Visualizing Opportunity Index Data Using a Dashboard Application: A Tool to Communicate Infant Mortality-Based Area Deprivation Index Information

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Abstract

Background An area deprivation index (ADI) is a geographical measure that accounts for socioeconomic factors (e.g., crime, health, and education). The state of Ohio developed an ADI associated with infant mortality: Ohio Opportunity Index (OOI). However, a powerful tool to present this information effectively to stakeholders was needed.

Objectives We present a real use-case by documenting the design, development, deployment, and training processes associated with a dashboard solution visualizing ADI data.

Methods The Opportunity Index Dashboard (OID) allows for interactive exploration of the OOI and its seven domains—transportation, education, employment, housing, health, access to services, and crime. We used a user-centered design approach involving feedback sessions with stakeholders, who included representatives from project sponsors and subject matter experts. We assessed the usability of the OID based on the effectiveness, efficiency, and satisfaction dimensions. The process of designing, developing, deploying, and training users in regard to the OID is described.

Results We report feedback provided by stakeholders for the OID categorized by function, content, and aesthetics. The OID has multiple, interactive components: choropleth map displaying OOI scores for a specific census tract, graphs presenting OOI or domain scores between tracts to compare relative positions for tracts, and a sortable table to visualize scores for specific county and census tracts. Changes based on parameter and filter selections are described using a general use-case. In the usability evaluation, the median task completion success rate was 83% and the median system usability score was 68.

Keywords

- data visualization
- area level deprivation
- geographical information system
- infant mortality
- social determinants of health

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Conclusion The OID could assist health care leaders in making decisions that enhance care delivery and policy decision making regarding infant mortality. The dashboard helps communicate deprivation data across domains in a clear and concise manner. Our experience building this dashboard presents a template for developing dashboards that can address other health priorities.

Background and Significance

Ohio ranked as the eighth-worst state in the United States for infant mortality in 2017, with 7.2 infant deaths per 1,000 births.[1,2] There is a large disparity between white and black infants; the infant mortality rate was almost three times as high among black infants (15.6 per 1,000 births for black infants vs. 5.3 for white infants in 2017).[2] Although a few causes of infant mortality are primarily due to genetic factors, there are medical, behavioral, and environmental risk factors that also increase the risk of infant mortality.[3,4] Medical and behavioral risks including hypertension; diabetes; unplanned pregnancy; drug, alcohol, or tobacco use; poor nutrition; late or inadequate prenatal care; and stress can interact with environmental risks such as poverty, poor social support, transportation barriers, and low food availability.[5–11] Women who live in low-income or highly segregated neighborhoods may have multiple risk factors that are exacerbated by their environment.[12]

Taken together, these risk factors disproportionately affect women in black communities and urban communities. For instance, preterm birth is among the leading risk factors for infant mortality; the proportion of preterm birth-related deaths was 41% for infants of black mothers in comparison to 34% for the general population.[13] Moreover, black mothers are more likely to experience the risk factors of late or inadequate prenatal care, unintended pregnancy, stress, poverty, anemia, hypertension, and obesity more than other races.[7,12] Despite reductions in the disparities between black–white infant mortality rates in some states, significantly higher infant mortality rates among black infants persist in certain geographic areas that public health programs need to address.[14,15] Areas with large disparities in infant mortality experience additional health disparities related to low socioeconomic status and poor health equity, encouraging interventions in these high-risk communities.[16,17]

Effective interventions or policies targeting infant mortality must account for multifaceted deprivations existing across communities.[18] Such deprivations have been measured by composite measures that are known as area deprivation indices (ADIs). ADIs are geographically based measures of socioeconomic status that take into account for factors that may include income, employment, transportation, crime, health, education, and housing quality.[19] There is evidence supporting the use of a geographic approach to map deprivation across multiple indices, which can inform policy makers about the areas with the highest concentration of at-risk individuals with the highest levels of need.[20–22] Measures of ADI have been associated with higher risk of and increased adverse birth outcomes.[23,24]

Insights using ADI can inform the enactment of reliable and effective interventions or policies targeting women in high-risk communities, including women in Ohio. There are multiple efforts in the United States to visually map disparities in opportunity that inspired this work.[25–28] The need for an Ohio-specific deprivation index was recognized among Ohio policy makers and researchers. This concern led to the development of the Ohio Opportunity Index (OOI). The OOI is a collaboration between the Ohio Department of Medicaid and researchers at The Ohio State University. To create the OOI, first, census data and other population-level data were aggregated across the seven domains of transportation, education, employment, housing, health, access to services, and crime. Within each domain, variables measuring different aspects of the domain were assessed and scored, such that each domain score is a combination of three to seven variables. These domains are weighted and then summed to yield an overall score. This overall score describes the relative deprivation/opportunity of different census tracts across the state. Once the OOI was created, additional collaboration was necessary to develop ideas for how this data will be communicated to stakeholders and the public in an effective manner.

A clear and concise approach to communicating ADI information is through the visualization of deprivations across geospatial boundaries to help identify clusters of risk factors. Data visualization can be broadly defined as a purposeful use of any physical object (digital or analog) for some form of analysis of data.[29] It is the graphical representation of data to enhance cognition that, when made interactive through a dashboard, also provides users with the ability to carry out multiple tasks to achieve their intended goals.[30–32] Interactively visualizing an ADI associated with infant mortality on a dashboard can present health care providers with valuable insights about their patients' social determinants of health and provide policy makers with information to make better decisions to alleviate infant mortality across the state. The dashboard we have developed represents one of the first of its kind for Ohio and will be a template for similar dashboards that can be used to effectively communicate information to stakeholders for other health care priorities. The priorities may include health inequities, chronic diseases, childhood development, and mental and behavioral health.

Objectives

The primary objective set forth by our funders was the development of a functional and interactive dashboard that included training material. Our secondary objective focused on designing

the dashboard to be user-centered, a process that involved engaging in cocreation of the tool with key stakeholders and ensuring that the tool was usable. We present a real use-case to describe the process for developing a dashboard solution to visualize ADI data in Ohio. For our design considerations, our use-case was built around two primary scenarios: (1) the public agency stakeholder using the dashboard to identify critical areas of health disparities that in turn could inform policy and resource allocation decisions; and (2) a community-based health organization referencing information on the dashboard to increase awareness about individuals' social determinants of health that in turn could influence care delivery. We document our journey through the design, development, deployment, and training elements associated with our dashboard solution. Specifically, our study describes the following: the creation of the OOI; use of Tableau to visualize this information as a dashboard; summary of the feedback from stakeholders for the improvement of the function, content, and aesthetics of the dashboard in-keeping with the user-centered approach we employed; and finally the usability testing of the dashboard that entails evaluations of the effectiveness, efficiency, and satisfaction with using the dashboard.

