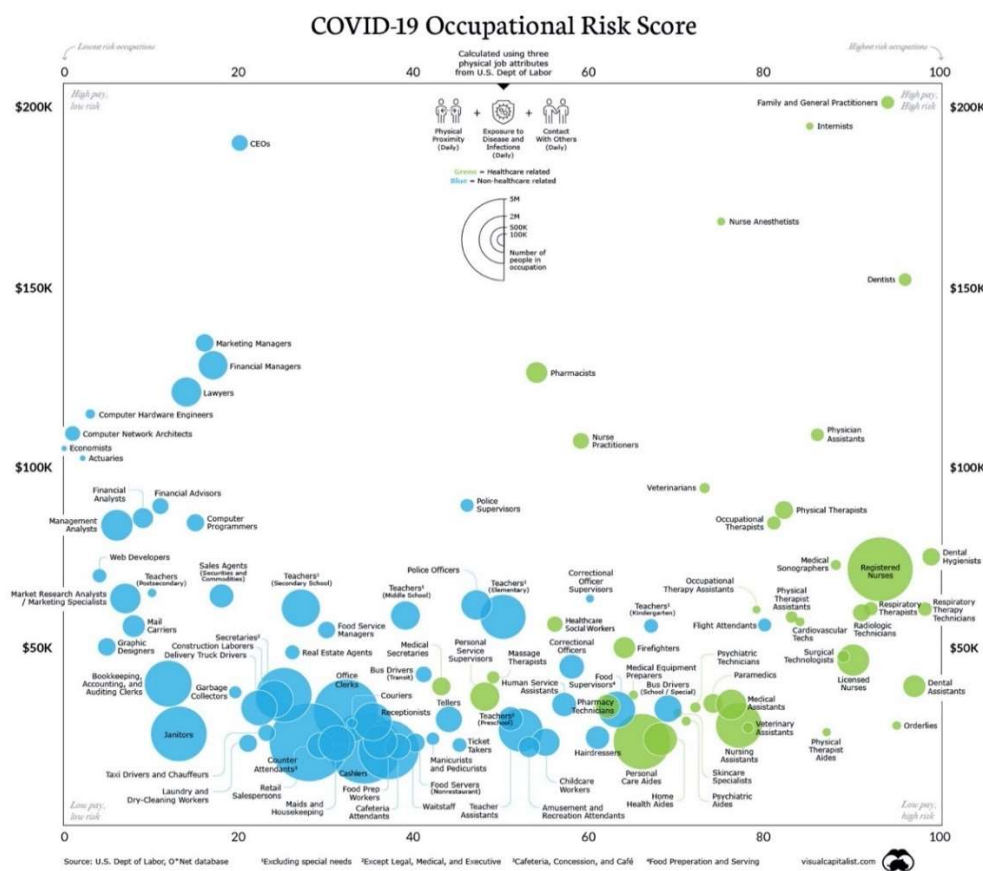

Figure 11. Occupations with heightened risk to COVID-19 based on physical job attributes based on U.S. Department of Labor's O*Net database. Image Credit: Marcus Lu (April 15, 2020).

While health care and social assistance industries are particularly vulnerable, economic vulnerability is not limited to occupations were physical exposure is highest. Industries are also impacted by the measures taken to mitigate the spread of COVID-19, such as "stay-at-home" orders and the closure of venues with significant capacity. In this analysis, *Jobs in Retail Trade*; *Jobs in Arts, Entertainment, and Recreation*, and *Jobs in Accommodation and Food Services* were examined in further detail. Of the 451,289 jobs in Milwaukee County across these sectors (U.S. Census, 2017), 9.6% were in Retail Trade (43,451 jobs), 2.0% were in Arts, Entertainment, and Recreation (8,970 jobs), and 8.8% were in Accommodation and Food Service (39,795 jobs).
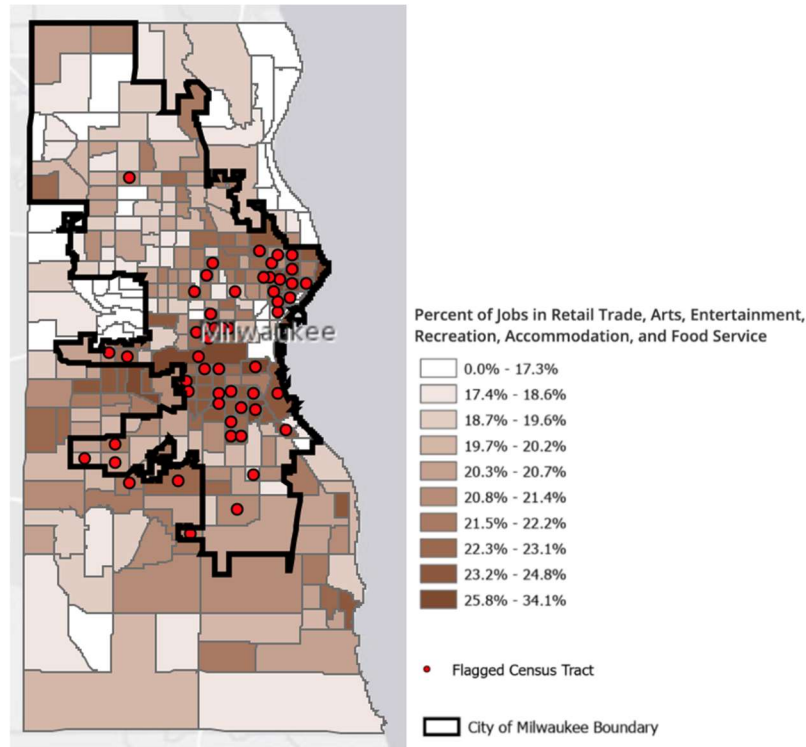
Figure 12. Geographic distribution of *Works in Highly Affected Industry* for the City/County of Milwaukee. Census tracts with 'flags' highlighted represent 90th percentile or higher values.

Focusing on the City of Milwaukee, flags associated with these industries are concentrated across Milwaukee's eastside and downtown and immediately north and south of the Menominee River Valley. This geographic distribution is largely anticipated, as performing arts, museum, and recreation industries have witnessed severe job losses nationwide (DiStefano, 2020). Additional flags are present along Milwaukee's western boundaries with the cities of Wauwatosa, West Allis, and Greenfield. When compared with "Jobs in Health Care and Social Assistance" (Figure 12), the geographic breadth of industries potentially affected by COVID-19 becomes especially noticeable, with only the city's far northwest and south underrepresented by the number of census tracts with values above the 90th percentile. Industries predominately located across the outlying areas on the urban-suburban periphery, however, may be impacted in other ways. As early indicators suggest, "the producers and wholesalers who supply customer-facing industries are also feeling the impact [of COVID-19], or will very soon" (Berube & Bateman, 2020). Given the preliminary availability of data, estimating the economic burden of COVID-19 upon individual industries and communities will likely necessitate continued analysis.

2.2   Existing Economic Vulnerabilities

According to a survey collected by the Pew Research Center (April 21, 2020), over 50% of lower-income adults indicated they or someone in their household has experienced job loss or a cut in

pay due to COVID-19 (Parker, Horowitz, & Brown, 2020), potentially exacerbating existing economic burdens. Based on the combination of households with mortgage or rent burden of 30% or more of their household income, "Housing Cost Burden" in Milwaukee County was explored. Of the 307,900 housing units surveyed in Milwaukee County, 42.1% have a housing cost burden in which their mortgage or rent is more than 30% of their monthly income (129,730 housing units). Of the 129,730 housing units with a housing cost burden, 28.0% are owned homes (36,306 housing units), and 72.0% are renters (93,424 housing units). Markedly, while housing burden is distributed more evenly across the City of Milwaukee than the combined EVI may suggest (Figure 13:A), concentrations of flags representing households with the highest housing cost burden—64.4% of more of households within a census tract—can be seen northwest of Milwaukee's downtown and immediately north of the Menominee River Valley. Census tract 14700, in particular, has the highest percentage of housing cost burden in the city—with 81.8% of housing units reporting mortgage or rent burden above 30% of their household income. Shifting attention to "Median Income" (Figure 13:B), the geographical distribution of flags is strikingly similar to Housing Cost Burden. Although the median household income in Milwaukee County is $45,774, flagged census tracts have an average household income of under $21,665.

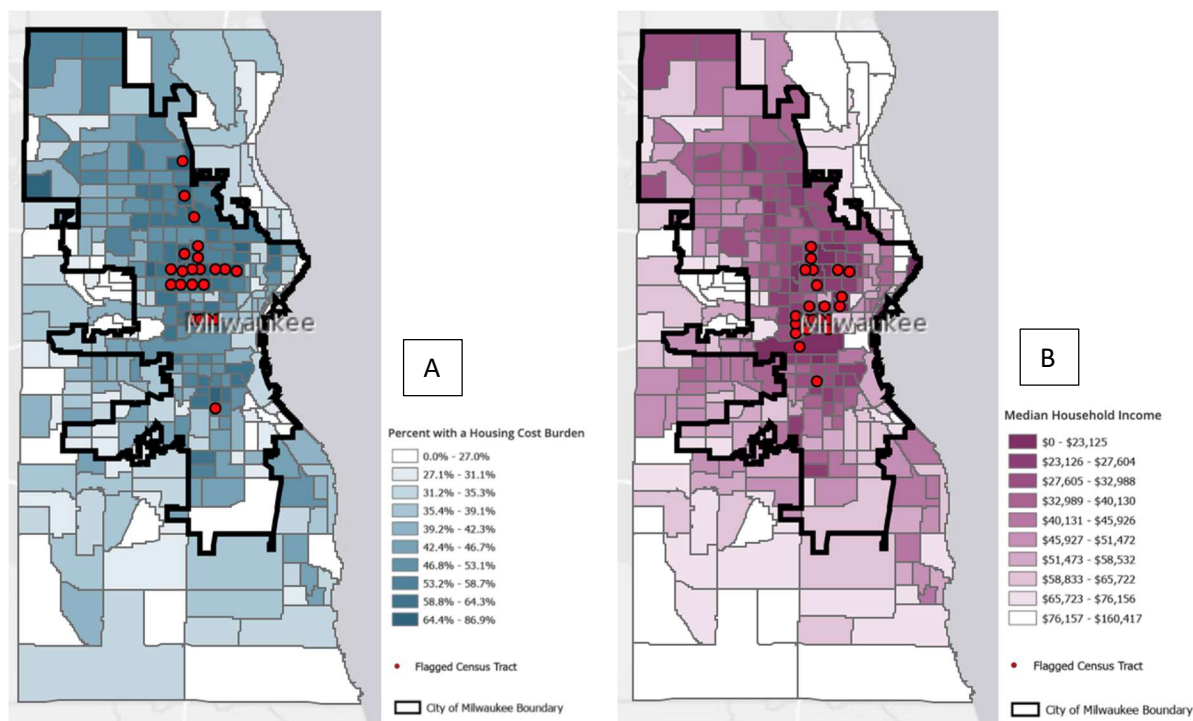**Figure 13.** Geographic distribution of (A) *Housing Cost Burden* and (B) *Median Income* for the City/County of Milwaukee. Census tracts with 'flags' highlighted denote 90th percentile or higher values.

