

# **COVID-19: A Geo-Spatial Public Health Tool for Identifying High Risk Groups and Areas for Rapid Immunization in North Carolina**

SCIENTIFIC WHITEPAPER



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## EXECUTIVE SUMMARY

As the availability of COVID-19 vaccine draws closer to market, production volumes are projected to be limited compared to population demands. Discussions by national committees, to identify high risk groups to target for initial vaccination have been underway.

Current recommendations support previous risk based high-risk population and occupational groups to receive initial vaccine allocation including, healthcare personnel, essential workers, persons with high risk medical conditions and older adults (>65 years). However, disparities in COVID-19 and impacts on race/ethnic groups, low income families, have also been recognized and potentially considered as part of vaccine allocation roll out plan. Having the ability to identify and target geographic areas where these high-risk populations are located could assist public health decision makers in a more rapid and efficient response to COVID-19 vaccine allocation and distribution.

Using funds provided by N.C. House Bill 1043 (2020, COVID-19 Recovery Act), East Carolina University, in collaboration with partners at Vidant Medical Center and ESRI, developed the Vaccine Priority Index (VPI), a freely available, online mapping tool, available at <https://enchealth.org/>.

Hospitals, health departments, policy makers and other decision makers in North Carolina stand to benefit by using the VPI tool to readily identify geographical areas of vulnerable populations and point locations of high risk facilities including hospitals, nursing and assisted living homes, meat packing facilities, FQHC's, pharmacies, correctional institutions and health departments. The purpose of the VPI is to identify areas in North Carolina where vaccine distribution should be prioritized, based on risk factors and existing vulnerabilities. The index combines measures related to individual risk for COVID-19, such as health condition and occupation, with measures to assess population-level risk, such as income, race, ethnicity, and household living status, to create a composite measure for vaccine priority. The index is applied at the census tract level for all tracts within North Carolina and is based on a within-state comparison. It does not compare priority to other states.

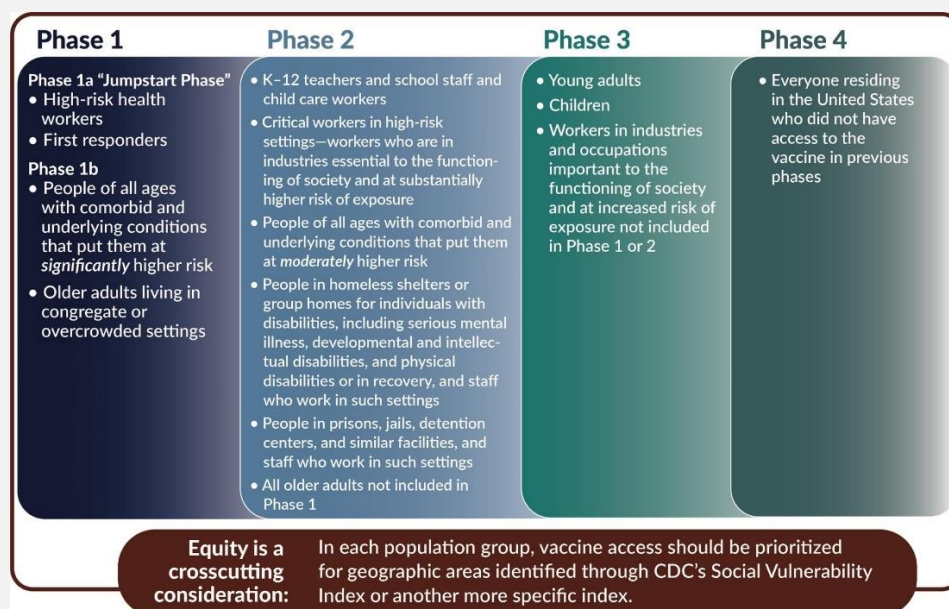
Presented here are the rationale and methods that describe the VPI, it's utility, usefulness and other considerations for using it as a public health tool to assist in the decision-making and planning process for immunizing vulnerable, high-risk populations in North Carolina.