Methods

Our dashboard represents a real use-case representing how design, development, and implementation occurred based on important relationships and needs that existed among stakeholders.

Setting

Our project is an extension of the Infant Mortality Research Project to improve birth outcomes. Our project consists of multiple stakeholders working together to examine the social, behavioral, and health risk factors that contribute to infant mortality and affect birth outcomes in Ohio. The project is sponsored by the Ohio Departments of Higher Education and Medicaid and funded in part by the Ohio Medicaid Technical Assistance and Policy Program. The project sponsors helped guide the research team by helping them collaborate to create a dashboard that met the sponsors' goals. Researchers at the Ohio State University and at the Ohio State University Center for Urban and Regional Analysis compiled the pertinent data sources and calculated the standardized measures, domain scores, and index score. The development of the dashboard provides an opportunity to understand and identify the social determinants of health experienced in Ohio census tracts that undermine health for individuals. The structure of the data and its presentation in the article are based on this project.

Our research team consisted of a biomedical informatician, an infant mortality subject matter expert, an expert in geographic information systems, a computer programmer, a project manager, and a scientific editor.

The Ohio Opportunity Index Dashboard

The Opportunity Index Dashboard (OID) utilizes the OOI, a measure of opportunities available to people in a given census tract. The index is constructed at the census tract level. Higher scores indicate relatively greater opportunity or lower deprivation; lower scores denote lesser opportunity or higher deprivation. The index is composed of 34 measures organized in seven domains. The primary end-users are subject matter experts; other users could include health care providers and the public. The current implementation reflects a partial rollout of the dashboard. The OID is on a password-protected online server accessible by the research team and project sponsors. The stakeholders are collaborating to provide a public version online in the future.

Data Structure and Development of Metrics

The index used for the OID is a relative measure that is a "composite of different dimensions or domains of deprivation"[22] and focuses on a specific area level. To limit cancellation effects of one domain over another, the index is weighted. In many ways, the OOI is similar to the deprivation indices used in England, New Zealand, and Scotland, where they have been used for targeted policy interventions and initiatives to alleviate social and economic problems such as poverty.[20–22]

The OOI is a measure comprising 34 variables that capture the social and economic opportunities present across Ohio. ►Table 1 provides an overview of variables included in the OOI and the approach used to combine the variables. Seven domains were identified as being associated with health and well-being: crime, education, employment, health, housing, transportation, and access to services. Several variables linked to each domain were identified through an iterative process (see ►Fig. 1 for variables associated with each domain). The primary sources for the variables used are: The American Community Survey, Ohio state databases (e.g., Housing Finance Agency, Department of Health, Department of Education, and Department of Medicaid data sets), Longitudinal Employer-Household Dynamics, and Infogroup business data. The data from these sources were extracted for the years 2012 to 2016.

Data for each variable was first obtained for 2,948 of the 2,952 census tracts in Ohio. The census tract level of aggregation provides a standard geographical area that can help generate statistically robust estimates and minimizes the potential for small area shrinkage estimations that may be prevalent at more granular levels. Following Townsend et al's[33] and Noble et al's[22] approach, we computed the OOI based on the following procedures:

(1) Standardizing and summing: Each variable is converted to a *z*-score (some are inverted to harmonize the direction of the values and make them comparable across variables). These *z*-scores are subsequently summed within each domain.

(2) Ranking: The summed *z*-scores for a domain are ranked and scaled to a range between 0 and 1 (with the least deprived tract having a 1/number of tracts score).

(3) Exponential distributing: An exponential distribution, according to Noble et al,[22] helps each domain have a common distribution, the same range, and identical maximum and minimum values. (This helps isolate the impact of domain weights when the domains are weighted and combined into a single index.) The distribution also helps to buffer the effect of

Table 1 Ohio Opportunity Index domains and variables associated with the domains

Domain	Variables
Transportation	• Public transit access[a] • Average commute time to employment[a] • Households without access to a vehicle[a]
Education	• Population with an associate's degree or higher[a] • Average school performance[b] • Average free and reduced lunch rate[b] • High school dropout rate[b]
Employment	• Low-wage job access by educational attainment[c] • Access to workforce or job training sites[d] • Unemployment rate[a]
Housing	• Median rent[a] • Median home value[a] • Concentration of existing low-income housing tax credit units[e] • Population living with overcrowding[a] • Population that moved 3+ times in the last year[a]
Health	• Poverty rate[a] • Preterm-birth rates[f] • Age-adjusted mortality rate[g] • Preventable emergency department admissions/visits[h] • Cardiovascular disease deaths/admits[h] • Diabetes admits/diagnoses[h] • Diagnosis with drug addiction or Medication Assisted Treatment[h]
Access	• Access to healthy food options[d] • Distance to nearest primary care physician[d] • Distance to nearest primary/secondary school[d] • Distance to nearest post office[d] • Availability of internet connection[i]
Crime	• Homicide, aggravated/sexual assault[j] • Robbery[j] • Burglary, larceny, motor vehicle theft[j] • Public drunkenness and driving under the influence[j] • Drug-related crime[j]

[a]American Community Survey.
[b]Ohio Department of Education.
[c]Longitudinal Employer Household Dynamics.
[d]Infogroup business data.
[e]Ohio Housing Finance Agency.
[f]Ohio Department of Health.
[g]Department of Vital Statistics, Ohio Department of Health.
[h]Ohio Department of Medicaid.
[i]Federal Communication Commission.
[j]Office of Criminal Justice Services, Ohio Department of Public Safety.

population size of the census tract, creates a "tail" that spreads out the most deprived census tracts in each domain, and regularizes the cancellation property used in the creation of the OOI. To achieve this, the ranks are transformed using the exponential distribution, making each domain's value range from 0 to 100. The transformed domain would be given by[22]:

$$X = -23\ln\{1 - R[1 - \exp - (100/23)]\}$$

Following Noble et al we retain the constant,[22] which determines that roughly 10% of census tracts have a score higher than 50. This skewness ensures that the combined domains do not cancel each other out, wherein the low opportunity in one domain can be cancelled out by a high opportunity in another.

(4) Factor analyzing: A factor analysis approach was used to attach weights to each domain to gauge the different levels of contribution in opportunity toward the OOI. This approach allows us to extract a "latent factor" called overall OOI with standardized coefficients that represent the specific contributions of each domain toward this factor.