Despite public calls for the development of COVID-19-attentive housing policies for low, middle, and high-income households, early indicators suggest that housing burden is felt differently

across income, as well as across renters and homeowners. While some state governors have negotiated with banks and credit unions to provide a 3-month suspension of mortgage payments, households paying rent have not been extended support at similar rates (Thomas & Lyons, 2020), nor have comprehensive systems been established to support landlords facing loss of rental income due to COVID-19 (Karnes, 2020). And although evictions and foreclosures have been halted in most states, Matthew Desmond and the Eviction Lab at Princeton University estimate that for the 1,678,088 renters in Wisconsin, such protections will begin to expire on April 30, 2020 (Eviction Lab, 2020). If COVID-19-related orders affecting landlords and tenants continue to expand and/or change, it is likely that existing economic vulnerabilities may be exacerbated with uneven impacts across states, cities, and communities.

2.3   Employment Accessibility

While commentators have been quick to describe working from home as the "future of work," early reports suggest that employment accessibility during COVID-19 is not distributed equally. According to the American Time Use Survey from the U.S. Bureau of Labor Statistics, only one in four US workers have a job that allows them to work from home, with full-time workers twice as likely than part-time workers to report measures of employment flexibility (Chalabi, 2020). Increasingly, working from home has been interpreted as a precarious privilege in the U.S.
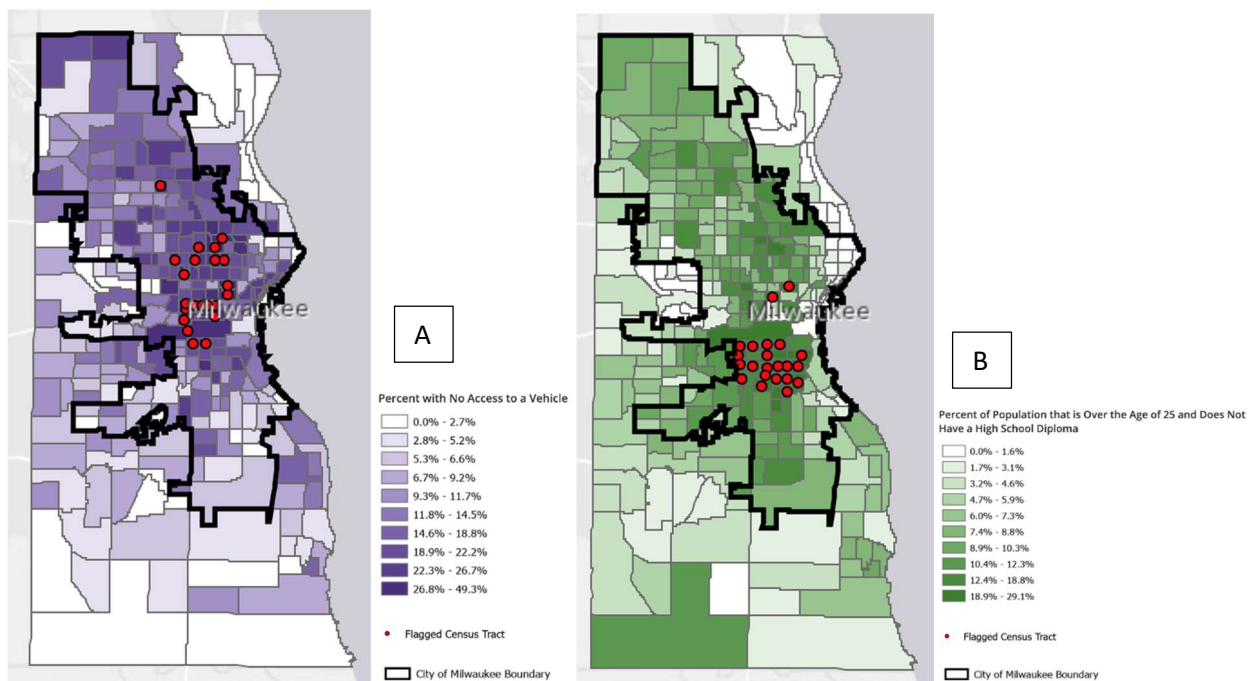

Figure 14. Geographic distribution of (A) *No Access to Vehicle* and (B) *No High School Diploma* the City and County of Milwaukee. Census tracts with 'flags' highlighted represent 90th percentile or higher values.

Three measures of employment accessibility were explored in this study (Figure 14): *No Access to Vehicle*; *No High School Diploma*; and *No Internet Access*. In the United States, approximately 36 percent of total transit commuters work in industries classified as "essential," leading some commentators to suggest that access to vehicles (Figure 14:A) may emerge as a potential indicator of employment accessibility during the COVID-19 pandemic. Of the 418,375 surveyed households in Milwaukee County, 12.5% do not have access to a vehicle (52,231 households). For the City of Milwaukee, flagged census tracts where more than 28.9% of households do not have vehicle access are concentrated in the city's center. Census tract 186000, for instance, 49.3% of the 418 households do not have access to a vehicle. Considering individuals without high school diplomas (Figure 14:B), of the 954,209 people in Milwaukee County, 8.0% adults over the of age of 25 do not have a high school diploma (76,720 adults over the age of 25). Flags associated with this variable are concentrated heavily in an area immediately south of Milwaukee's Menominee River Valley, coinciding with the Silver City, National Park, Mitchell Park, Clark Square, and Walker's Point neighborhoods.
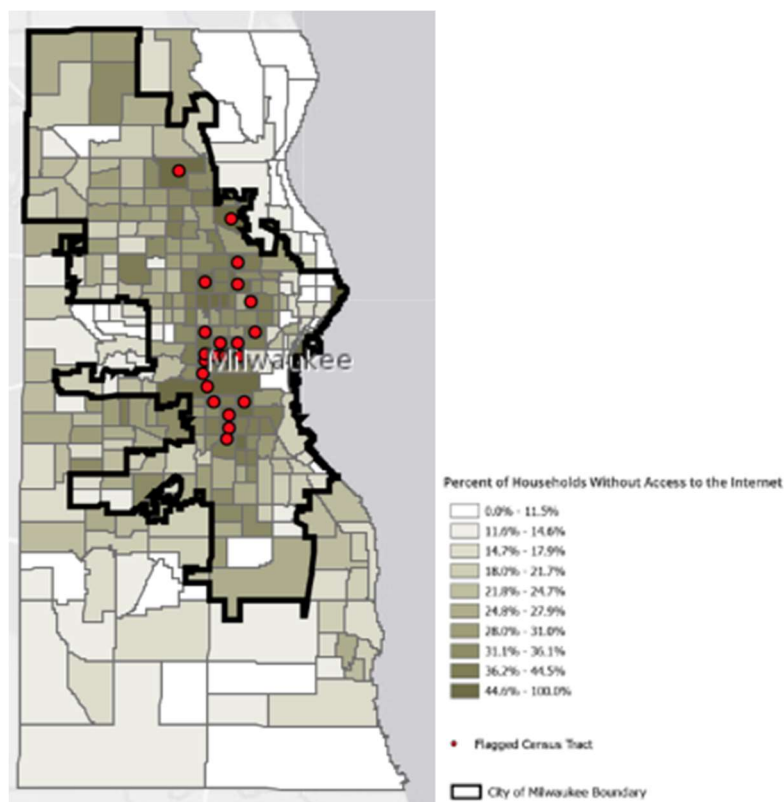
Figure 15. Geographic distribution of *No Access to Internet* for the City and County of Milwaukee. Census tracts with 'flags' highlighted represent 90th percentile or higher values.

In Figure 15, the geographic distribution of households without access to the internet. Of the 382,070 households surveyed in Milwaukee County, 25% do not have access to the interest. In the City of Milwaukee, flagged census tracts where more than 52% of households (90th

23

percentile) did not have internet access, an area of in Milwaukee's center extending north and south of the Menominee River Valley is noticeable. According to a recent report by Milwaukee Public Media (Quirmbach, 2020), efforts are underway to develop an "emergency internet map" for the State of Wisconsin, providing a resource for approximately 650 internet locations.