## I. Background

### Prioritizing Vaccine Distribution

In September 2020, the National Academies of Sciences released the *Preliminary Framework for Equitable Allocation of COVID-19 Vaccine*. [1] Although the report's recommendations stemmed from the report, *Committee on Equitable Allocation of Vaccine for the Novel Coronavirus*, guidance from other national advisory groups including, the Advisory Committee on Immunization Practices (ACIP) and state, local, tribal and territorial (SLTT) in COVID-19 vaccine allocation were considered as part of the decision making process.

As described in the report, the Committee recognized that when available, allocation for initial supply of vaccine would be tightly constrained. Setting priorities for the equitable allocation of vaccine are challenging given the many risks and exposure factors that various populations and occupational groups face. It was noted that assigning priority at the individual level posed considerable constraints and were impractical for delivering to geographically distributed individuals.



**Figure 1.** National Academy of Medicine - Phased Approach to Vaccine Access (NAM, 2020)

Considering the many factors associated with allocation, the committee operationalized provided risk criteria by characterizing population and occupational groups based on the risks they faced and ability of a vaccine to reduce those risks. Using the best available evidence, the Committee's recommendations included a four "**phased**" successive approach to specific population groups for COVID-19 vaccine allocation (see Figure 1). In Phase 1 (highest priority), high-risk population groups would receive initial vaccine that included high risk workers in healthcare facilities, first responders, people with significant comorbid conditions and older adults in congregate or overcrowded settings.

Considerations for disparities and impacts on race/ethnic groups, low income families, etc. in COVID-19, were also highly recognized. To address this issue, the Committee recommended the use of the existing Social Vulnerability Index (SVI) as a tool to assist when considering equitable vaccine distribution. In brief, the SVI and other vulnerability tools are data driven ranking systems, used primarily in a mapping application by emergency disaster management personnel to assist with identifying economic loss, providing social services and public assistance following natural disasters. [1,2]

## II. Why Consider a New Vulnerability Mapping Tool?

The concept of using maps and public health surveillance can be traced back to 1854 when Dr. John Snow demonstrated the link between deaths and contaminated drinking water from a well located on Broad Street in London. Since that time, great strides in medicine and technology have advanced efforts for identifying existing disease hot spots and areas of new disease clusters. Although these tools are useful, they are primarily based on identifying individuals or groups of cases of people that have existing illness or disease. In pandemic situations, like COVID-19, having access to available tools that can readily identify high-risk groups of individuals or special populations that can be targeted in advance for intervention and prevention strategies can be of great importance.

The social, economic, and health geography of North Carolina varies considerably across the state; regions, counties, and census tracts differ in population density, urban and rural status, income, race, ethnicity, and health status. Likewise, COVID-19 morbidity and mortality rates have differed widely across the state as well. Some areas and some groups have been highly impacted, particularly the elderly and staff in nursing homes, but also frontline health workers, first responders, and workers in occupations deemed “essential.” Some individuals have resources to help them cope with the virus, while others do not. For example, low-wage workers often lack health insurance, do not have transportation to get tested, or go to work when they are ill because they cannot afford to miss work. Such challenges pose considerable exposure risk to COVID-19 including the individual, their co-workers, families and others in their communities.

The ability to identify geographical areas where high-risk, vulnerable populations are located would be an ideal way for health decision makers to plan where to target vaccine intervention strategies. One method for distributing a vaccine across the state would be by direct population – each region or county would receive a share of the available vaccine, based on population. Such an approach would not be the most efficient, nor the most effective way to protect the highest risk groups, as it does not account for the inherent differences in risk and vulnerability experienced by different individuals and populations.

Another more accurate approach would be to prioritize populations based on their risk, or vulnerability to suffering adverse effects. The SVI is one approach. The SVI has been used extensively in the context of natural disasters. However, the SVI does not consider important and relevant factors associated with health status or high contact occupations, that are relevant

to COVID-19 vaccine allocation. As COVID-19 spreads, decision makers need the ability to quickly identify the areas and specific locations of high-risk populations that need vaccine. A mapping tool could help assist with overcoming this challenge.