The data file used for our dashboard contains one row per census tract. For each tract, the data comprises variables that report the county, the OOI score, and the seven constituent domains. The current data file contains information for only one period, with the goal of incorporating additional period and a longitudinal element to the dashboard once additional data for the domain variables become available.

Dashboard Structure

The original request from project sponsors divided the dashboard into three components: (1) visualizing OOI scores for a specific census tract on the Ohio map displayed with the help of a choropleth map; (2) visualizing plots of OOI or domain scores between tracts to compare relative positions for tracts; and (3) visualizing sortable scores in a table for a specific census tract. The project sponsors requested an interactive display that allows the user to select specific parameters that in turn would update the display. Other sponsor requirements included using Tableau as the visualization software, deploying the dashboard to a secure Tableau Server environment, creation of a training manual, and conducting feedback and usability sessions to solicit input on the OID from end-users.

Tableau Data Visualization

As noted by Wahi and Dukach,[34] statistical software packages such as SAS, STATA, and SPSS have been traditionally used for health data analytics, but these products are limited in regard to visual capabilities and require knowledge of programming languages. Tableau uses VizQL, a visual query language that can convert drag-and-drop actions into data queries.[35] Tableau Desktop allows the visualization team to first connect to a data set (stored in files, warehouses, and online clouds), and subsequently use a front-end interface to concomitantly query the data and view the results in different graphical forms (e.g., charts, graphs, and maps). Independent worksheets containing specific visuals can then be arranged together on dashboards that can communicate key insights. These visuals can also be linked together by the creation of filters, parameters, and actions to make the dashboard react to user actions that direct the visuals to display a specific type of information (e.g., highlighting or subsetting a specific census tract) across one or more visuals.

For geospatial visualizations, Tableau can automatically recognize several geographical fields and generate respective latitude and longitude coordinates. These include state,

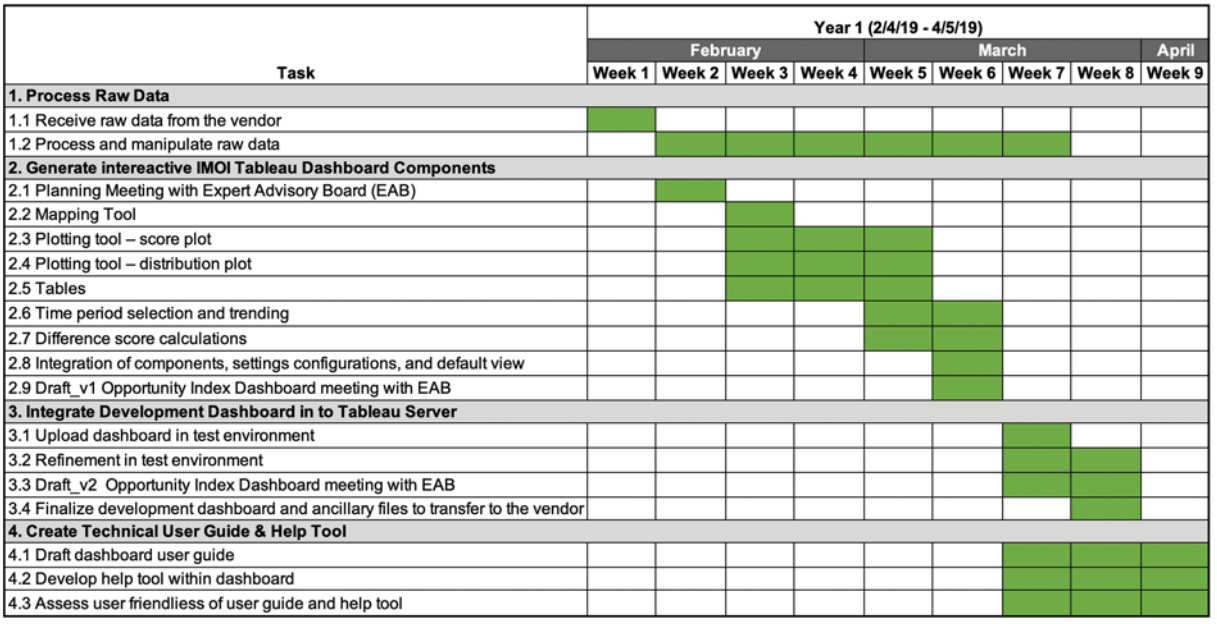

Fig. 1 Key milestones and project timeline for the Ohio Opportunity Index Dashboard.

county, metropolitan statistical area, and ZIP code. However, as our geographical focus is on census tracts, we imported an Esri[36] shapefile of Ohio with vector data that included the latitudes and longitude coordinates for the state's census tracts. We linked our data set file with this shapefile in Tableau Desktop using the Federal Information Processing Standards code as the primary key.

Iterative Testing of Prototype and Usability Evaluation

Our approach to developing, testing, and deploying the OID followed a user-centered design approach. This approach involved constant engagement with various stakeholders (representatives and end-users from project sponsors and subject matter experts that formed an external advisory board), who provided our team with feedback at predefined milestones on the progress of the project. These key milestones are presented in the project timeline (see ►Fig. 1).

Additionally, our team conducted a usability study with the end-users from project sponsors after a production-ready version of the OID, which incorporated feedback from prior versions, was deployed on the Tableau Server.

The usability study involved an evaluation of the OID that focused on the effectiveness of the dashboard and satisfaction from its use, these are primary outcomes that have been similarly employed by other dashboard evaluations.[37–39] Wu et al define effectiveness as the accuracy and completeness of achieving goals and satisfaction as subjective opinions of use. Given the use of dashboards to discover insights through exploration, we recognize the challenges with operationalizing an efficiency metric on dashboard use and chose to informally track this metric.[40] Six potential end-users from our state agency participated in our usability evaluation session. Prior research has shown that a single iteration of usability testing with at least five participants uncovers 85% of usability problems.[41] Of the six participants, two participants had analyst roles and four participants had administrative roles with varying levels of seniority. Our study and all instruments were reviewed by our institutional review board and deemed exempt (see page 522 of the ►Appendix A for the instruments).

For this usability study, we operationalized effectiveness in two ways: (1) administer a survey and focus group to inquire about participants' expectations for the OID, challenges with using the dashboard, and potential improvements to the tool; and (2) cognitive tests to assess their ability to successfully accomplish seven tasks that reflect potential uses of the dashboard. Results from the survey and focus group were recorded and summarized. We scored successful completion of tasks with the number 1 and a 0 otherwise. In regard to efficiency, we operationalized this by benchmarking the time the participants needed to complete tasks with a preestablished time to completion threshold (i.e., 15 minutes for all tasks) that was deemed reasonable based on a priori tests completed by three members of our research team.