3. TOTAL VULNERABILITY INDEX (TVI): INTEGRATION OF HVI AND EVI

Figure 16 presents the integration of the HVI and the EVI data into a Total Vulnerability Index (TVI), created by adding all 'flags' per census tract in the City of Milwaukee. Of the 212 census tracts in the City of Milwaukee, 132 were flagged with either Health or Economic Vulnerabilities. Six census tracts had between 9 - 12 flags, 23 census tracts had between 5 - 8 flags, 103 census tracts had between 1 - 4 flags, and 80 census tracts had 0 flags in the TVI.
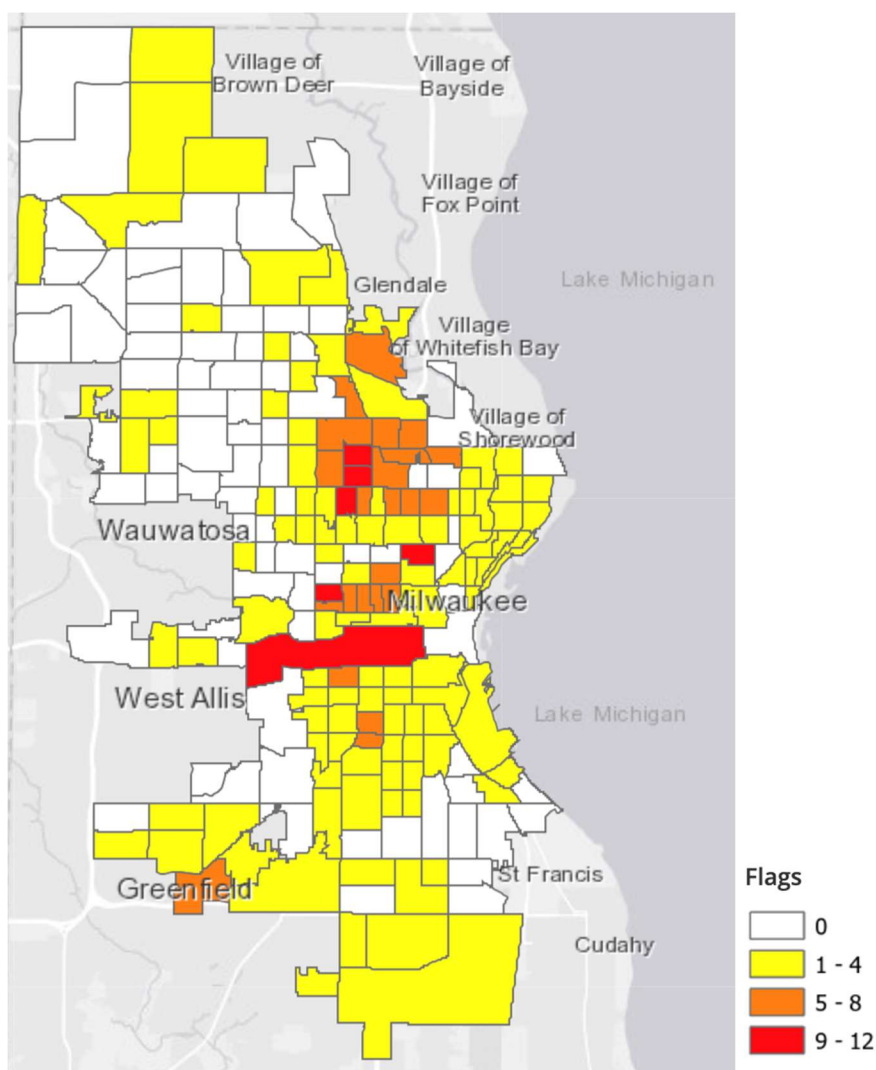

Figure 16. Total Vulnerability Index (TVI). Index created by adding all 'flags' in HVI and EVI.

As presented in Figure 16, the census tract with the most flags, 186800, is located in the Menomonee River Valley and has thirteen flags. It raised eight health flags, obesity, diagnosed diabetes, COPD, coronary heart disease, kidney disease, lack of health insurance, disabilities, and jobs in the health care and social assistance industry. It also raised six economic flags: jobs in retail trade, jobs in art, entertainment, and recreation, median income, no access to vehicle, and no access to internet. The census tract with the second most flags, 186000, is located in the Halyard Park neighborhood and has eleven flags. It raised seven health flags: obesity, diagnosed diabetes, COPD, coronary heart disease, kidney disease, population over the age of sixty-five, and disabilities. This census tract also raised four economic vulnerability flags: median income, no access to vehicles, no high school diploma, and no access to internet.

4. COMPARISON TO REPORTED COVID-19 CASES

Reported COVID-19 case data was acquired from the Milwaukee County COVID-19 tracking dashboard. As of April 22, 2020, the City of Milwaukee had 1,741 COVID-19 cases and Milwaukee County had 2,357 COVID-19 cases. Figure 17 presents this dataset.
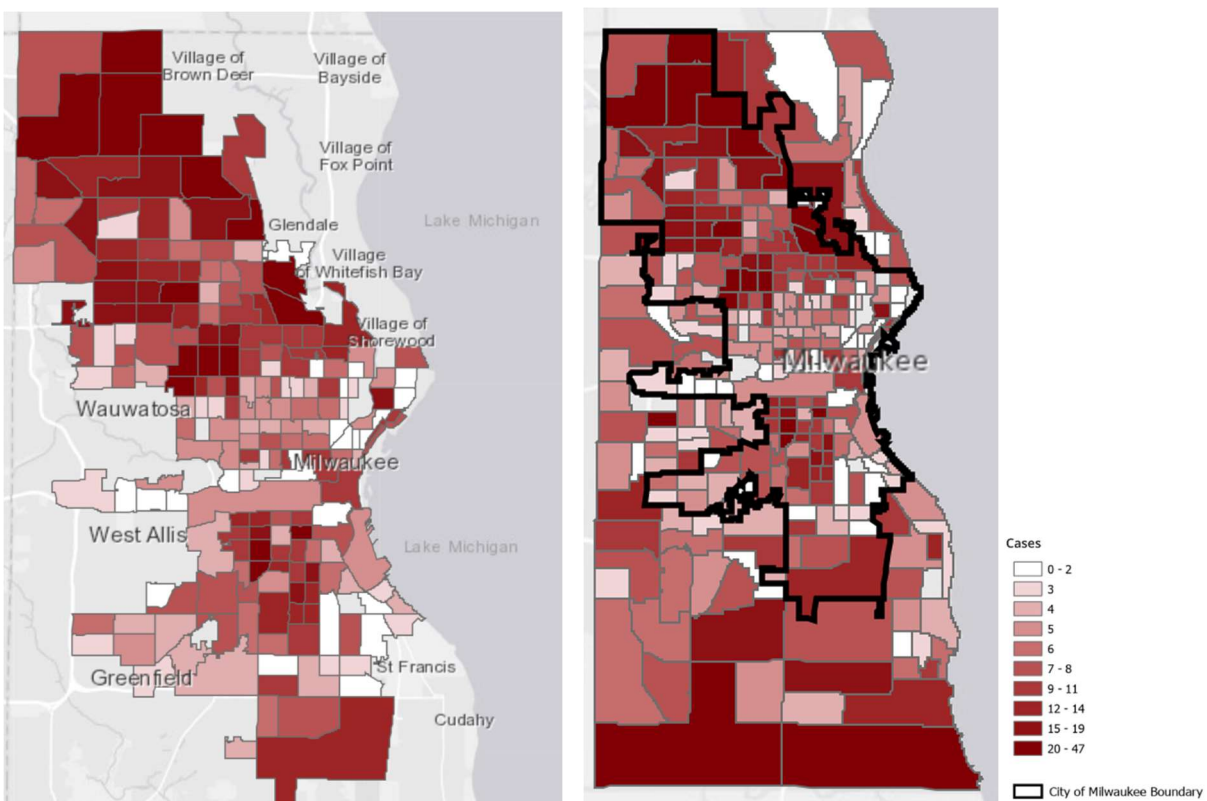

Figure 17. Geographic distribution of reported COVID-19 cases in City of Milwaukee (Above Left) and Milwaukee County (Above Right) as of April 22, 2020.

Markedly, as of April 22, 2020, the census tract with the greatest number of flags (186800) had only five COVID-19 cases. Similarly, the census tract with the second highest number of flags (186000) had only four COVID-19 cases. Alternatively, for the two census tracts with the highest number of reported COVID-19 cases—Census Tracts 102 (47 cases) and 700 (24 cases)—the total number of vulnerability flags is noticeably low, with Census Tract 102 having 3 flags and Census Tract 700 having only 1 flag. Based on these results, our TVI suggests that areas with high health and economic vulnerability are not necessarily the locales with the highest number of reported COVID-19 cases (Figure 18) and may in fact suggest an inverse relationship.
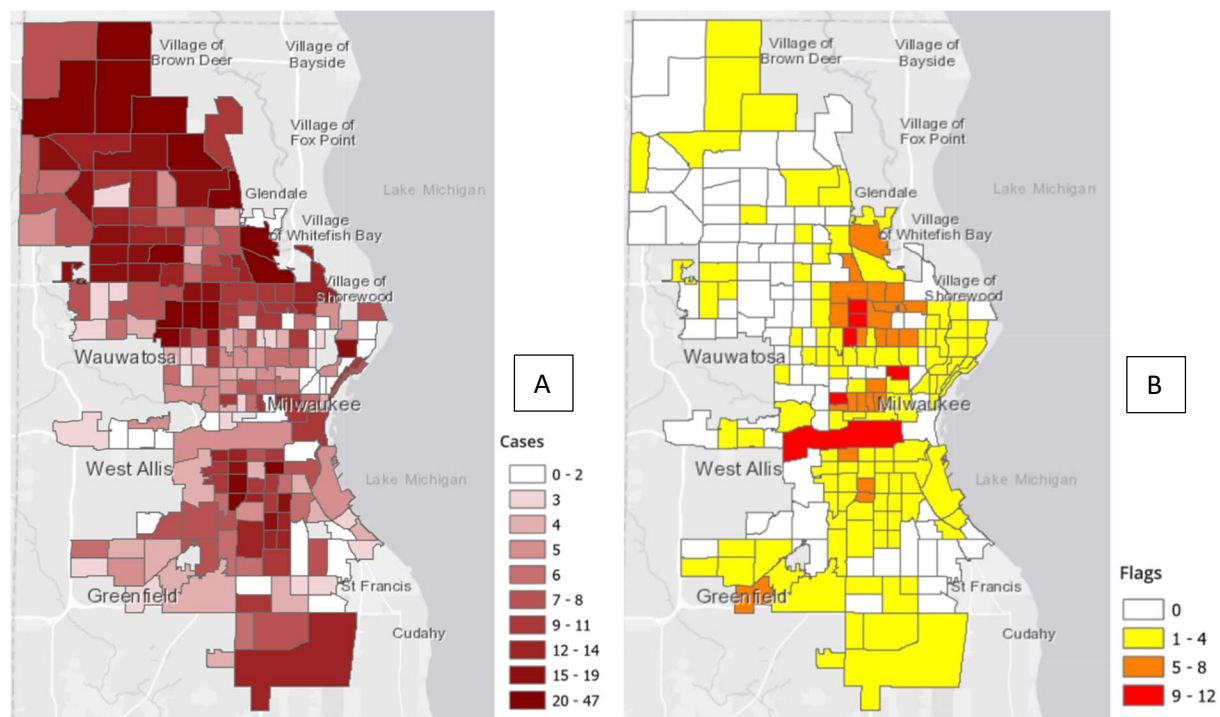
Figure 18. Geographic distribution of (A) *Reported Cases of COVId-19 (4/22/2020)* for the City of Milwaukee, compared to Total Vulnerability Index (B) for the City of Milwaukee.