### III. A Vaccine Priority Index for N.C.

On October 16, 2020, the State of North Carolina released its COVID-19 Vaccination Plan. As part of the plan, it used the National Academy of Medicine framework in consultation with the N.C. COVID-19 Vaccination Planning Team to prioritize critical populations in N.C. to receive the vaccine. Similarly to the NAM recommendations, it identified high risk health workers, staff in long term care, people over 65 and staff of congregate living settings (migrant farm camps, jails, prisons, homeless shelters, and anyone with two or more chronic conditions identified by CDC to be high risk for COVID-19 complications.[2]

In this application, a Vaccine Prioritization Index (VPI) was developed for N.C., modeled on the SVI themes and the NAM recommended priority framework. Health and risk data were incorporated into the index in order to identify geographic areas in N.C. where high-risk populations are located, and vaccine prioritized. Below we briefly explain these advantages and challenges.

- **Efficient**, the VPI translates priority groups (e.g., NAM recommended Phase 1A and Phase 1B priority groups) into a ranked index value to quickly determine where vulnerable groups are located.
- **Rapid Visualization**, key point locations of high-risk facilities including hospitals, nursing and assisted living homes, meat packing facilities, FQHC's, pharmacies, correctional institutions and health departments can readily be found. Additional base map layer features including roads and other imagery can be added to maps. As new location centers emerge (e.g., large vaccination sites or drive through sites) can easily be incorporated into the model.
- **Vaccine Delivery**, while the data is derived from the US Census, and nationally derived datasets, it is only a metric or a guide to assist with the vaccine delivery and distribution process.

The purpose of the VPI is to identify areas in North Carolina where vaccine distribution should be prioritized, based on risk factors and existing vulnerabilities. The index combines measures related to individual risk for COVID-19, such as health condition and occupation, with measures to assess population-level risk, such as income, race, ethnicity, and household living status, to create a composite measure for vaccine priority. The index is applied at the census tract level for all tracts within North Carolina and is based on a within-state comparison. It does not compare priority to other states.

### IV. Understanding the VPI Methodology

The VPI is modeled on the social vulnerability index, and borrows some core variables from the SVI, but also uses additions to incorporate risk and vulnerability data that are pertinent to a

pandemic, but not included in the SVI. The VPI uses a similar ranking methodology to the SVI to assign index values to each census tract based on individual variables. Individual index values are then combined to create “themes” and the themes are combined to create an overall priority index.

## Data

The VPI contains 14 variables that describe risk and vulnerability relative to the COVID-19 virus. Eleven of the variables are derived from Census data at the tract level (American Community Survey 5-year data, 2014-2018). Two variables are from the CDC’s Diabetes Atlas, and are at the county level, and one is from Center for Medicare and Medicaid Services Chronic Conditions Data Warehouse data, also at the county level. The 14 variables are combined into 5 themes: social and economic status; minority status and language; housing situation; at risk population; and health status. Index scores are calculated for each theme, then combined to create an overall VPI index score for each census tract.

The variables and themes are listed in the table below.

Themes				
Social and Economic Status	Minority Status & Language	At-Risk Population	Housing	Health Status
Variables				
<ul style="list-style-type: none"> <li>• % below poverty</li> <li>• % unemployed</li> <li>• Avg. per capita income</li> <li>• % no high school diploma</li> </ul>	<ul style="list-style-type: none"> <li>• % minority</li> <li>• % that speak English “less than “well”</li> </ul>	<ul style="list-style-type: none"> <li>• % age 65 or older</li> <li>• % of population who list occupation in high-risk group</li> </ul>	<ul style="list-style-type: none"> <li>• % of households crowded</li> <li>• % of people who live in group quarters</li> <li>• % of housing that is multi-unit</li> </ul>	<ul style="list-style-type: none"> <li>• % of adults who have diabetes</li> <li>• % of adults who are obese</li> <li>• % of Medicare beneficiaries age 65 or older who have 2 or more chronic health conditions</li> </ul>