Satisfaction was operationalized through the 10-item System Usability Scale (SUS) and administered at the end of the usability session.[42] The SUS is a flexible questionnaire designed to assess any technology, and is relatively quick and easy to complete. It consists of 10 statements that are scored on a 5-point scale of strength of agreement. These scores are first transformed, where individual SUS scores are converted to a consistent, positive score range from 1 to 10 by either taking the raw score and subtracting by 1 and multiplying by 2.5 (for positive questions) or taking the raw score and subtracting from 1 and multiplying by 2.5 (for negative questions). These scores are subsequently totaled for each responded for a score range of 0 to 100. A higher score indicates better usability. As a general rule, a lower score means that the system needs continued improvement.[42]

Data Analysis

We used descriptive statistics to analyze task completion. Descriptive statistics were also used to summarize the SUS

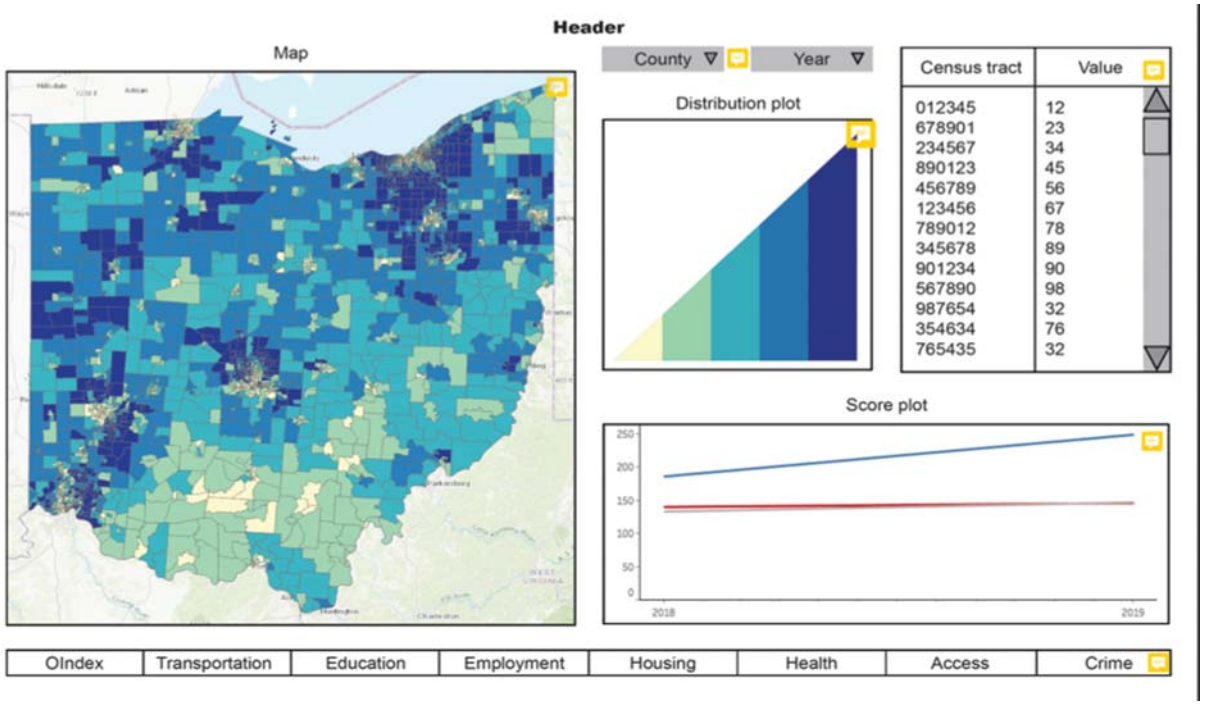

Fig. 2 Adobe InDesign mockup of the Opportunity Index Dashboard (OID). Comments at the top right of each component consisted of a brief description of that component.

scores across all evaluators of the dashboard, and mean scores for each SUS question are graphically displayed. Analysis of the usability metrics was performed using Microsoft Excel.

Results

The dashboard team initially created a mockup of the OID in Adobe InDesign (see ►Fig. 2). This document contained the critical elements of the dashboard as defined by the project sponsors and was annotated to briefly describe key aspects of the dashboard. This document was then presented at an external advisory board meeting, where the subject matter experts and representatives from the project sponsors provided initial feedback.

►Table 2 lists the initial feedback factored into the development of the prototype dashboard. An initial prototype of the OID was created and presented to the stakeholders along with a brief functional test with project sponsor end-users. Together, several improvements to the dashboard were suggested, and we summarize these in ►Table 3. For our summaries, we generally categorize feedback into one of three groups: (1) function, issues that are related to thoughtful navigation of the dashboard;

Table 2 Feedback and rationale from dashboard mockup

Problem	Rationale
Content	
• Reverse OOI scores from least opportunity having higher OOI scores to having lower scores	As the OOI score was to demonstrate opportunity and not deprivation, reversing the values from the original score allowed for easier interpretation
• Switch from quantile to septile groups of the OOI score to use in the state-level heat map	Using quantiles did not provide adequate contrasts between OOI scores, and it was decided that the septile distribution was easier for interpretation
• Remove temporal trend function in the score plot	The data used for calculating the OOI score is currently static and this functionality would only be required for a future iteration when additional years of OOI data are available
Aesthetics	
• Increase the size of the map and allow the map to zoom in to a specific county	Provide end-users with a convenient map that was easy to read and help them focus on census tracts within a county of interest for the end-user

Abbreviation: OOI, Ohio Opportunity Index.

Table 3 Feedback and rationale from initial prototypes

Problem	Rationale
Function	
• Turn off hovering and switch to selection feature	Rapid changes while hovering made it distracting for the end-user to navigate the dashboard
• Selection of county results by filtering dashboard content to only the census tracts within that county	This helped the end-users specifically assess the census tracts within a county of interest
• Provide an icon by each component to help the end-user understand it	Provide end-users with a conveniently located icon to quickly understand what the information a specific component can provide them
• Display street and highway patterns	Allow end-users to get a better sense of the communities present within a census tract by locating them using streets and highways
• Improve dashboard performance and load time	Improving response time of the dashboard components would ensure that end-users continued to use the dashboard over time
Content	
• Include a breakdown of domain scores in the table and provide standard deviations from the mean of a census tract for each domain variable in the score plot	As the raw values were highly skewed for domain variables, use of standard deviations provided for a simple and quick means for end-users to gauge whether a census tract's score is better or worse than its standardized mean for a specific variable
• Switch distribution plot from using rank on the *Y*-axis to actual OOI score in the *Y*-axis	The linear ramp was misleading because it led to misinterpretation of the OOI score and did not let the user quickly identify the distribution of the OOI scores across all census tracts
Aesthetics	
• Use a divergent color scheme for the heat map	The initial green-gold color scheme made it difficult to identify census tracts that were in the middle septile groups on the heat map.
• Allow each domain variable to cluster together when multiple census tracts are selected	Provide end-users with a convenient means through which they can directly compare how two or more census tracts are performing for a specific domain or domain variable
• Switch the score plot from line plots to bar graphs	The connecting of dots across domains provided no statistical or theoretical significance; bar graphs were more effective at communicating scores across domains or domain variables

Abbreviation: OOI, Ohio Opportunity Index.