The initial results of the TVI in this study may suggest that the relationship between measures of vulnerability and rates of reported COVID-19 cases are more complex than initial reporting suggests. Such insights, notably, should be reexamined considering new and disaggregated data on COVID-19 cases for the City of Milwaukee and Milwaukee County. Moreover, by using alternative variables, metrics, and processes of vulnerability assessment, new geographic patterns in health and economic vulnerability to COVID-19 may also arise. In the next section, a range of sociodemographic characteristics are explored in order to highlight the potential impact of certain variables upon personal and collective vulnerability to COVID-19.

5. SOCIODEMOGRAPHIC CHARACTERISTICS

A total of eight sociodemographic variables were examined secondary to the health, economic, and total vulnerability indices (Table 3). The populations which these characteristics describe have been found to be disproportionally affected by COVID-19 in preliminary studies. Although "recognition of the critical importance of societal determinants of health is now commonplace in public health" (Krieger, Gonsalves, Bassett, Hanage, & Krumholz, 2020), recent demands by civil rights and medical professionals for state and federal agencies to release sociodemographic data on COVID-19 impacts underscores the challenges communities face in understanding COVID-19.

	Race and Ethnicity
	English Proficiency
	Households with Elderly
	Households with Children
Sociodemographic Characteristics	Occupants per Room
	Poverty
	Public vs Private Health Insurance
	Owner or Renter

Table 3. List of all sociodemographic characteristics examined.

In order to assess the relationship between the selected sociodemographic variables and potential health and economic vulnerabilities to COVID-19, census tracts flagged in the Total Vulnerability Index (TVI) were compared with city-wide data for each sociodemographic variable for the City of Milwaukee. Table 4 presents the results of this comparison, highlighting census tracts with 7 or more flags, corresponding with the red/orange areas in Figure 16.

Sociodemographic Profile - City vs. Most Vulnerable Tracts (7+ flags)

	White	Black	Hispanic/Latino	Asian	Am. Indian	Other	Lack English Proficiency	Households w/ Children
City	45.47%	40.72%	18.78%	4.71%	1.60%	7.66%	7.53%	31.46%
Tracts w/ 7+ Flags	30.37%	57.28%	19.54%	1.72%	1.36%	8.89%	8.67%	27.58%

	Households w/ Elderly	w/o High School Diploma or GED	Home Owner	Renter	Poverty	>1 per Room	w/ Private Health Insurance	w/ Public Health Insurance
City	20.18%	10.21%	42.05%	57.95%	20.80%	3.17%	54.14%	44.59%
Tracts w/ 7+ Flags	23.34%	16.47%	24.25%	75.75%	42.35%	2.65%	38.36%	57.27%

Table 4. Comparison of sociodemographic characteristics with Total Vulnerability Index (TVI).

The results of the sociodemographic comparison strongly align with current literature on COVID-19. Markedly, sociodemographic variables that have a relatively *higher* percentage of census tracts with 7 or more vulnerability flags than the percentage of population/household (e.g. Black, Renter, Poverty) arguably underscores the potentially disproportionate impact of COVID-19 across sociodemographic characteristics. However, certain sociodemographic characteristics in the comparative analysis diverged from recent reports of COVID-19 impacts. For instance, although Households with Children were expected to face unique hardships due to COVID-19 (Turner, 2020), the number of census tracts with 7 or more flags was less than the percentage of total households with children in the City of Milwaukee. Still, much can be explained by the variables used to construct the HVI, EVI, and integrated TVI. Flagging of census tracts with populations of 65 years of age and over most likely resulted in the moderating of total vulnerability scores held by households with children. Similarly, flagging census tracts with characteristics generally associated with lower income (e.g. Median Income, Low Employment Accessibility) may have resulted in the tempering of vulnerabilities felt by homeowners—despite indicators that homeowners with FHA-insured mortgages are experiencing hardship due to COVID-19 (HUD Public Affairs, 2020). In order to evaluate the results of this comparison in greater detail, both *Race and Ethnicity* and *Occupants per Room* were examined further.

5.1 Race and Ethnicity

While data on the number of cases, hospitalizations, and deaths that can be attributed to COVID-19 are still emerging (CDC, 2020), recent reports suggest that the pandemic is affecting racial and ethnic minority communities at disproportionately higher rates across the United States (Ro, 2020). African American and Hispanic communities in the United States have been the most visible minority groups in these discussions, with some cities reporting that the impact and consequences of COVID-19 have been 2 to 3x higher in predominantly Black and Hispanic

communities than in predominantly white communities (Nania, 2020). In the City of Milwaukee and Milwaukee County (Figure 19), severe levels of black-white racial segregation are evident.
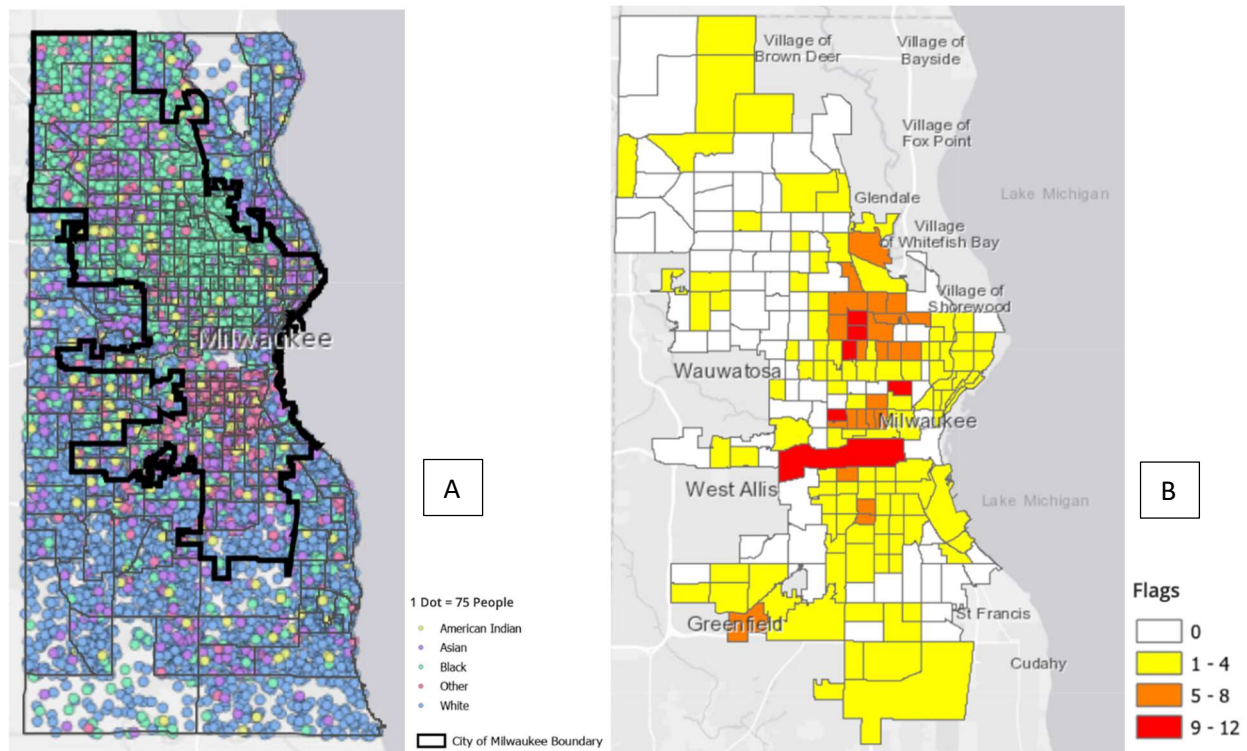

Figure 19. Geographic distribution of (A) *Race* for the City and County of Milwaukee compared to (B) *Total Vulnerability Index* for the City of Milwaukee.

In Figure 19, a comparison exploring the geographic distribution of racialized groups (A) and the Total Vulnerability Index (B) is presented for the City of Milwaukee. While some commentators have argued that "Americans of all ethnicities are starting to be more alike than different, and looking for social explanations for our current health crisis may impede rather than enhance understanding" (Charen, 2020), disaggregated racial demographic data of confirmed COVID-19 cases and/or death rates from 29 states complied by the COVID-19 Racial Data Tracker underscore the extent of emerging racial disparities related to COVID-19 (Kendi, 2020). Notably, the distribution of Black communities (Green) across central Milwaukee and toward the northwest coincides with a concentration of flagged census tracts north of the Menominee River Valley, including Census Tract 6500 (9 flags, 93.8% Black) and 6400 (9 flags, 98.4% Black).
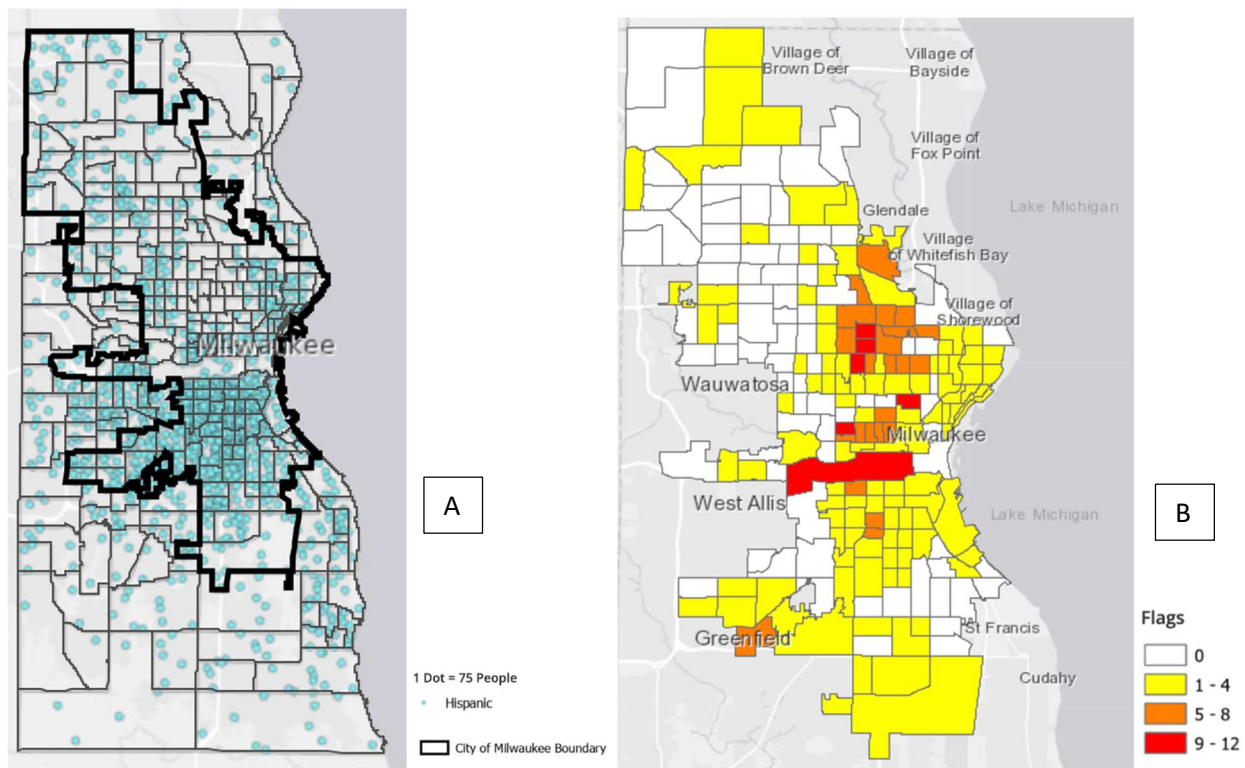
Figure 20. Geographic distribution of (A) *Ethnicity* (Hispanic) for City and County of Milwaukee, compared to the Total Vulnerability Index (B) for City of Milwaukee.