**Figure 1.** Vaccine Priority Index Themes and Variables

## VP Index

To construct the VPD Index, scores are calculated by ranking all census tracts in the state from low to high on the individual variable. A census tract with a lower percent in poverty is presumed to have lower vulnerability, for instance; a tract with a higher percent in poverty has

a higher vulnerability. The exception is income, which is ranked high to low, since tracts with a higher income are presumed to have lower vulnerability, and lower income is presumed to have higher vulnerability. Once ordered by low to high vulnerability, each census tract is assigned a rank number. North Carolina has 2193 census tracts. The rank number is then used to create an index value. Census tracts with no population, or a zero value for the variable being ranked (no individuals in poverty live in that tract, for instance) are not assigned a rank, and receive a zero value for that index. The index value is the rank number divided by the total number of tracts for that variable (with a slight adjustment to ensure the lowest census tract has a value of 0 and the highest has a value of 1). Census tracts with low index values have low vulnerability on that variable, and tracts with high values have high vulnerability on that variable. The method and formula for the index is borrowed directly from the Social Vulnerability Index; some variables are changed.

$$\text{Vaccine Priority Index} = (\text{rank} - 1) / n - 1$$

To calculate themes, indexes for individual variables are summed together, and then the summed values are re-ordered, low to high. A new rank is assigned for the summed value, and a new, combined index value is calculated, using the same method. To calculate the overall VP index, the 5 theme indices are summed and re-ranked, and their rank number is used to calculate the final index.

## Themes and Variables

**Theme 1, Social and Economic Status**, and **Theme 2, Minority Status and Language**, are borrowed directly from the SVI index. They contain the same variables and are calculated in the same way for the most part, but they are ranked just for the state of North Carolina. The raw values for the variables are from the SVI data set, but they are re-ranked for just the state of North Carolina. In the SVI, when variables are ranked, they are compared to all census tracts in the entire US. Their rank is determined from that, and their index value is calculated based on that rank. For the VPI, which is North Carolina specific, the raw values for the variables are ranked against just the two thousand census tracts within North Carolina. Using that rank, an index is calculated. Thus, a direct comparison of the index value with the SVI data set might reveal some small differences. The position of any North Carolina census tract relative to others in the state would not change, however.

**Theme 3: At-Risk Populations**, combines the percent of the population that is age 65 and over and the percent of the population whose occupation is healthcare or as a first responder.

Increased age is a risk factor for becoming ill from COVID19, and, for those who do become ill, for getting seriously ill. Increased age also puts individuals at higher risk for dying from COVID19. Therefore, census tracts with a higher percent of individuals over age 65 are at higher priority for vaccine distribution. This measure uses the Census American Community Survey 5-year estimate of the number of individuals over age 65 for each census tract, divided by the total census tract population. Census tracts are then ranked lowest to highest based on

the percent 65 and over. Having a greater percent of individuals over age 65 means greater risk, and thus higher priority for the vaccine.

Certain occupations are at greater risk for contracting COVID-19 because they are in a workplace where they come in contact with COVID-positive individuals (such as healthcare) or because they are in an occupation where social distancing may not be possible (such as first responders). Due to their occupation, these groups have a higher individual risk both for getting COVID and for transmitting it to others, and they have been identified by the National Academies of Medicine as priority for the vaccine. Census tracts with a high proportion of individuals in frontline occupations should be prioritized. Using Census data, we calculated a percent of the total population in each census tract for three occupational groups corresponding with healthcare workers and first responders.

For healthcare workers, we combined three occupational categories: healthcare practitioners, healthcare technical occupations, and healthcare support occupations. Healthcare practitioners includes physicians of all specialties, as well as physician assistants, nurses, and dentists. Health technologists and technicians includes licensed practical nurses, EMTs, and health equipment technicians, including respiratory technicians. Healthcare support occupations includes home health aides, nursing assistants, and cleaners and orderlies in a health care setting.

We used the protective service occupation category for first responders. It includes law enforcement, firefighters, and correctional service workers. We summed the number for each of these groups to create a total number of frontline workers (health and first responder) for each census tract. Then, using that number and the total population for each census tract, we calculated a percent of the population in that census tract that was a frontline worker. A census tract with a higher percent of frontline workers is at a higher risk for the disease, and thus requires a higher priority for the vaccine.

We then created a combined index for the at-risk population theme. This theme combined the percent of the population age 65 and over with the percent frontline workers. This provides an overall assessment of the level of vulnerability in the tract based on age and occupation.

**Theme 4: Housing**, is housing arrangement. COVID-19 is a highly contagious virus, and studies to date show most transmission occurs in social settings, such as in congregate living, close work environments, and social occasions such as church services, weddings, funerals, restaurants and bars. The home is an important transmission setting, and one where many people are not able to socially distance from one another. Most individuals also cannot quickly or easily change their living circumstance. Those whose living situation is, by nature, congested or close to others have the highest risk. Thus, this theme combines three Census variables that describe features of the home and living situation that may increase risk for COVID-19, primarily due to the closeness of the setting, proximity to others, and the inability of individuals to socially-distance.



This theme is similar to the Housing and Transportation theme in the SVI index, but we have eliminated the “no vehicle” variable and the “mobile homes” variable, as they are less relevant for COVID risk. While not having access to a vehicle can indicate lower resources, and may impact the ability to reach healthcare resources, we felt that characteristic was already captured by the poverty and income variables in the Socio-economic status theme. Likewise, we felt the mobile homes variable did not contribute an important risk factor for COVID transmission.

The first variable in the housing theme is multi-unit housing. This variable assesses setting such as apartment buildings, where, while not living in the same unit, people are nonetheless in close proximity, sharing hallways, elevators, and mail stations. The variable measures the percent of housing units in a census tract that are part of a structure that contains 10 or more units. A census tract with a higher percent of housing of this nature would have a higher risk for COVID, simply due to the increased proximity of people, and an increase potential for spreading the virus.

The second variable in the housing theme is crowded housing. This variable is based on the census count of the number of persons per room in occupied housing units. Housing units (rental or owner occupied, house or apartment) with more than 1 person per room are considered crowded. Note, this measures persons per all rooms in the housing unit, not bedrooms. A housing unit with more people than total rooms in the unit would be classified as crowded. Based on that definition, the variable assesses the number of housing units in a census tract that are crowded, as a percent of all housing units in the census tract. Census tracts with a higher percent of crowded units are more vulnerable to COVID-19, because there are more people who live in circumstances where they cannot socially distance.

The third variable for the housing theme is the percent of individuals in the census tract who live in group quarters. The census counts all people based on where they live as of April 1<sup>st</sup> in a given year. The group quarters classification measures those people who live in institutional settings, as opposed to individual housing units. Group quarters includes people who live in nursing homes, assisted living, college dorms, psychiatric hospitals or other long-term healthcare institutional settings, and correctional facilities. Such congregate living arrangements have emerged as one of the riskiest settings for the spread of COVID-19, and numerous outbreaks have been tied to these settings. The group quarters variable measures the number of persons in the census tract that live in such a setting, as a percent of all people in the tract. Where the percent is higher, there is a higher level of vulnerability.

Each individual variable in the housing theme is ranked from lowest to highest, and an index is calculated based on the rank divided by the number of census tracts. The individual indices are then summed and re-ranked, and the combined rank is used to create an overall housing theme index.

**Theme 5: Health Status.** It is widely recognized that individuals with certain underlying health conditions are at significantly higher risk of severe COVID-19 illness, or death. While the exact reasons and extent of this are not fully understood, the course of the pandemic thus far has

demonstrated that individuals with diabetes, heart disease, kidney disease, COPD, obesity, and immune compromised individuals are all at risk for more severe illness and death if they contract COVID-19. Individuals with 2 or more of these or other serious health conditions are at an especially elevated risk.

The VPI includes a Health Status theme that groups data on the prevalence of diabetes, obesity, and chronic illness in North Carolina communities and assigns a higher vulnerability score based on higher levels of prevalence of these conditions. These scores are at the county level not the census tract level, because health status data is not available at a census tract level. The county value for the variable is assigned to each census tract within the county. Three variables are combined for this theme.

The first two variables for health status are the percent of adults in the county with diabetes (diabetes prevalence) and the percent who are obese. This data comes from the CDC's Diabetes Atlas, which is derived from the Behavioral Risk Factor Surveillance System data. The BRFSS is an annual health telephone survey conducted by states but standardized at the national level. Annual sample sizes for the survey for most North Carolina counties are too small to create reliable county-level estimates, but the Diabetes Atlas pools several year's data together and applies modeling techniques to create county estimates for some health factors, including percent of adults with diabetes and percent of adults who are obese. While these health conditions are not the only ones that may increase COVID risk, they are both important factors. Given that health status data is not readily available at the county level, we felt that this data could provide a uniform, reliable general estimate for health status at the county level.