(2) content, problems with information provided in the dashboard that complicate or lead to misinterpretation of data; and (3) aesthetics, concerns that impede the dashboard from having a minimalist design that effectively communicates information.

These improvements were all incorporated in a production version of the dashboard and reflect comments that were made over the course of several months and multiple in-person/virtual meetings.

Usability Evaluation: Effectiveness and Efficiency

In regard to expectations for use, it was noted that end-users might use it to identify health disparities occurring among health beneficiaries with specific health conditions. The median success rate in regard to task completion rate for the seven tasks by our participants was 83%, with participants finding three tasks particularly challenging. Focus group feedback indicated that misinterpretation of metrics and incorrect use of dashboard components were the primary causes for failure to complete the tasks. Several participants noted that prior knowledge about the dashboard software could have significantly helped in the use of the OID. For example, it could have helped to know how to quickly reset views, resize the map, and use keyboard shortcuts. The approximate time range to complete tasks ranged between 20 and 30 minutes.

Final Usability Evaluation: Satisfaction

►Fig. 3 illustrates the average scores for each of the SUS domains. The dashboard median SUS score of 68 (interquartile range 1.9) indicated good usability. A majority of participants noted that the dashboard was not unnecessarily complex and was an approachable tool. There was, however, some ambivalence about ease of use and challenges to quickly learn to use the dashboard.

Based on the feedback from our final usability session, we improved an existing training manual we had developed for the OID, which would aid end-users. This manual was developed to familiarize the end-user with the components present in the OID. Each section of this guide explained the capabilities of a different component (available by authors upon request). We also used the feedback to improve the visual elements on the OID to make sure the information presented was better able to aid the end-user to use the

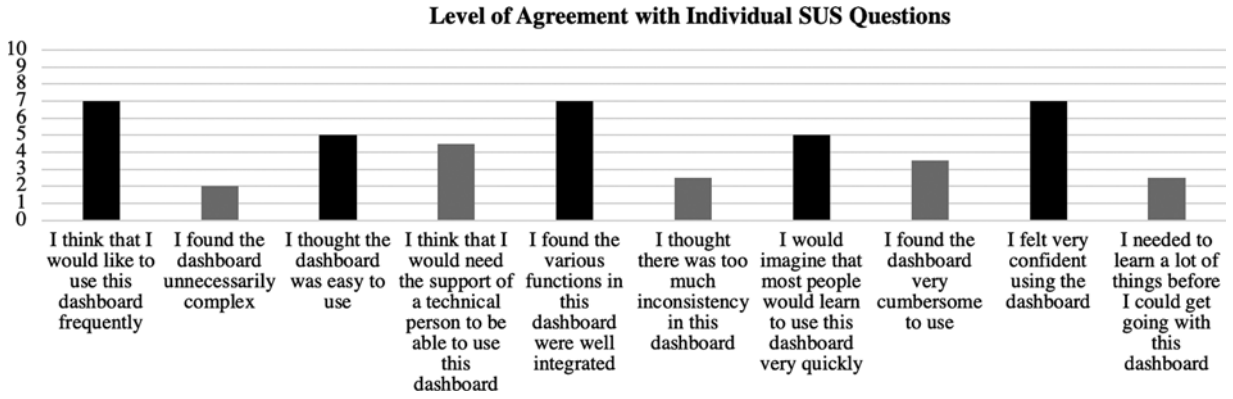

Fig. 3 Summary of System Usability Scores (SUS) by individuals' components. Bars in black are positively worded and those in gray are negatively worded. Negatively worded responses are transformed in order for lower scores to indicate more favorable responses.

dashboard. ►Fig. 4 provides an overall snapshot of the current OID. ►Fig. 5 illustrates how the map displays census tracts that belong to a specific septile group based on the end-user's selection on the OI septile groups legend. ►Fig. 6 is a snapshot of the dashboard when one county, Harrison, is selected. ►Fig. 7 is a snapshot of the dashboard when three census tracts within Harrison County are selected and compared for the Health domain. In the figure, the table provides the summary score for the Health domain, and hovering over each census tract in the table provides its ranking for that domain across all the census tracts in the state. The distribution plot highlights where each tract falls in regard to the score distribution across all the census tracts. The score plot provides a comparison of the census tracts for a specific measure used to compute the Health domain, and each score represents a standard deviation from the mean. Deviations greater than plus or minus 1 indicate the census tract has a subcategory score greater than 95% of the scores from other census tracts. Deviation greater than plus or minus 2 are greater than 99.7% of scores.

Discussion

Environmental disparities are associated with poor health and both infant and adult mortality, encouraging geographical research to describe, visualize, and imagine solutions for these disparities. The OID was created to visualize 7 key domains made up of 34 variables that vary geographically to show the areas with the highest and lowest levels of opportunity. The census-tract level map of Ohio shows scores that further describe the specific disparities experienced. These results suggest that the health care delivery system could be more responsive to the needs of patients with more complex underlying social determinants of health, particularly for women of reproductive age. It could help health care providers deliver better health care as they are cognizant of the social