Similarly, the geographic distribution of "Hispanic" ethnic groups (Light Blue) in the City of Milwaukee coincides strongly with flagged census tracts south of the Menominee River Valley (Figure 201 including Census Tract 15900 (7 flags, 67.3% Hispanic) and 16900 (7 flags, 77.7% Hispanic). Alas, it is not the case that census tracts with a higher percentage of Hispanic persons can be tied conclusively to COVID-19 susceptibility. As our study was conducted in the absence of disaggregated racial and ethnic data for COVID-19 cases, these results are suggestive.

5.2   Occupants Per Room

While population density is explored in the HVI, Occupants per Room was also examined as a sociodemographic characteristic crosscutting our heath and economic vulnerability indices. In our comparative sociodemographic analysis (Table 4), the percentage of census tracts with 7 or more flags is slightly *lower* (2.65%) than the percentage of total households with more than one occupant per room (3.17%). By examining the geographic distribution of census tract-level percentages with high level of room occupancy, however, areas of spatial concentration are noticeable (Figure 21). Understanding this sociodemographic characteristic is of import for distinguishing areas where social distancing measures may be challenging, if not unattainable.
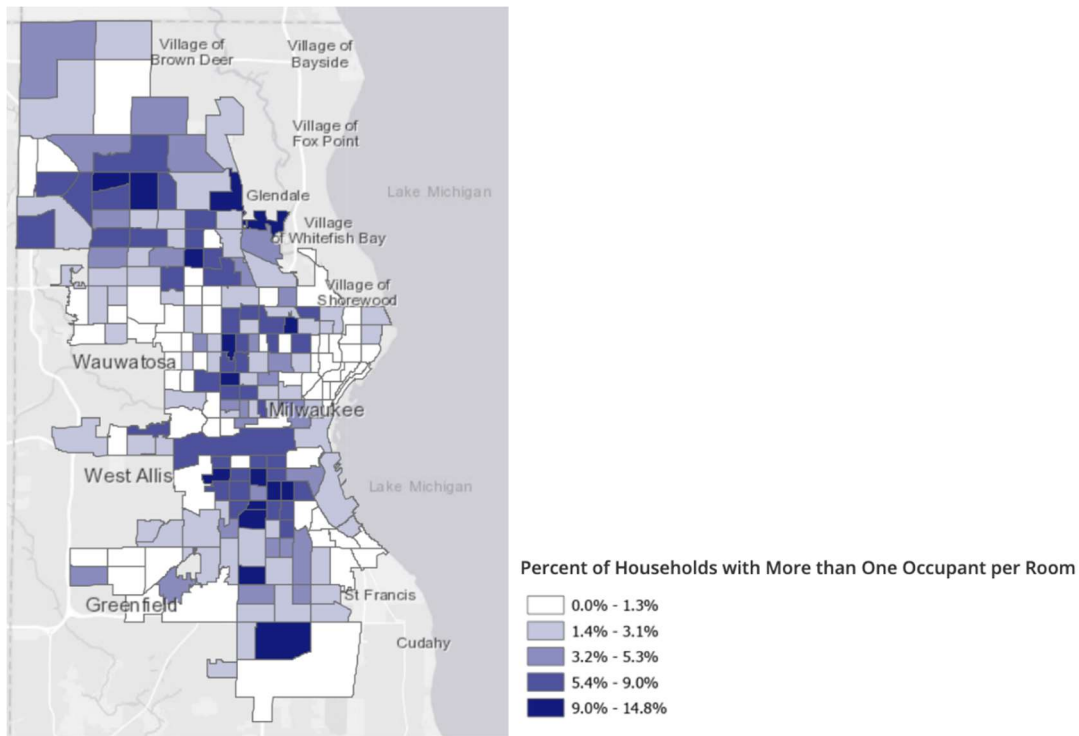
Figure 21. Geographic distribution of *Occupants Per Room* for City and County of Milwaukee.

According to researchers at the Coronavirus Resource Center at John Hopkins University & Medicine, "as decision makers contemplate medium-term economic versus public health trade-offs, they must do so with an acknowledgement of the severely skewed nature of the costs of distancing" (DeLuca, Papageorge, & Kalish, 2020). Despite early indicators that social distancing can slow the curve of COVID-19 transmission, social distancing social distancing is costly and at moments arguably unfeasible for multigenerational and complex households, where individuals cannot enact self-quarantine protocols (Anthony, 2020). In other ways, for many vulnerable populations quarantine can mean remaining in emotionally and physically dangerous environments, as early reports suggesting a rapid rise in gun sales (Powder, 2020) and domestic-violence related homicide during the COVID-19 pandemic suggests (Campbell, 2020). For homeless and LGBTQ-homeless populations, the simultaneous need for social distancing and access to safe shelter has become increasingly difficult during COVID-19, as unsupportive family members and shelter residents can often exacerbate existing vulnerabilities (Kuhr, 2020)

6. ESRI BUSINESS ANALYST – WISCONSIN BUSINESSES (2018)
In addition to our analysis of health, economic, and 'total' vulnerabilities to COVID-19 in the City of Milwaukee and Milwaukee County, our study created several maps of businesses that are likely to be immediately affected by closure or the need to highly limit operation due to the 'Safer at Home' executive orders issued at City and State level during the week of March 25th

2020. The data for this map series was derived by selecting businesses by their North American Industry Classification System (NAICS) code from the ESRI/Infogroup Business Analyst dataset.
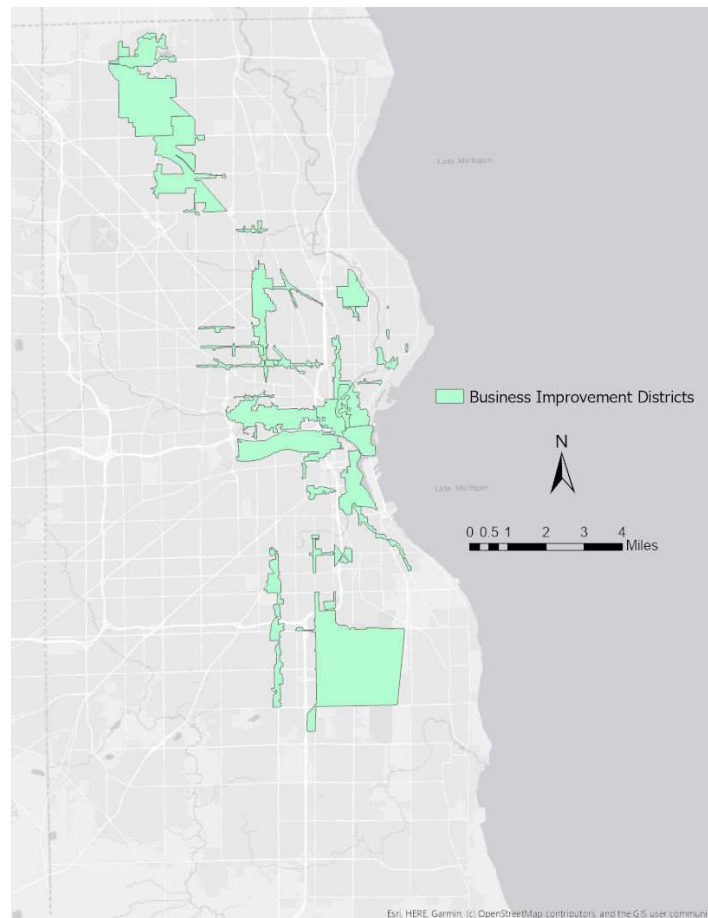

Figure 22. Geographic distribution of Business Improvement Districts (BIDs) in the City of Milwaukee.

Given that part of the mission of the City of Milwaukee's Department of City Development is providing support to Business Improvement Districts (BIDs), businesses within BIDs that are likely to be affected by the consequences of COVID-19 were examined in detail. Figure 22 presents the geographic distribution of BIDs across the City of Milwaukee, and Table 6 (See Appendix) provides summary of closure statistics by BID, as well as the number of employees potentially affected.