Counties were ranked from lowest to highest, with those with the highest percent diabetes and percent obesity having the most risk, and a rank number assigned. The rank number was then divided by the total number of counties (n), using the same method as the census tracts with the other variables, and an index value was assigned. The county index value was applied for all census tracts within a county. Lower index values corresponded with lower vulnerability, and higher with higher vulnerability.

The third variable in the health status theme is the percent of Medicare beneficiaries in the county over age 65 who have two or more chronic health conditions. The data is from the Center for Medicare and Medicaid Services Chronic Conditions Data Warehouse, and it only includes information for Medicare beneficiaries. For the data set, an individual is defined as having a chronic condition if CMS administrative data show they had a claim for a service or treatment related to that condition within the previous year. There are 21 health conditions that are included in the CMS list of chronic conditions, including diabetes, heart failure, chronic kidney disease, and stroke, but also including other conditions. CMS makes available a public data set that shows the percent of beneficiaries by county that have two or more conditions, although the conditions are not specified. As mentioned above, good quality health status data is scarce at the county level, so we chose this data set for its reliability and consistency. We use it as a measure of population health, and we believe it can provide a general estimate for health status in the county. As with the CDC data, we used a county rank to create a county

index value, and then applied that value to all census tracts within the county. We then combined the indices for the three health status variables into one overall health status index.

## V. How to use the NC VPI Tool

As shown in **Figure 2**, to use the VPI tool, go to ENC Health website (<https://enchealth.org/>), click the “Vaccine Priority Index (VPI), read and click “OK” to agree to the terms of use. Select the VPI category from the Global Filter. High index values indicate higher vulnerable population priority areas; low index values indicate lower vulnerable population priority. The pop-ups over the geographic areas show the estimated count of high priority individuals in each county and Census tract. Turn the map layers on or off the right hand panel to display the VPI or the [CDC’s Social Vulnerability Index \(SVI\)](#). Zoom in to display key point locations, such as nursing homes, pharmacies, or health clinics. Use the filters on the left to filter for areas based on index categories or the number of priority individuals.

### View Counties

- On the Map Layers panel, click the eye icon to turn a layer on or off. Start by turning the Vaccine Priority Index – Counties layer on and turning off the Vaccine Priority Index – Census Tracts layer (so you can see the Counties layer). On the map, counties are shaded based on their VPI value. Darker colors indicate a higher priority; lighter colors indicate a lower priority.
- Click on a county and a pop-up opens that displays the numeric index value and the number of Phase 1A and Phase 1B individuals that live in that county. Priority individuals for Phases 1A and 1B include healthcare workers, first responders, residents in nursing homes and assisted living facilities, and individuals with chronic health conditions. The tool allows policymakers to easily identify how many people in each county and Census tract are eligible for vaccination in Phases 1A and 1B, and to visualize those areas with the highest priority.
- Scroll down in the pop-up to see additional measures, such as per capita income and poverty rate.
- Click the eye icon again to turn off the Vaccine Priority Index – County layer, and then turn on the Vaccine Priority Index – Census Tract layer.
- For additional information about how the VPI combines variables like poverty, race, age, and occupation to create the index, scroll down to the VPI Methodology section below.



Figure 2. ENC Health and accessing VPI

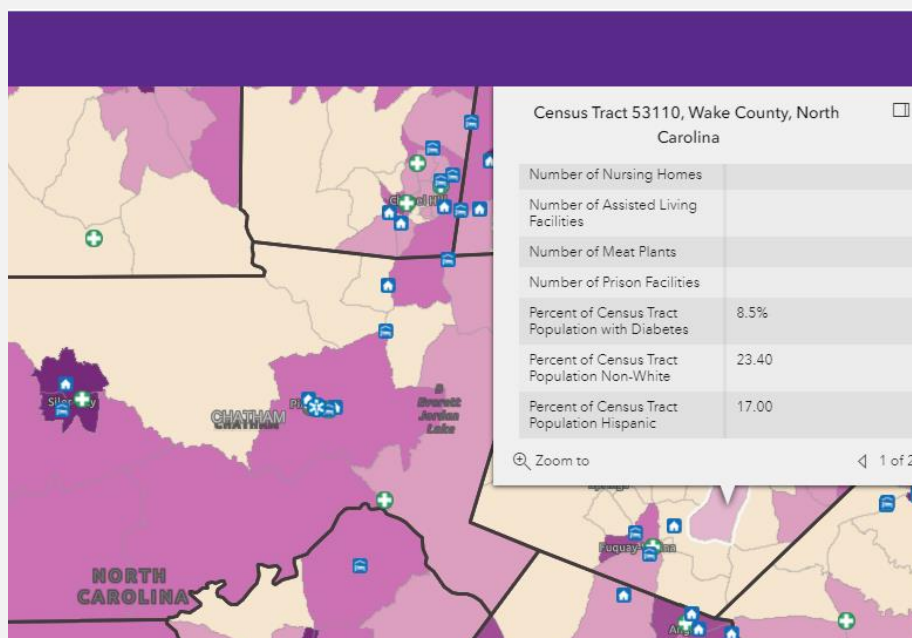


Figure 3. Zoom in to view features within Counties and Census tracts.

### View Census tracts within counties

- On the Map Layers panel, click the eye icon to turn a layer on or off. Start by turning the Vaccine Priority Index – Counties layer on and turning off the Vaccine Priority Index – Census Tracts layer (so you can see the Counties layer). On the map, counties are shaded based on their VPI value. Darker colors indicate a higher priority; lighter colors indicate a lower priority.

- Click on a county and a pop-up opens that displays the numeric index value and the number of Phase 1A and Phase 1B individuals that live in that county. Priority individuals for Phases 1A and 1B include healthcare workers, first responders, residents in nursing homes and assisted living facilities, and individuals with chronic health conditions. The tool allows policymakers to easily identify how many people in each county and Census tract are eligible for vaccination in Phases 1A and 1B, and to visualize those areas with the highest priority.
- Scroll down in the pop-up to see additional measures, such as per capita income and poverty rate.
- Click the eye icon again to turn off the Vaccine Priority Index – County layer, and then turn on the Vaccine Priority Index – Census Tract layer.

For additional information about how the VPI combines variables like poverty, race, age, and occupation to create the index, scroll down to the VPI Methodology section below.

### **Use the filters to investigate special populations and priority areas**

Using filters in combination with layers allows the user to tailor questions and investigate more detailed connections between variables.

- Keep the VPI – Census Tract layer on and zoom back out to the state level.
- Using the filter panel on the left-hand side of the map, go to the Vaccine Priority Index Category filter and pick the “High” category. The map filters to show only those Census tracts in the highest priority group.
- Keeping the Vaccine Priority Index – Category filter on, scroll down until you see the filter for Total Population Age 65 and Over. The range note on the filter tells you that, for North Carolina Census tracts, this variable ranges from a low of 0 to a high of 3,933 . We want to identify those high-priority tracts that also have an especially high number of individuals over 65.
- Enter a range value of 2,000 to 3,933 in the filter. This filters your results to only display high priority tracts that also have 2,000 or more people over age 65. Only one Census tract shows up, in Rutherford County (west of Charlotte).
- Keeping the over 65 filter as is, go back up to the Vaccine Priority Index – Category filter, and change the category to “Low.” Two Census tracts show up: one in Chatham County and one in Transylvania County. Even though these tracts have low VPI values, they nonetheless have a high number of residents over age 65. These tracts might have a high per capita income or some other factor that reduces their overall risk, but it still might be important to know that they are among the highest in the state in terms of number of individuals over 65 years of age.

## **VI. Considerations for Public Health and Decision Makers**

As a highly communicable, infectious agent, COVID-19 threatens the health and safety of society. Prevention and intervention efforts led by public health leaders can help mitigate such

risks to protect communities. The VPI is one component that can be used to assist decision makers spatially identify areas and locations of vulnerable populations when planning and preparing to mitigate risk, allocate resources and aid in recovery efforts.

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