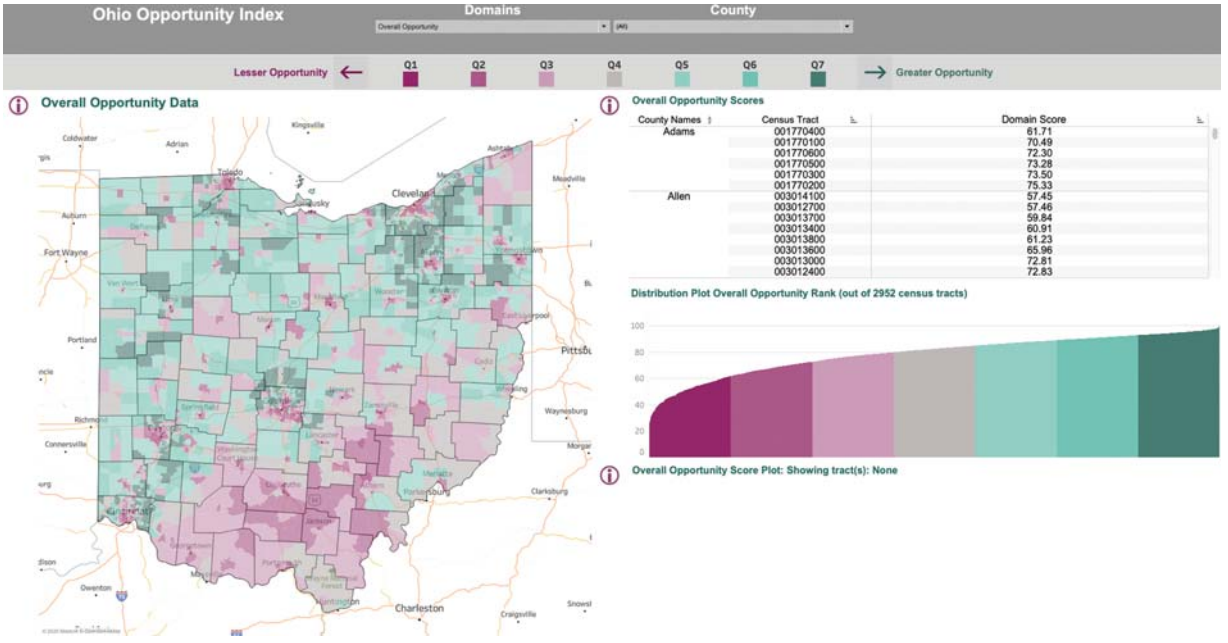

Fig. 4 Overall snapshot of the Opportunity Index Dashboard (OID). The OID offers four major components: a map, a table, a distribution plot, and a score plot. The score plot, located in the bottom right, activates only when the end-user selects an appropriate subset of census tracts.

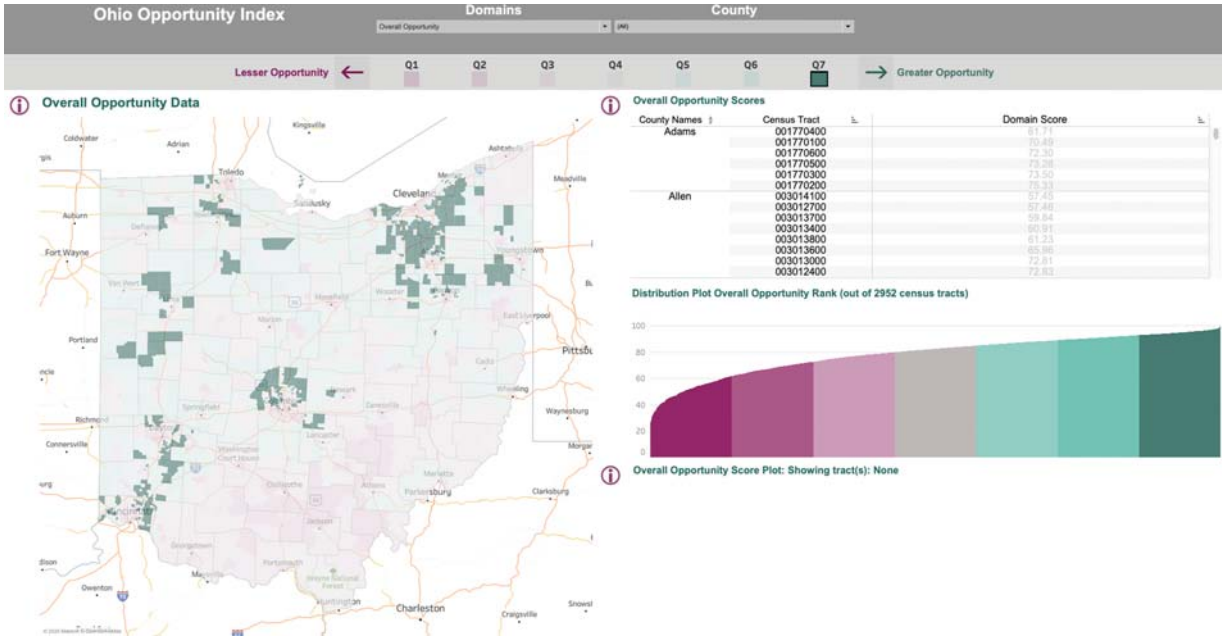

Fig. 5 Snapshot of how the map displays census tracts that belong to a specific septile group based on the end-user's selection on the Ohio Opportunity Index (OOI) septile groups legend. By selecting a septile in the map legend, the corresponding census tracts are highlighted on the map to show their geographic distribution.