The BIDs with the highest percentage of likely closed businesses include the sizable Airport Gateway (19%), the Historic Third Ward (21%), Cesar E. Chavez Drive (22%), South 27th Street (22%), Greater Mitchell Street (27%), East North Avenue (28%), Kinnickinnick Avenue (30%), Edgewood Oakland (33%), Brady Street (42%), and Oak and Loc (45%). The least affected BIDs are likely Reed Street Yards (0%), Schlitz Park (5.5%), Riverfront Plaza (6%), 30th Street Industrial

Corridor (6.5%), Center Street Marketplace (6.5%), West Burleigh Street (8%), Kinnickinnick River (8.7%), Riverworks (8.7%), Villard Avenue (9%), and Atkinson, Capitol and Teutonia (9.5%). As presented in Figure 23, the number of potentially impacted *non*-BID located businesses in Milwaukee County are numerous, warranting additional considerations.
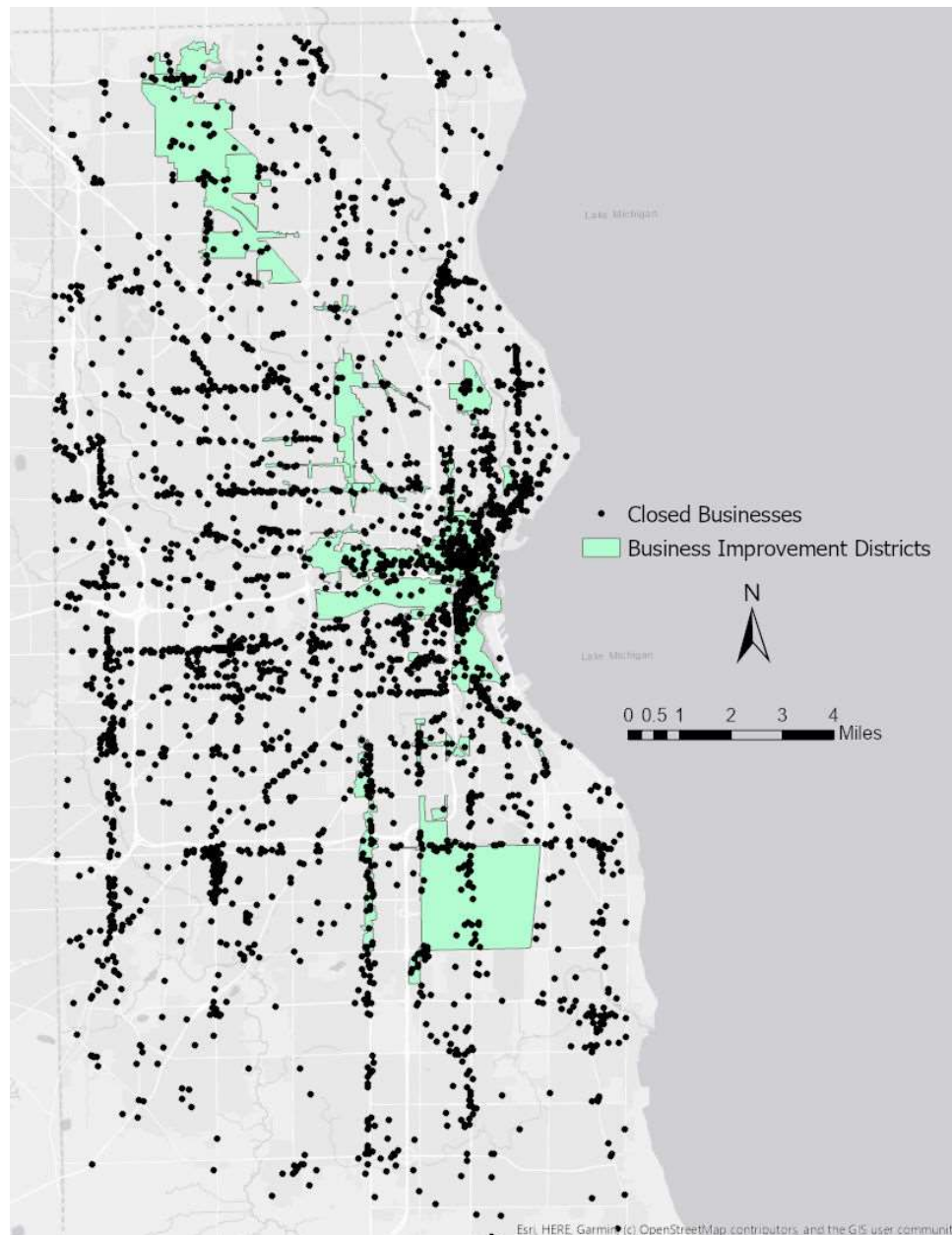

Figure 23. Geographic distribution of businesses which were required to close or substantially limit operation by order of the City of Milwaukee Health Department on March 25, 2020, and in subsequent amendments. Business data for this map was gathered by ESRI/Infogroup and was current as of February 2018 and was accessed from ESRI Business Analyst in April 2020.

Attentiveness to individual BIDs can provide added insight. Though Schlitz Park and Historic King Drive apparently have relatively low percentages of closed businesses, if we compare these BIDs by the numbers of employees likely affected, the 5.5% closure at Schlitz Park represents 565 employees, and the 9% closure at King Drive represents 782 employees. This is according to the 2018 Infogroup Data available through Esri and filtered by the NAICS codes given in the Appendix. The BIDs that came up with the highest numbers of affected employees are Menomonee Valley, with 3,188, and Historic Third Ward, with 2,635. However, it must be noted that these numbers differ from reality, and likely significantly so. Our method lists Walker Forge Inc as being closed, yet their website boasts that they are open and hiring. Infogroup lists Walker Forge Inc as the largest employer in the Third Ward, with 800 employees. Due to time constraints and the size of the dataset, it was not possible to check the veracity of all results. Menomonee Valley came up with the highest number of likely affected employees, 3,188. Potawatomi Casino is the largest employer in Menomonee Valley, with 2500 employees. Potawatomi is in fact closed, but the third largest "closed" employer, Palermo's Pizza Factory (305 employees), was not closed until May 1, 2020, when it was notified by the Milwaukee Health Department that five employees tested positive for COVID-19. (FOX6 NEWS, 2020).

6.1. Potential Impacts of COVID-19 on Small and Minority-Owned Businesses

As understanding of the economic consequences of COVID-19 expands across cities in the U.S., attentiveness to the potential challenges faced by small and minority-owned businesses has grown considerably. Recent reports highlight that both large and thriving companies received loans (e.g. LA Lakers, Shake Shack), while many small and minority-owned businesses were effectively shut out of the first round of funding executed by the Small Business Administration (Kurtzleben et al. 2020; Popken 20). Moreover, as the majority of COVID-19 rescue loans tie a significant portion of loan forgiveness to employee payments, small and minority-owned businesses without employees are expected to be particularly vulnerable (Adams, 2020). Figure 24-27 suggest that businesses with a small employees (blue) correlate strongly with census tracts anticipated to have a high degree of economic vulnerability, particularly on Milwaukee's south side. That many of these small businesses fall outside of the city's BIDS, suggesting a need for more comprehensive development efforts.
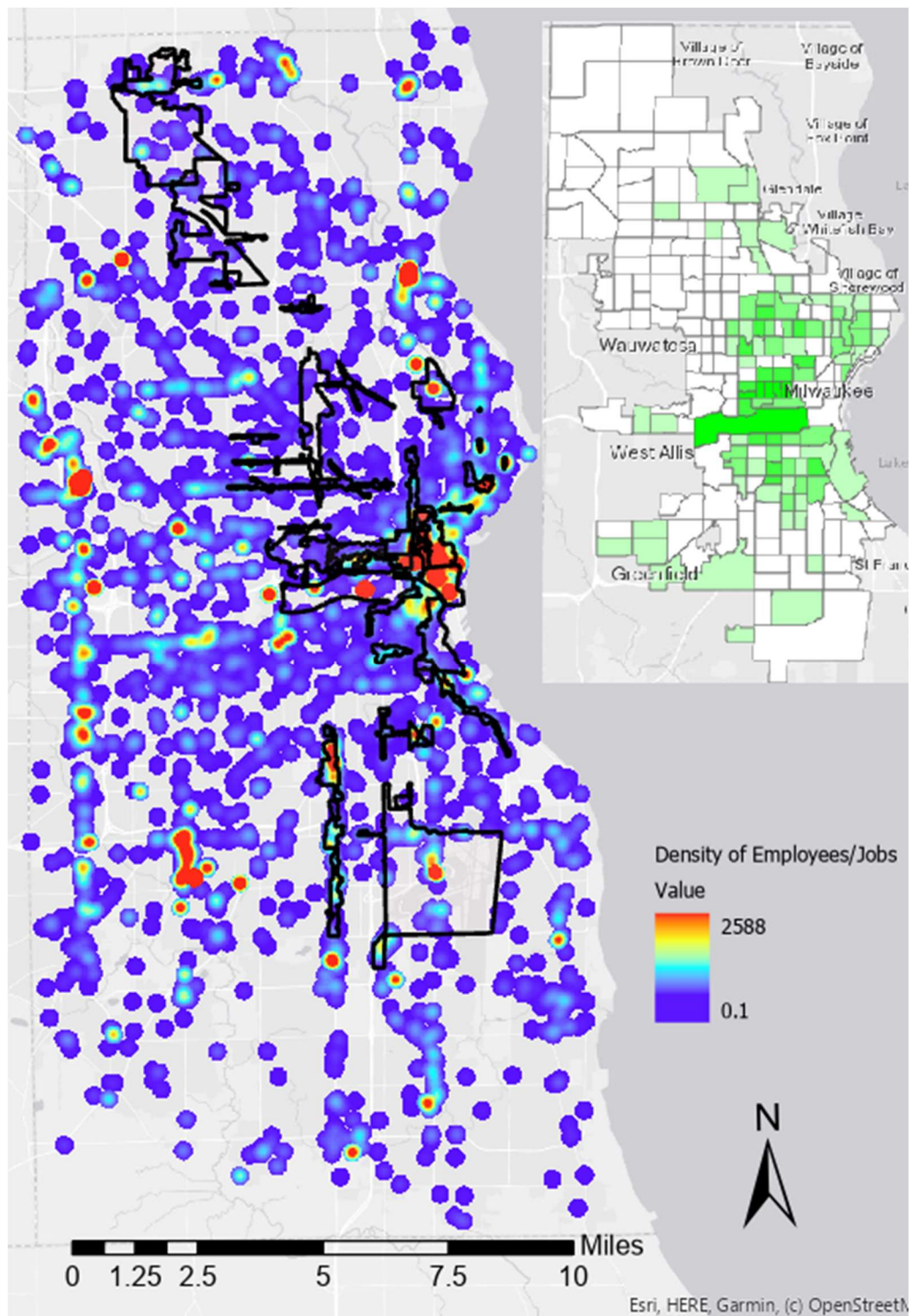
Figure 24. Kernel Density showing closed businesses in Milwaukee County due to COVID-19. Each circle represents an area around a business, with a radius of 1000 ft. Blue indicates the number of employees (often 0-4) within that area, while red indicates a higher number of employees. Areas with many circles but with little red represent areas containing more small businesses. 0.1 = 1 employee per 1000 square feet. **Inset Map:** EVI Index for comparison

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While the number of business in the United States that do not have employees is estimated at roughly 78%, the current president of the U.S. Black Chambers notes that "of the 2.6 million black-owned business, 2.5 million have no employees" (Adams, 2020). In other words, the 96% of black-owned businesses that do not have employees may be overlooked or structurally unable to receive COVID-19 rescue loans. Other commentators have drawn attention to the structural barriers facing minority-owned businesses attempting to seek COVID-19 recovery (Hopkinson & Perry, 2020), including but not limited to a "historical lack of access to capital, discrimination, immigration status and language barriers" (Balaskovitz, 2020).
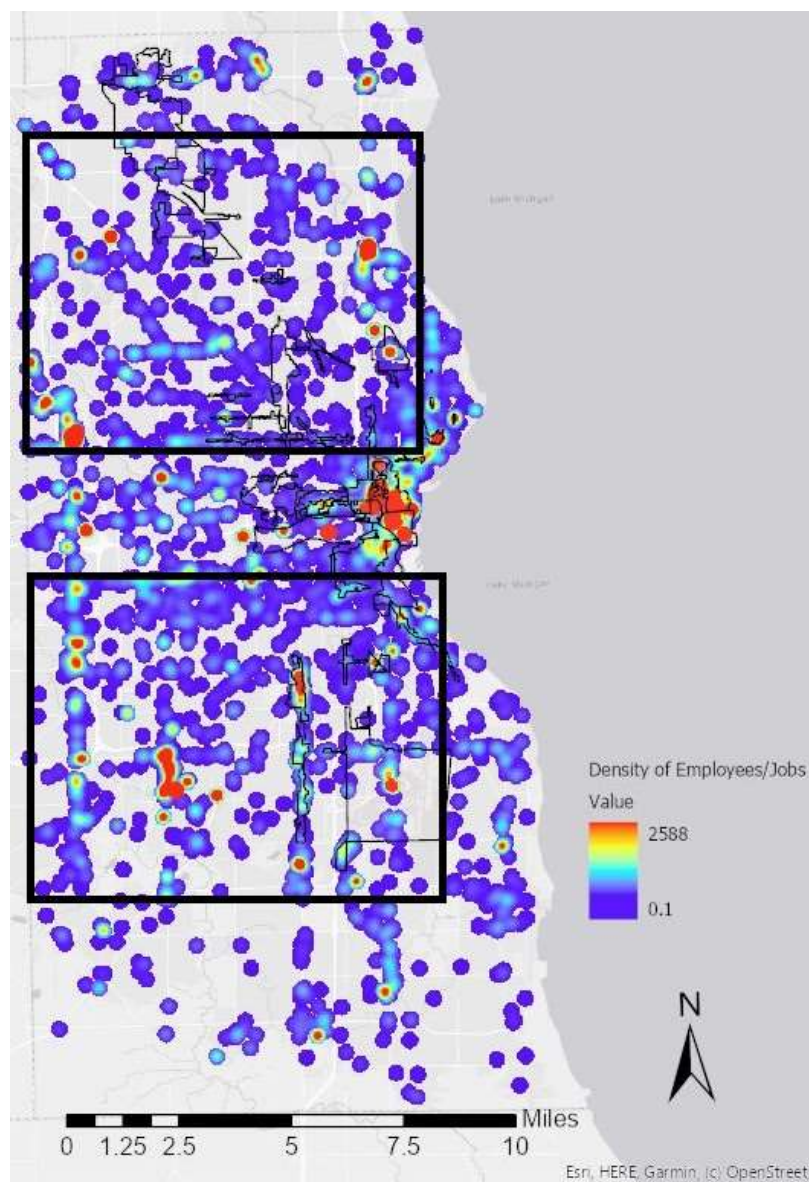

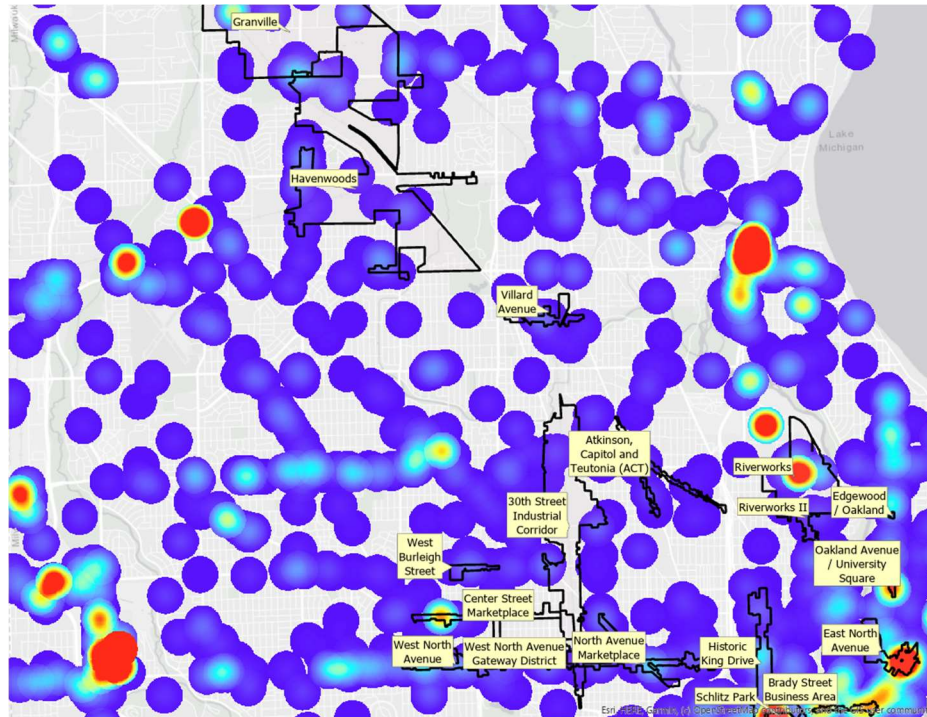**Figure 25:** Location of areas detailed in Figures 26 and 27 below.

Figure 26. Detail view of closed businesses employee density north of Menominee Valley, BIDs are labeled and outlined in black.
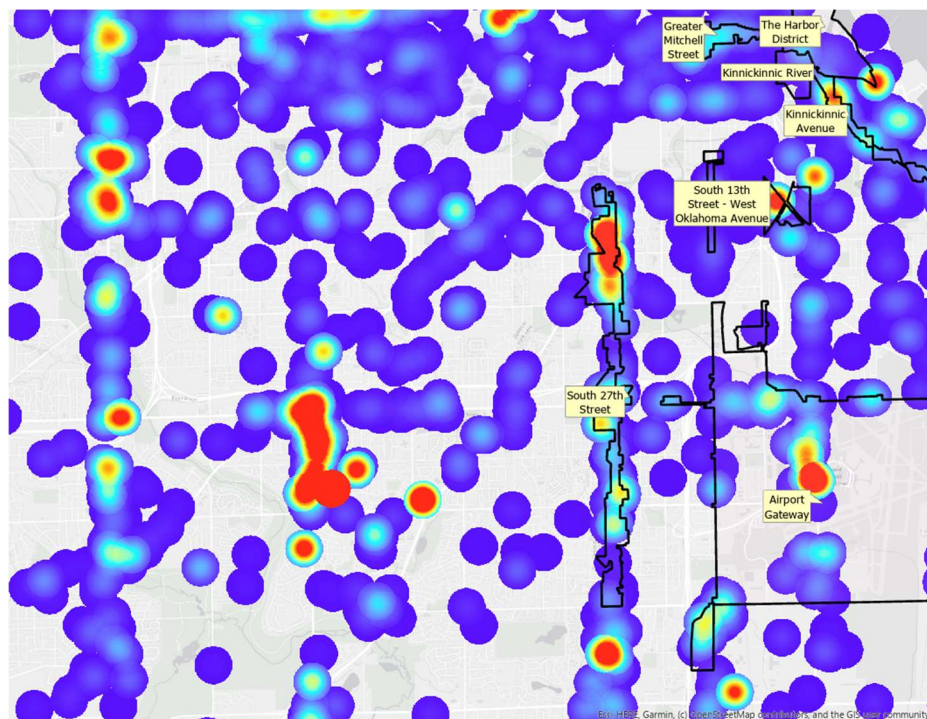

Figure 27. Detail view of closed businesses employee density south of Menominee Valley, BIDs are labeled and outlined in black.

The economic impacts of COVID-19 upon small and minority-owned business may exacerbate preexisting vulnerabilities faced by minority workers, a group that has been greatly affected by job loss and pay cuts due to COVID-19 (Kimberley, 2020) (Maxwell & Solomon, 2020). Furthermore, early reporting suggests (Perrett, 2020), underscoring the importance for local, state, and federal entities to grapple with and anticipate the potentially disproportionate impacts of COVID-19 upon communities. In the City of Milwaukee, the fact that many of small and minority-owned businesses fall outside of BIDs may necessitate the development of new and proactive strategies to support particularly vulnerable areas.

LIMITATIONS

There are several limitations to our study that should be noted.

Census Participation

Since we heavily used Census and Census-related data, our results are affected by the limitations of such data, namely that some areas have much lower participation in the Census. Generally, those who do not participate in the Census tend to have characteristics such as lower educational attainment or less internet access. This could skew our results toward portraying less vulnerabilities than are present.

COVID-19 is a new disease

As such, research on health risk factors is ongoing and constantly changing. Since this is a global emergency, many scientists have abandoned their regular research to devote their attention solely to COVID-19 and stopping its spread. There is emerging consensus on many facts, however, much remains to be learned and information on the disease is often incomplete and or even contradictory.

Limited testing

Inadequate supply of COVID-19 test kits results in only those individuals who are highly symptomatic being tested. A high percentage of those infected are known to experience mild or no symptoms yet still be contagious. The county data for number of cases merely represents those who were ill enough to receive a test, and who had the means to get one.

No Demographic data on Mortality

This possibly resulted in missing factors that should have been included in our vulnerability analysis.

No Air Quality Data

There is evidence that air quality influences susceptibility to infection. Meaningful air quality data is not available on the scale of this analysis.

Flagging variables above the 90th percentile is an arbitrary threshold

For example, the 90th percentile for obesity in Milwaukee County is a rate of 33.9% in the population, yet almost every tract has an obesity rate between 20 and 30%. Our intent was to identify those populations *most* at risk within Milwaukee, so a threshold had to be chosen. The 90th percentile threshold is used in other existing Social Vulnerability Indices.

There is no comprehensive list of which businesses have been closed during 'Safer at Home'

By selecting the broad categories of Arts, Entertainment & Recreation, Accommodation & Food Services, and Retail Trade, and then removing businesses categorized as essential using NAICS designation codes, we arrived at an approximation. Most businesses that can remain open are doing so, sometimes operating in a limited capacity. This includes restaurants, bars, arts and crafts supply stores, lawncare companies, and more.

CONCLUSION

The purpose of this project has been to identify differences in vulnerability within the City of Milwaukee to the COVID-19 pandemic. By creating indices of health, economic, and sociodemographic variables specifically associated with higher vulnerability to coronavirus, we hope to aid the Milwaukee Department of City Development in the process of deciding where to apply their resources.

As noted in the Discussion, throughout the United States racial and ethnic minorities are disproportionally affected by the Coronavirus pandemic. The data clearly shows that Milwaukee is no exception. Longstanding racial segregation and inequality means that people in certain neighborhoods are both at higher risk of infection, and in greater danger of serious adverse health and economic impacts resulting from infection. Specifically, these are the neighborhoods south of the Menominee Valley, and the neighborhoods north of the Menominee Valley and extending towards the northwest. While race and ethnicity do not appear to play a direct role in health risk factors, sociodemographic characteristics that often accompany them do.

A significant pattern that emerged from our analysis is the very high concentration of workers in the fields of Health Care and Social Assistance on Milwaukee's north side. Between 66-98% of residents in this area report their race on the census as Black, with many tracts comprised of 95% or higher reporting their race as Black. As mentioned in the Discussion, throughout the city most census tracts have at least 10% of workers in Health Care and Social Assistance. In the area coinciding with zip codes 53210, 53206, 53218, 53209, and 53212, 25-32% of workers are employed in these fields. This, in combination with the presence of many other vulnerability

flags in the same area, is cause for great concern due to the high exposure risk in those fields of work. Other vulnerability flags present include: Housing Cost Burden above 66.27% of household income, Median Income below $21,665, and Pre-Existing Conditions.

South of the Menominee Valley, roughly coinciding with zip code 53204 and parts of 53215 and 53207 is where Milwaukee's Hispanic population is most dense, with tracts reporting between 60-80% Hispanic. Here we find a very high percentage of people lacking health insurance, and a very high percentage of people with low English proficiency. 14 of the study area's 22 flags for High Population Density are in this area, and it also has somewhat higher than the county average for Number of People per Room. In census tracts 16900 and 16800 respectively, 32.4% and 29.2% reported lacking health insurance in 2014-2018. The prevalence of public health insurance over private by roughly 2 to 1 in this area means the actual percentage of those insured is likely even lower now, due to recent contractions in public health insurance under the Trump administration. An individual lacking health insurance and with low proficiency in English is potentially in a very dangerous position should they become seriously ill and require medical intervention. This area was not flagged in the 90th percentile for Pre-Existing Conditions, however Pre-Existing Conditions are prevalent across the entire city, and the percentages in tracts south of the Menominee Valley are not much lower than in the tracts that received flags.

Lastly, there was some coincidence between our Economic Vulnerability Index map and the presence of small businesses either directly affected by 'Safer at Home', or in vulnerable industries. The kernel density of businesses by number of employees shows that particularly on the south side, in areas that scored higher in the Economic Vulnerability Index, there are many cool-colored circles representing businesses with small numbers of employees. The pattern is less clear on the north side, but still evident. Most of these small businesses are not within a Business Improvement District.

This analysis illustrates why some Milwaukee communities are likely more vulnerable to the COVID-19 crisis than others. Identification of these specific areas within the City provides the groundwork for the Department of City Development and offers guidance toward future policy decision-making as well as the appropriate distribution of government resources.

AKNOWLEDGEMENTS

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WORKS CITED

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APPENDIX

NORTH AMERICAN INDUSTRY CLASSIFICATION SYSTEM (NAICS) CODES

Procedure for selection of Milwaukee County businesses as follows:

Base Query, select the categories: "Arts, Entertainment & Recreation", "Accomodation & Food Services", and "Retail Trade".

NAICS LIKE '71%' Or NAICS LIKE '72%' Or NAICS LIKE '44%' Or NAICS LIKE '45%'

The following were removed from the selection generated by the Base Query (the given descriptions are not verbatim to the NAICS designation):

Auto Dealers	NAICS LIKE '4411100%' Or NAICS LIKE '4411200%'
Auto Tire Shops	NAICS LIKE '44132001%' Or NAICS LIKE '81119616%'
Automotive Parts	NAICS LIKE '441310%'
Bicycles	NAICS = '45111005' Or NAICS = '45111006' Or NAICS = '45111007'
Cellular Phones	NAICS = '81121301 ' Or NAICS LIKE '5172120%' Or NAICS = '44314204'

Confectioners	NAICS = '44529202'
Dollar Stores	CONAME LIKE '%DOLLAR%'
Electric Vehicle Charging Stations	NAICS = '44719010'
Fast Food	CONAME = 'WENDY''S' Or CONAME = 'ARBY''S' Or CONAME = 'MC DONALD''S' Or CONAME = 'SONIC DRIVE-IN' Or CONAME = 'TACO BELL' Or CONAME = 'POPEYES LOUISIANA KITCHEN' Or CONAME = 'KFC' Or CONAME = 'BURGER KING' Or CONAME = 'CULVER''S' Or CONAME = 'QDOBA MEXICAN EATS' Or CONAME = 'WINGSTOP' Or CONAME = 'PANDA EXPRESS' Or CONAME = 'FIVE GUYS' Or CONAME = 'CHECKERS DRIVE-IN RESTAURANT' Or CONAME = 'JIMMY JOHN''S' Or CONAME = 'BOSTON MARKET' Or CONAME = 'CHILI''S GRILL & BAR' Or CONAME = 'POTBELLY SANDWICH SHOP' Or CONAME = 'COUSINS SUBS' Or CONAME = 'SUBWAY' Or CONAME = 'CHIPOTLE MEXICAN GRILL' Or CONAME = 'NOODLES & COMPANY' Or CONAME = 'GOLDEN CHICKEN' Or CONAME = 'J J FISH & CHICKEN' Or CONAME LIKE 'GOLDEN CHICKEN CARRY-OUT%' Or CONAME = 'J & J FISH & CHICKEN'
Fishing Bait	NAICS = '45111017 ' Or NAICS = '45111020 ' Or NAICS = '45111019 '
Health Food or Supplement Store	NAICS LIKE '4461910%'
Gas Stations	NAICS LIKE '4471900%'
Golf Courses	NAICS = '71391002'
Grocery Stores	NAICS LIKE '445110%' Or NAICS LIKE '445120%'
Guns	NAICS = '45111023' Or NAICS = '45111024' Or NAICS = '42391021'
Hardware	NAICS LIKE '444110%' Or NAICS LIKE '444130%' Or NAICS LIKE '444190%'
Liquor Stores	NAICS LIKE '445310%'

Nature Parks	NAICS = '71219004'
News Businesses	NAICS LIKE '45121202%'
Nursery, Garden, Farm Supply	NAICS LIKE '4442201%'
Paint Stores	NAICS LIKE '44412003%'
Pet Supplies	NAICS LIKE '4539100%'
Pharmacies	NAICS = '44611009'
Powersports	NAICS LIKE '44122%'
Tobacco Stores	NAICS LIKE '453991%'
Vegetable Markets	NAICS = '44523001' Or NAICS = '44523003'

Table 5: NAICS Codes of 'essential' businesses which remain open during the 'Safer at home' order which were removed from the selection of Milwaukee County businesses for the analysis.

EMPLOYEE STATISTICS BY BID

BID	total businesses in 2018	businesses likely closed in April 2020	percentage of businesses closed	Total employees of likely closed businesses	mean number of employees per business	median number of employees per business	max number of employees at a single business
Downtown Management District	2672	373	14.0	7937	21.27	10	800
Avenues West	656	96	14.6	1099	11.44	5	150
Historic Third Ward	645	138	21.4	2635	19	6	800
Milwaukee Riverwalk	636	101	15.9	2949	29	10	550
Granville	500	57	11.4	796	13.9	7	120
Airport Gateway	500	94	18.8	2024	21.5	11	150
South 27th Street	391	86	22.0	2181	25.3	10	300
Historic King Drive	336	30	8.9	782	26	5	550
Havenwoods	291	38	13.1	247	6.5	5	20
Kinnickinnic Avenue	279	84	30.1	605	7.2	5	50
Riverworks	207	18	8.7	487	27	9.5	335

East North Avenue	179	50	27.9	678	13.5	10	100
Menomonee Valley	176	23	13.1	3188	138.6	10	2500
Westown	161	24	14.9	458	19	10	100
South 13th Street West Oklahoma Avenue	157	25	15.9	414	16.5	4	300
North 76th Street West Brown Deer Road	156	28	17.9	380	13.57	8	80
30th Street Industrial Corridor	155	10	6.5	51	5.1	4	13
Greater Mitchell Street	148	40	27.0	188	4.7	4	21
West North Avenue	122	27	22.1	164	6	3	30
The Harbor District	122	20	16.4	325	16.25	6.5	160
North Avenue Marketplace	109	19	17.4	109	5.73	4	20
Atkinson Capitol and Teutonia ACT	105	10	9.5	37	3.7	3	10
Brady Street Business Area	95	40	42.1	385	9.6	6	100
Center Street Marketplace	92	6	6.5	213	35.5	2.5	195
West Burleigh Street	73	6	8.2	33	5.5	3.5	14
Cesar E Chavez Drive	55	12	21.8	42	3.5	2	12
Schlitz Park	55	3	5.5	565	188.33	10	550
Villard Avenue	54	5	9.3	27	5.4	4	10
West North Avenue Gateway District	47	8	17.0	45	5.6	5	15
Downer Avenue	42	11	26.2	315	28.6	11	100
Oakland Avenue University_Square	35	16	45.7	252	15.75	10	72
Riverfront Plaza	34	2	5.9	45	22.5	22.5	35
Kinnickinnic River	23	2	8.7	4	2	2	3
Reed Street Yards	11	0	0.0	0	0	0	0
Edgewood Oakland	9	3	33.3	12	4	3	8
735 North Water Street	1	0	0.0	0	0	0	0

Table 6: Employee Statistics by Business Improvement District (BID). 2018.