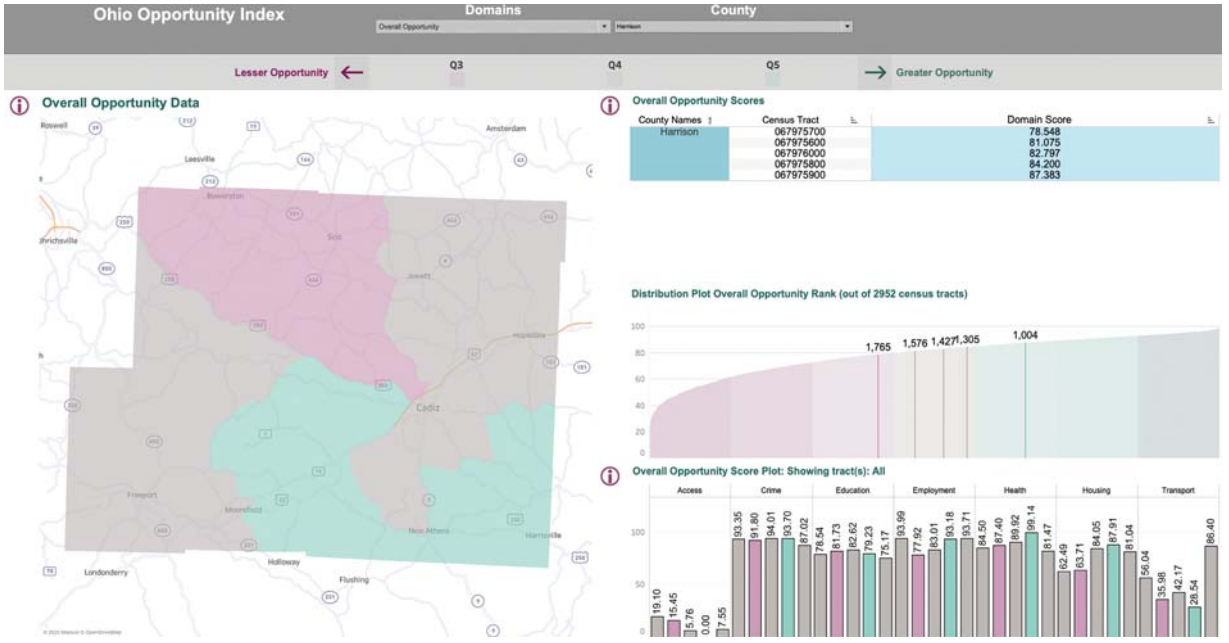

Fig. 6 Snapshot of the dashboard when one county is selected. When a county is selected, the score plot will populate to show the domain scores for each census tract within that county to allow for comparisons by the end-user. The map also zooms in on the selected county.

determinants of health. Both health care providers and public health programs can focus efforts that provide multidisciplinary services that combine health and social care in lower OOI census tracts. In addition, this information can be used to prioritize getting people likely to experience multiple risk factors into health care and preventative care before, during, and after pregnancy. It should be noted that the deprivation index used for our study is positively framed as an "opportunity" because there is the potential to learn from communities that are successful or performing well over time.

Despite this being the first large-scale opportunity index developed for the state of Ohio, there are similar efforts to map deprivation or opportunity in other parts of the United States. There is a national OID that maps by state and county on four domains, education, economy, health, and community, and with an overall score.[27] The major difference is that the OID maps by census tract and has additional variables and seven distinct domains. The national dashboard includes some of the variables in the OID housing and employment domain under "economy" and includes similar variables to

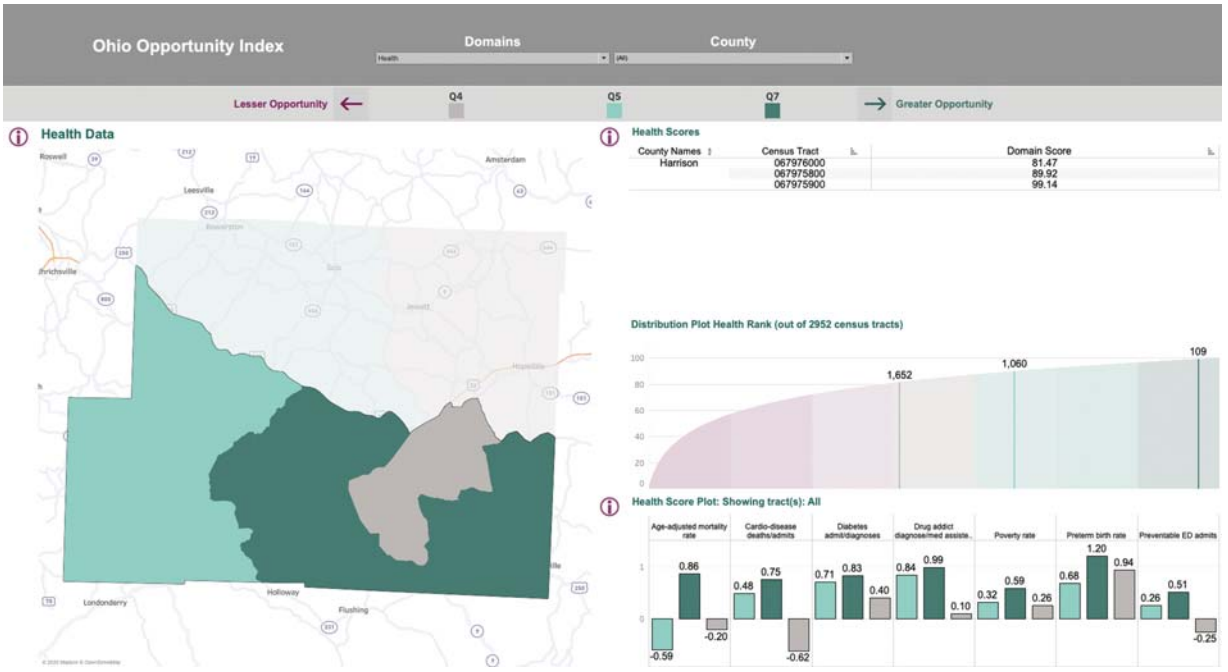

Fig. 7 Snapshot of the dashboard when three census tracts within a county are selected and compared for health. By selecting individual census tracts, the map will further highlight them. In addition, in this view, a single domain has been selected, and the score plot has adjusted to display the applicable domain scores as a standard deviation from the mean.

the OID access to services and crime domains in the "community" domain, but it does not include any variables related to transportation and has fewer health, housing, crime, and access variables throughout. One feature the national index has is an average score that each county is compared with, while the OID compares census tracts to each other. An average reference score may be a potential improvement for the OID to implement, however, the statistical implications of rolling up scores need further consideration. There is also a national Children's Opportunity Index that uses data for the 100 most populated metro areas in the United States, however, individual domains are not shown.[25]

One statewide effort is the Virginia Health Opportunity Index, which shows four separate domains and one overall score that are each visually mapped.[26] This is the closest visualization to the OID, and differs mainly on the availability of within-domain variable scores. Another statewide dashboard is the Regional Opportunity Index in California, and this has multiple layers to view six domains or an overall score, with comparisons for each census tract to the mean.[28] This dashboard differs from the OID because it does not rank census tracts compared with each other outside of the mapped colors. The dashboard, however, does have very extensive displays for variables within each census tract. Both the OID and these other efforts can be further improved by identifying strengths and weaknesses of other dashboards to inform future developments.

In keeping with the user-centered design approach, the most updated version of the dashboard has incorporated the feedback from the usability evaluation. It is noteworthy that respondents did not find the dashboard unnecessarily complex based on the results of the system usability survey. However, the findings from the cognitive tests and focus group revealed a need for technical assistance to better understand the metrics used in the creation of the OOI and some basic functions within Tableau. These findings have implications for the further refinement of the dashboard; future strategies may involve the creation of instructional videos on certain features of Tableau allowing users to reset views, resize the map, and use keyboard shortcuts, as well as videos explaining the metrics used to create the OOI. Research has shown that print and video as instruction media are used differently by users and each medium has its benefits and shortcomings[43]; the development of instructional videos will complement the training manual that has already been created in response to the evaluation feedback.

There are some potential concerns to consider when disseminating this tool to a wider audience. The OOI is a measure of a neighborhood rather than the individuals residing in it, and there may be interpersonal variation in opportunity; allocating funding to the people in the most need within a district therefore require more individualized data. Researchers and policy makers using the index need to exercise caution when presenting and sharing this tool and take care to avoid attaching any derogatory connotations of low opportunity areas with the people residing within them. Caution should be used when using this measure for purposes outside of policy making and research, as certain industries may try to use this tool to take advantage of communities at either end of the opportunity scale. Finally, OOI domains impacted rural and urban areas in different ways, and policy makers should take the individual variables into account when developing interventions instead of attempting a one-size-fits-all approach for low domain scores.

The index may be further revised in the future. Upcoming iterations could involve data that deconstruct variations that may exist between racial groups or socioeconomic factors. Additional years of data would allow for learning about temporal trends in opportunity data. This will specially enable end-users to view changes in census tracts over time for both overall and individual domain scores. Updates for different time periods will enable studies of effectiveness of interventions and funding, along with displaying social change as populations move to different areas. From a policy perspective, considerations for linking OOI scores to locations of service provision and specific health outcomes (such as infant mortality) across the census tracts could greatly inform decisions on targeting areas in need of resources. The demand for geospatial tools to display risk will continue to grow as improved data visualization tools proliferate and changing community dynamics lead to more individualized areas of risk.

Conclusion

Our Tableau dashboard provides an optimal software platform for a dashboard solution for visualizing opportunity index data across Ohio. Our journey through the development, design, and implementation of the dashboard provides a template for how other dashboards related to infant mortality or similar health care priorities can be approached. We submit that there may be other approaches that exist in this space; however, our study provides a detailed documentation of our experience that can be selectively or holistically replicated to benefit the development of future dashboards.

Clinical Relevance Statement

This dashboard application aims to assist health care leaders in making decisions that enhance health care delivery and policy decision making regarding infant mortality. The dashboard helps leverage deprivation data across various domains and communicates it in a clear and concise manner. Our experience and the template for this dashboard, moreover, present an opportunity for developing dashboards that can address other health care priorities.

Multiple Choice Questions

1. What was the primary reason for reversing the Ohio Opportunity Index scores used in the production Opportunity Index Dashboard?
   a. Allowed for easier interpretation.
   b. The information factored more dimensions of the Opportunity Index.
   c. Cheaper in cost.
   d. Correct for statistical skewness.

   Correct answer: The correct answer is option a. The purpose of the Ohio Opportunity Index score was to demonstrate opportunity and not deprivation, reversing the values from the original score allowed for easier interpretation. It is positively framed to as an "opportunity" because there is the potential to learn from communities that are successful or performing well over time.

2. How were the variables of the seven domains of the Ohio Opportunity Index reported in the Opportunity Index Dashboard?
   a. Raw values.
   b. Logged values.
   c. Inverse values.
   d. Standard deviations.

   Correct answer: The correct answer is option d. As the raw values were highly skewed for domain variables, use of standard deviations provided for a simple and quick means for end-users to gauge whether a census tract's score is better or worse than its standardized mean for a specific variable.

Protection of Human and Animal Subjects

Our study was reviewed by our institutional IRB and deemed exempt.

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Conflict of Interest

C.M.S reports grants from Ohio Department of Education and Medicaid, during the conduct of the study. N.F. reports grants from Ohio Department of Education and Medicaid, during the conduct of the study. A.A. reports grants from Ohio Department of Education and Medicaid, during the conduct of the study. T.G. reports grants from Ohio Department of Education and Medicaid, during the conduct of the study. P.J. reports grants from Ohio Department of Education and Medicaid, during the conduct of the study.

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Appendix A

Ohio Opportunity Index Usability Index Usability Evaluation: Cognitive Test

Your Name _____

Your Title _____

How have you used, or how do you expect to use, the Opportunity Index in your work?

1. Log in to the Dashboard: go.osu.edu/OID
   Username ODM_OID
   Password: XXXXXXXXXXXXX
2. Census tracts in quantile 1 (Q1) have the lowest levels of opportunity. On the map, find at least one way to highlight all census tracts in Q1.
3. Reset the map to its original display.
4. Select **Defiance County** on the table. Identify the census tracts in **Defiance County.** Record the following scores for these three census tracts:
   4a. Overall OI score for **039958100** _____
   4b. Education Sub-component score for **039958600** _____
   4c. Housing Sub-component score for **039958800** _____
5. In the table, make sure counties are sorted in alphabetical order. Then sort by overall OI score in descending order.
6. Find census tract **039958700** in Defiance County in the distribution graph (the graph immediately below the table) for overall OI.
   6a. In which quantile does it fall? ____
   6b. Where does it fall for the transport domain score? ____
7. Compare the OI score for census tracts **039958800** and **039958200** in Defiance County, as well as for each of the domain scores (access, crime, etc.). Describe the differences you see for Access, Crime, Education, Employment, Health, Housing, Transport, and OI.
   Tract 039958800:
   Tract 039958200:

Ohio Opportunity Index Dashboard: System Usability Survey

For each of the following questions, please circle the number that best reflects your reaction to the Opportunity Index Dashboard:

1. I think that I would like to use this dashboard frequently.
   Strongly Disagree (1) (2) (3) (4) (5) Strongly Agree
2. I found the dashboard unnecessarily complex.
   Strongly Disagree (1) (2) (3) (4) (5) Strongly Agree
3. I thought the dashboard was easy to use.
   Strongly Disagree (1) (2) (3) (4) (5) Strongly Agree
4. I think that I would need the support of a technical person to be able to use this dashboard.
   Strongly Disagree (1) (2) (3) (4) (5) Strongly Agree
5. I found the various functions in this dashboard were well integrated.
   Strongly Disagree (1) (2) (3) (4) (5) Strongly Agree
6. I thought there was too much inconsistency in this dashboard.
   Strongly Disagree (1) (2) (3) (4) (5) Strongly Agree
7. I would imagine that most people would learn to use this dashboard very quickly.
   Strongly Disagree (1) (2) (3) (4) (5) Strongly Agree
8. I found the dashboard very cumbersome to use.
   Strongly Disagree (1) (2) (3) (4) (5) Strongly Agree
9. I felt very confident using the dashboard.
   Strongly Disagree (1) (2) (3) (4) (5) Strongly Agree
10. I needed to learn a lot of things before I could get going with this dashboard.
    Strongly Disagree (1) (2) (3) (4) (5) Strongly Agree

Please share any additional feedback that we can use to improve the Opportunity Index Dashboard: