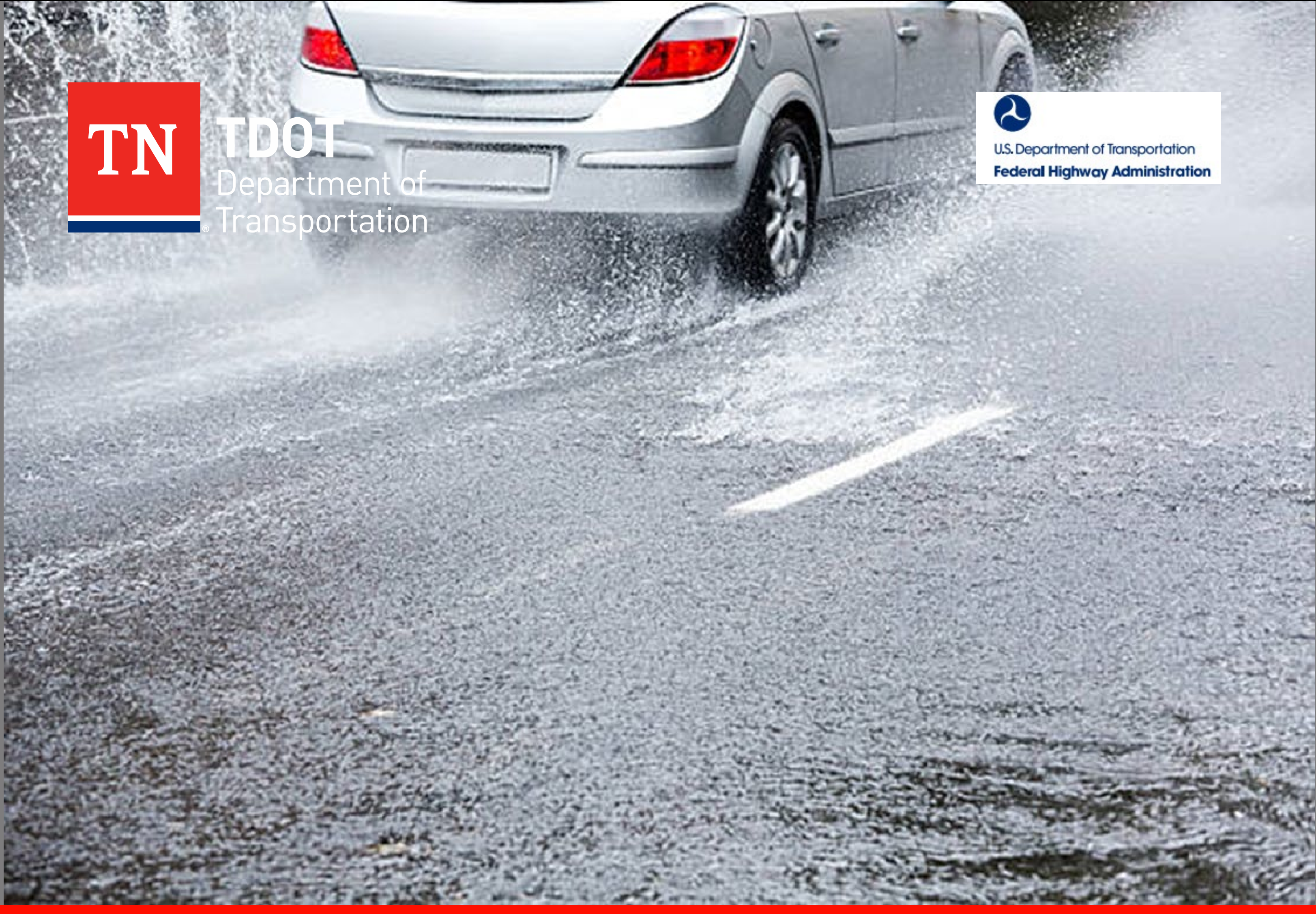

Enhanced GIS Legacy Database for TDOT Legacy Data Phase III: Power BI Applications

Research Final Report from Vanderbilt University | Madeline Allen and Mark Abkowitz | August 31, 2022

Sponsored by Tennessee Department of Transportation Long Range Planning Research Office & Federal Highway Administration

VANDERBILT UNIVERSITY

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16. Abstract
TDOT has embarked on an initiative to develop data analytics and visualization capabilities using the Microsoft Power BI platform to serve the agency's needs. Critical to the success of this initiative is the ability to identify, develop and serve a range of applications across TDOT's various divisions, covering a variety of operating modes within the state. However, to date only a few Power BI applications have been developed by agency staff, largely due to the lack of opportunity to design, develop and implement Power BI in ways that leverage information that TDOT obtains and manages. As a result, there are missed opportunities associated with performing both basic and comprehensive data analytics that become possible once TDOT staff become more aware and proficient in the use of Power BI.

The objective of this project was to create Power BI applications that enable more informed decision-making by TDOT in providing safe, secure, efficient and environmentally-friendly passenger and freight transport. This was accomplished by working in collaboration with TDOT staff to conceive, develop and implement Power BI applications for various TDOT divisions. An added goal of this research was to help mainstream the use of Power BI across the organization by providing the necessary knowledge, skills and experience to TDOT staff in support of workforce development.

This report contains a description of the following Power BI applications that were developed as part of this project. The Tennessee Crash and Safety Analytics Tool (TCAST) can be used to facilitate comprehensive safety analyses for Tennessee roadways. The Tennessee Pavement Analytics Tool (TPAT) enables users to explore the impact of pavement projects on roadway safety for Tennessee roadways.

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Executive Summary

The objective of this project was to create Microsoft Power BI applications that enable more informed decision-making by the Tennessee Department of Transportation (TDOT) in providing safe, secure, efficient, and environmentally friendly passenger and freight transport. This was accomplished by working in collaboration with TDOT staff to conceive, develop and implement Power BI applications for various TDOT divisions. An added goal of this research was to help mainstream the use of Power BI across the organization by providing the necessary knowledge, skills, and experience to TDOT staff in support of workforce development.

Technical Approach

At the outset of this endeavor, the research team met with TDOT Long Range Planning staff to identify Power BI applications with potential to improve the agency's mission. Candidate applications were then ranked according to priority, resulting in selection of the following for immediate development:

- Crash Safety Analysis
- Pavement Management

For each of these applications, the following multi-step process was performed in a sequential manner: 1) meet with TDOT staff to learn about available data and understand data analysis needs that could potentially be met by developing a Power BI analysis tool, 2) develop a storyboard that included a description of desired capabilities, functions and performance metrics, 3) invite storyboard feedback from TDOT following which the Power BI design specification was developed, 4) produce the application for beta testing, and lastly 5) finalizing the application and delivering the tool to TDOT to serve and maintain.

The TDOT Crash and Safety Analytics Tool, coined TCAST, is designed to facilitate comprehensive safety analyses for Tennessee roadways. The tool enables the user to query and display crash data, and provides dynamic data visualizations, as well as crash rate analyses for the queried results. All crashes since 2015 are included and regularly updated with new data. The following analyses are supported:

- Crash time and location
- Road and crash characteristics
- Crash functional class and facility type
- Crash hot spot identification
- Crash conditions
- Crash characteristics
- Comparisons between counties
- Annual crash rates
- Crash rate data range comparison

All roadway and crash data used for this application was retrieved from the Tennessee Roadway Information Management System (TRIMS) database, specifically from the Traffic, Road Segment, Geometrics, Roadway Description, Crash, Crash Driver/Vehicle, and Crash Motorist/Non-Motorist tables. Yearly Annual Average Daily Traffic (AADT) for traffic segments was obtained from the

Tennessee Traffic Information Management and Evaluation System (TN-TIMES) traffic station counts. GIS geoprocessing tools and Python were used to create the Crash and Roadway Traffic tables. Most crash attributes were obtained from the main TRIMS crash table, with further information on the people and conditions involved in each crash obtained from the other two tables. The Roadway Traffic table contains segmentation and descriptive attribute data as well as traffic counts, where available. The segmentation in this table was created through an overlay of the Road Segment, Geometrics, Roadway Description, and Traffic TRIMS tables. An AADT table downloaded from TN-TIMES was joined to the overlaid TRIMS roadway data table to create a finalized table with both roadway and traffic information.

The TDOT Pavement Analytics Tool (TPAT) is designed for the user to assess the impact of pavement projects on roadway safety for Tennessee roadways. The tool enables the user to perform batch analyses on any number of projects, and provides crash rate analyses for 1-, 2-, and 3-years before and after pavement projects. Pavement quality data from HPMA, pavement project data from PPRM, roadway and crash data from TRIMS, and traffic count data from TN-TIMES are included in the tool's database. All pavement project data was retrieved from PPRM from 2013 to present.

The projects included in this tool represent a variety of work types. These include resurfacing projects, as well as other project types which could have altered a road's pavement, such as widening, new construction, and realignment. The following analyses are supported:

- Road location
- Project characteristics
- Static pavement project table
- Filtering by crash characteristics
- Dynamic pavement project table
- Pavement quality over time

An interface also exists between TPAT and TCAST in that the user can explore crash rates for a specific project using TCAST by plugging the ID number and beginning and end log miles into the Crash Time and Location page of TCAST and utilize TCAST analysis capabilities thereafter.

In addition to the applications themselves, user manuals were prepared for TCAST and TPAT, respectively.

Findings and Recommendations

The activities associated with this project have demonstrated the high value of developing Power BI applications in supporting TDOT's mission. The agency is blessed with a large amount of data characterizing physical and operational characteristics of transportation assets in the state. Yet, at the same time, this amount of data can be overwhelming, making it difficult to support informed decision-making. Power BI offers a platform for organizing large amounts of disparate data into a cohesive and practical environment for performing analyses in support of a variety of TDOT's roles and responsibilities. It has the added value of being able to display results in several formats, including maps, graphs, tables, and other visual means that are best suited for understanding and communicating key observations.

In this project, PowerBI applications were developed to meet two priority needs, namely crash and safety analytics, and pavement management. The resulting tools, TCAST and TPAT, have been shown to be effective in utilizing data coming from multiple sources that enable TDOT staff to answer high-level questions, to delve deeply into root causes of problems, and to measure the effectiveness of planned interventions. This project has also provided an opportunity for TDOT staff to become more familiar with the use of PowerBI, which can serve as a catalyst for further workforce development.

In addition to recommending the continued and expanded use of TCAST and TPAT within the agency, it is suggested that TDOT move forward with the development of other Power BI-based tools, as there are several areas where such activity would prove meaningful. Examples include identifying locations of extreme weather hot spots, assessing transportation access for socially disadvantaged populations, studying truck parking, and public engagement, among others. Concurrently, it is recommended that TDOT invest in Power BI training for its workforce in order to expand this resource capability.

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Chapter 1 Introduction

The Tennessee Department of Transportation (TDOT) has embarked on an initiative to develop data analytics and visualization capabilities using the Microsoft Power BI platform to serve the agency's needs. Critical to the success of this initiative is the ability to identify, develop and serve a range of applications across TDOT's various divisions, covering a variety of operating modes within the state. However, to date only a few Power BI applications have been developed by agency staff, largely due to the lack of opportunity to design, develop and implement Power BI in ways that leverage information that TDOT obtains and manages. As a result, there are missed opportunities associated with performing both basic and comprehensive data analytics that become possible once TDOT staff become more aware and proficient in the use of Power BI.

The objective of this project was to create Power BI applications that enable more informed decision-making by TDOT in providing safe, secure, efficient, and environmentally friendly passenger and freight transport. This was accomplished by working in collaboration with TDOT staff to conceive, develop and implement Power BI applications for various TDOT divisions. An added goal of this research was to help mainstream the use of Power BI across the organization by providing the necessary knowledge, skills, and experience to TDOT staff in support of workforce development.

This report contains a description of two Power BI applications that were developed as part of this project. The Tennessee Crash and Safety Analytics Tool (TCAST) can be used to facilitate comprehensive safety analyses for Tennessee roadways. The Tennessee Pavement Analytics Tool (TPAT) enables users to explore the impact of pavement projects on Tennessee roadway safety.

Chapter 2 Methodology

At the outset of this endeavor, the research team met with TDOT Long Range Planning staff to identify Power BI applications with potential to improve the agency's mission. Candidate applications were then ranked according to priority, resulting in selection of the following for immediate development:

- Crash Safety Analysis
- Pavement Management

For each respective application, the following multi-step process was performed in a sequential manner:

Step 1: Meet with Potential TDOT Users

Meetings were arranged with TDOT staff engaged in managing and analyzing information related to applications involving Crash Safety Analysis and Pavement Management, respectively. The purpose of these meetings was to learn about available data and understand data analysis needs that could potentially be met by developing corresponding Power BI analysis tools.

Step 2: Develop Application Storyboards

Using the previously obtained information, a storyboard for each application was prepared. Each storyboard included a description of desired capabilities, functions and performance metrics. Once prepared, each storyboard was shared with potential TDOT users for review and comment. Their feedback was subsequently incorporated into a revised storyboard, which served as the Power BI application development specification.

Step 3: Develop Selected Applications

Based on the respective Power BI application development specifications, a first-generation Power BI tool was developed. This version of the tool was shared with potential TDOT users for beta-testing, following which the application was revised based on feedback received and made ready for agency use.

Step 4: Implement Application within TDOT

Each completed Power BI application was delivered to TDOT, for the purpose of having the agency serve and maintain the application thereafter. As part of the transfer process, a user guide was prepared for each tool and delivered to TDOT staff as an aid to enable full use of the Power BI application capabilities.

Chapter 3 Results and Discussion

3.1 Crash Safety Analysis Tool

The TDOT Crash Analytics and Safety Tool (TCAST) can be used to facilitate comprehensive safety analyses for Tennessee roadways. The tool enables the user to query and display crash data, and provides dynamic data visualizations, as well as crash rate analyses for the queried results. Roadway and crash data from the Tennessee Roadway Information Management System (TRIMS) and traffic count data from the Tennessee Traffic Information Management and Evaluation System (TN-TIMES) are included in the tool's database. All crashes since 2015 are included, and regularly updated with new data. The tool interface includes an initial overview page, followed by nine pages of filters and visualizations, as described below. Note that the tool is designed such that if a user makes filter selections on a particular page, analysis results on all subsequent pages are automatically updated. For example, if the user selects a single county, the remaining filter options are limited to activities within that county (e.g., only traffic segment IDs that are located in that county will be displayed).

Crash Time and Location: This page enables the user to filter crashes by various time- and location-related variables, including date range, year, crash time, urban vs. rural, county, route number, traffic segment ID, route name, and route ID number. Additionally, the user can filter by log mile range, applicable after a single route ID number has been selected.

Road and Crash Characteristics: Here, the user can filter crashes by road and crash characteristics variables, including through lanes, access control, divider, location type, highway type, functional class, crash severity, hit and run, construction zone, type of crash, truck or bus involved, number of vehicles involved, impaired driver, non-motorist involved, number of people involved, weather, lighting, speed limit, annual average daily traffic, and surface conditions.

Crash Functional Class and Facility Type: This page provides multiple visuals showing crashes based on functional class, location type, and time of day. The map on this page symbolizes crashes by severity; hovering the cursor over a specific crash displays a tooltip that provides information on the coordinates of the crash as well as the collision type, location type, traffic segment ID, and log mile.

Crash Hot Spots: A heat map is displayed on this page, showing the frequency of crash occurrences based on a variety of location-based filters, including county, functional class, location type, route number, route name, and traffic segment ID.

Crash Conditions: This page includes several visuals that show crashes based on lighting, weather, surface conditions, speed limit, number of through lanes and severity.

Crash Characteristics: Several visuals are presented on this page that show crashes based on the type of collision, severity, non-motorist involvement, construction zone presence, hit-and-run collisions, truck or bus involvement, impaired driver involvement, turn lane presence, and median presence.

Comparisons Between Counties: This page enables the user to compare crashes in multiple counties, and provides information on crashes by collision type, severity, truck or bus involvement, and location type. There is a map on this page that adjusts automatically when counties are selected and can also be explored manually. Crashes can be displayed by month, quarter, or year.

Annual Crash Rate Analysis: Here, the user can generate annual crash rates for a specified time period (currently available data includes the entire year for 2015 through 2020, and up to mid-October of 2021). Location-based filters are provided which enable the user to make adjustments to the crash query, in addition to the selection of year(s). Selections can also be made for county, route name, route number, traffic segment ID, route ID number, and log mile range. The page contains visuals that display annual crash rates based on crash severity and location type, and show the number of people injured, incapacitated, and killed in the associated crashes. Both Tennessee statewide crash rates (without geographic filters applied to them) and crash rates based on filter selections are provided to enable comparisons between what is occurring at the state level with the more specific analysis.

Crash Rate Data Range Comparison: This page enables comparisons of crash rates between two different date ranges as specified by the user. Note that it is highly recommended based on the Federal Highway Administration (FHWA) guidelines that a minimum of 12 months is examined in either date range. This page also includes visuals that display the crash rate by severity and location, as well as the total number of people killed, injured, and incapacitated in the crashes.

All roadway and crash data used for this application was retrieved from the TRIMS database, specifically from the Traffic, Road Segment, Geometrics, Roadway Description, Crash, Crash Driver/Vehicle, and Crash Motorist/Non-Motorist tables. Yearly Annual Average Daily Traffic (AADT) for traffic segments was obtained from TN-TIMES traffic station counts. GIS geoprocessing tools and Python were used to create the Crash and Roadway Traffic tables. Most crash attributes were obtained from the main TRIMS crash table, with further information on the people and conditions involved in each crash obtained from the other two tables. The Roadway Traffic table contains segmentation and descriptive attribute data as well as traffic counts, where available. The segmentation in this table was created through an overlay of the Road Segment, Geometrics, Roadway Description, and Traffic TRIMS tables. An AADT table downloaded from TN-TIMES was joined to the overlaid TRIMS roadway data table to create a finalized table with both roadway and traffic information.

Additional information about TCAST and corresponding use cases are included in the TCAST user guide, which appears in Appendix A of this report.

3.2 Pavement Management Tool

The TDOT Pavement Analytics Tool (TPAT) can be used to explore the impact of pavement projects on roadway safety for Tennessee roadways. The tool enables the user to perform batch analyses on any number of projects and provides the user with crash rate analyses for 1-, 2-, and 3-years before and after pavement projects. Pavement quality data from the Highway Pavement Management Application (HPMA), pavement project data from TDOT's Program, Project & Resource Management System (PPRM), roadway and crash data from TRIMS, and traffic count data from TN-TIMES are included in the tool's database. All pavement projects since 2013 and crashes since 2012 are included, and regularly updated with new data. The tool interface includes an initial overview page, followed by six pages of filters and visualizations, as described below.

Road Location: This page allows the user to filter by location-related variables, including county, route number, route name, urban vs. rural, and route ID number. Additionally, the user can filter by log mile range, applicable only after a single route ID number has been selected. As filter selections are made on this page, tables and visuals on all subsequent pages are automatically updated, so when a selection is made (e.g., a single county is selected), all the other filters show the remaining filter options (e.g., only traffic segment IDs that are located in that county will be displayed).

Project Characteristics: On this page, the user can filter by project characteristics, including program type code, project work type, contractor ID, project identification number (PIN), project completion date, total project length, and estimated project cost.

Static Pavement Project Table: Displayed here is a table showing the results of a batch analysis completed on all projects in the filtered selection. The main content in the table includes crash counts and crash rates for 1-, 2-, and 3-years before and after each project, as well as a 3-year percent change. Other data in the table includes the PIN, completion date, work type code, program type code, ID number, total project length, beginning and end log miles, and scope of work. It is important to note that this table is static; that is, it includes all crashes on the roads in the filtered project selection regardless of other geographic or crash filters. This is in contrast to the dynamic pavement project table described below. There are two filters included on this page - project work type and PIN; note that modifying selections within these filters will impact the filtered selection on all other pages. If interested in more detailed crash safety analysis, the user can associate information in this table for a specific project with the TCAST tool, by plugging the ID number and beginning and end log miles into the “Filters: Crash Time & Location” page of TCAST and exploring results presented in the subsequent TCAST pages.

Filtering by Crash Characteristics: Here, one can filter by crash characteristics, including characteristics of weather, surface conditions, lighting, type of crash (e.g., angle, head on, etc.), severity, and construction zone.

Dynamic Pavement Project Table: This page provides a table displaying the results of a batch analysis completed on all the projects in the filtered selection, BUT only for the crashes in the geographic and crash characteristic filtered selection (e.g., if the user selected “Wet” on the Surface Condition filter on the previous page, the resulting crash counts and crash rates in this table would only include crashes that occurred during wet conditions). The table includes crash counts and crash rates for 1-, 2-, and 3-years before and after each project, as well as a 3-year percent change. Other data in the table includes PIN, completion date, work type code, program type code, ID number, total project length, filtered project length, filtered beginning and end log miles, and scope of work. There are two filters included on this page - project work type and PIN; modifying selections within these filters will impact the filtered selection on all other pages. Similar to the static table, the user can further explore crash rates for a specific project using TCAST by plugging the ID number and beginning and end log miles into the “Filters: Crash Time & Location” page of TCAST.

Pavement Quality Over Time: This page contains line graphs displaying four pavement quality indices and average rut depth over time. The four indices displayed are: Pavement Quality Index (PQI), Pavement Distress Index (PDI), International Roughness Index (IRI), and Pavement Smoothness Index (PSI). These visuals are expected to be most helpful when a small number of projects are selected. Also, the project completion date is not shown in these visuals and should be considered when evaluating how the project impacted pavement quality on the specific road segment.

The projects included in TPAT represent a variety of work types. These include resurfacing projects, as well as other project types which could have altered a road's pavement, such as widening, new construction, and realignment. Pavement quality data was retrieved from HPMA from 2016 to present. It is important to note that TDOT does not collect pavement quality data annually on all road segments. Rather, data is collected in both directions every year only on interstates. Pavement quality on other road types, such as state routes or local roads, is collected on an alternating schedule. For these roads, pavement quality data is typically available for either only even or odd years.

All pavement project data was retrieved from PPRM from 2013 to present. All roadway and crash data used for this application was retrieved from the TRIMS SDE database, specifically from the Traffic, Road Segment, Crash, and Crash Driver/Vehicle tables. Yearly AADT for traffic segments was obtained from TN-TIMES traffic station counts.

The data model behind the TPAT interface consists of a database of related tables containing pavement, projects, roadway, and traffic data. The relationships between these tables are defined by where their features intersect on TDOT's linear referencing network. To effectively connect these tables, which contain data obtained from multiple different databases, a pre-processing script was developed in Python to generate the tables for the data model. The process performed by the script relied heavily on ArcGIS linear referencing tools to overlay route feature tables and identify relationships between features. The script was developed so that the tool's database could be updated with new data through a repeatable process, which can accept a standardized set of inputs, and produce a new set of tables which can be directly connected to the tool's database.

Additional information about TPAT is included in the TPAT user guide, which appears in Appendix B of this report.

Chapter 4 Conclusion

The activities associated with this project have demonstrated the high value of developing Power BI applications in supporting TDOT's mission. The agency is blessed with a large amount of data characterizing physical and operational characteristics of transportation assets in the state. Yet, at the same time, this amount of data can be overwhelming, making it difficult to support informed decision-making. Power BI offers a platform for organizing large amounts of disparate data into a cohesive and practical environment for performing analyses in support of a variety of TDOT's roles and responsibilities. It has the added value of being able to display results in several formats, including maps, graphs, tables, and other visual means that are best suited for understanding and communicating key observations.

In this project, PowerBI applications were developed to meet two priority needs, namely crash and safety analytics, and pavement management. The resulting tools, TCAST and TPAT, have been shown to be effective in utilizing data coming from multiple sources that enable TDOT staff to answer high-level questions, to delve deeply into root causes of problems, and to measure the effectiveness of planned interventions. This project has also provided an opportunity for TDOT staff to become more familiar with the use of PowerBI, which can serve as a catalyst for workforce development.

In addition to recommending the continued and expanded use of TCAST and TPAT within the agency, it is suggested that TDOT move forward with the development of other Power BI-based tools, as there are several areas where such activity would prove helpful. Examples include identifying locations of extreme weather hot spots, assessing transportation access for socially disadvantaged populations, studying truck parking, and public engagement, among others. Concurrently, it is recommended that TDOT invest in Power BI training for its workforce in order to expand this resource capability.

Appendix A - Tennessee Crash Analytics and Safety Tool (TCAST) User Guide

Version 1.0, Last Updated: December 2021

A.1 Tour of the Tool

The TDOT Crash Analytics and Safety Tool (TCAST) can be used to facilitate comprehensive safety analyses for Tennessee roadways. The tool enables the user to query and display crash data, and provides dynamic data visualizations, as well as crash rate analyses for the queried results. Roadway and crash data from TRIMS and traffic count data from TN-TIMES are included in the tool's database. All crashes since 2015 are included, and regularly updated with new data. The tool interface includes an initial overview page, followed by nine pages of filters and visualizations, described below.

A.1.1. Filters: Crash Time & Location

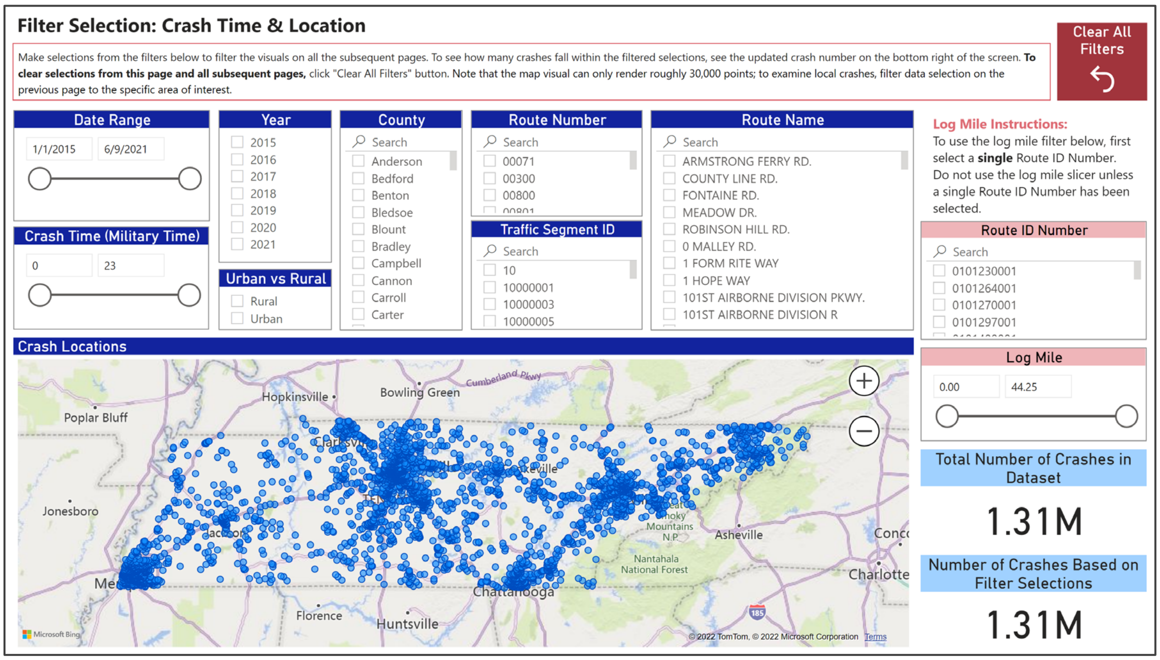


Figure A 1 Filtering by various Time and Location variables

The page shown in Figure A.1 allows you to filter by various time- and location-related variables, including date range, year, crash time, urban vs. rural, county, route number, traffic segment ID, route name, and route ID number. Additionally, the user has the ability to filter by log mile range, which should be done only after a single route ID number has been selected. As you make filter selections on this page, visuals on all subsequent pages are automatically updated, so when a selection is made (e.g., a single county is selected), all the other filters show the remaining filter options (e.g., only traffic segment IDs that are located in that county will be displayed). The number on the bottom right corner of the page under "Number of Crashes Based on Filter Selections" allows you to monitor how many crashes are still included in the data being analyzed and visualized. The map on this page renders roughly 30,000 points and can be helpful when making different geographic selections; just keep in mind that if the number of crashes being examined is above 30,000, then this map will not show every crash. See the disclaimer at the top of the Power BI page for additional information and instructions.

A.1.2. Filters: Road & Crash Characteristics

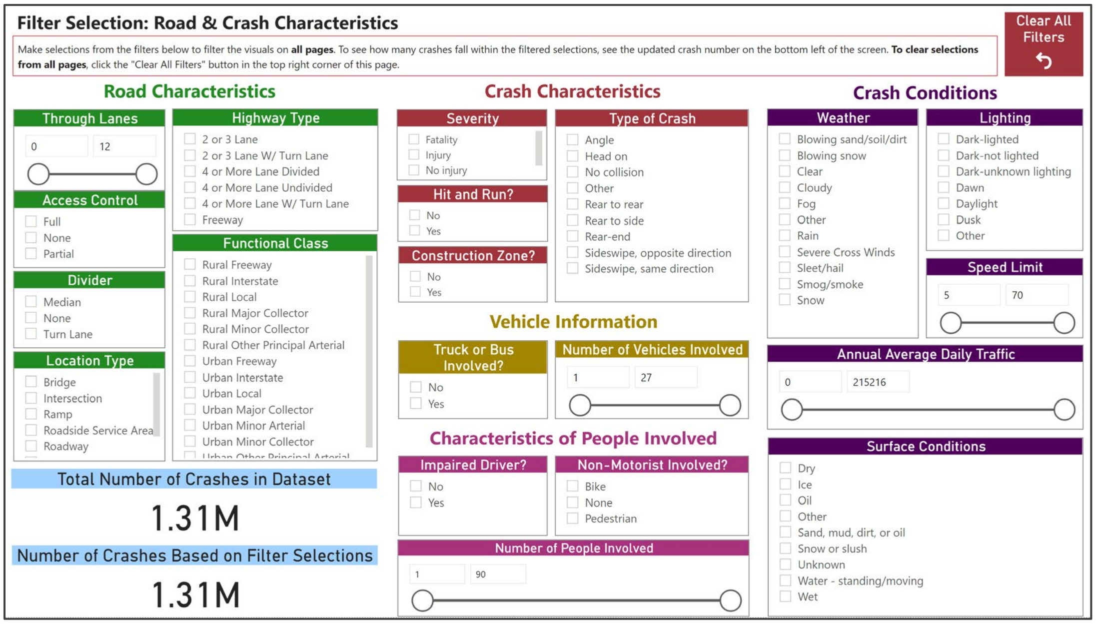


Figure A 2 Filtering by Road and Crash Characteristics variables.

As displayed in Figure A.2, this page allows you to filter by road and crash characteristics variables, including through lanes, access control, divider, location type, highway type, functional class, crash severity, hit and run, construction zone, type of crash, truck or bus involved, number of vehicles involved, impaired driver, non-motorist involved, number of people involved, weather, lighting, speed limit, annual average daily traffic, and surface conditions. As on the previous filter page, visuals on all subsequent pages are automatically updated as you make filter selections, thus only showing crash records that are still viable given previous filter selections. See the disclaimer at the top of the Power BI page for additional information and instructions.

A.1.3. Crash Functional Class and Facility Type

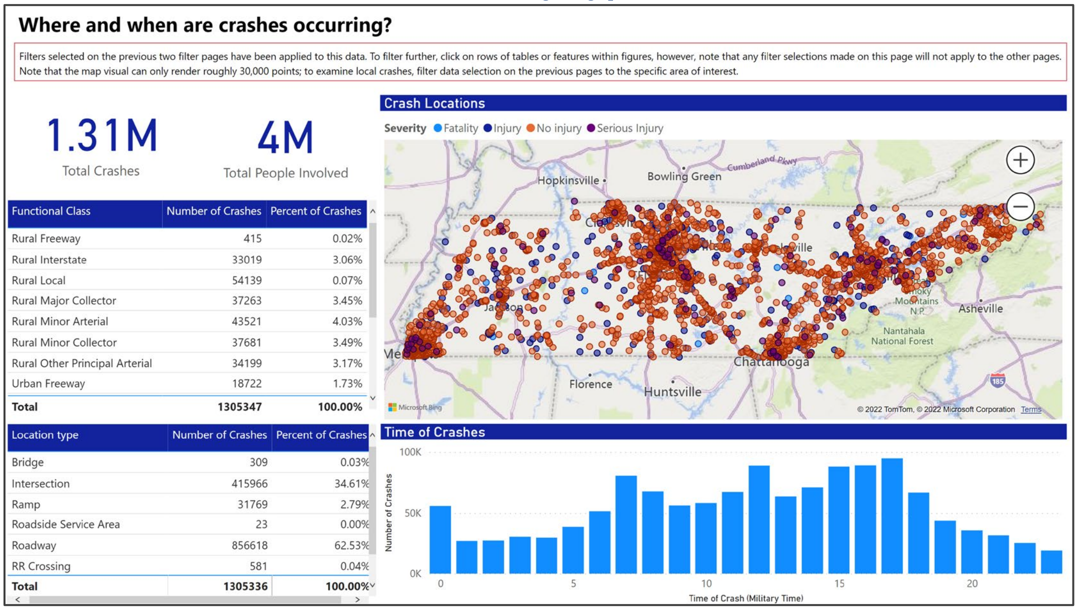


Figure A 3 Crashes based on Functional Class and Facility Type.

The page depicted in Figure A.3 includes multiple visuals that show crashes based on the following variables: functional class, location type, and time of day. The map on this page symbolizes crashes by severity. Hovering your cursor over a specific crash on this map displays a tooltip that provides information on the coordinates of the crash as well as the collision type, location type, traffic segment ID, and log mile. The map on this page renders roughly 30,000 points, so keep in mind that if the number of crashes in the filtered selection is above 30,000, then this map will not show every crash. See the disclaimer at the top of the Power BI page for additional information and instructions.

A.1.4. Crash Hot Spots

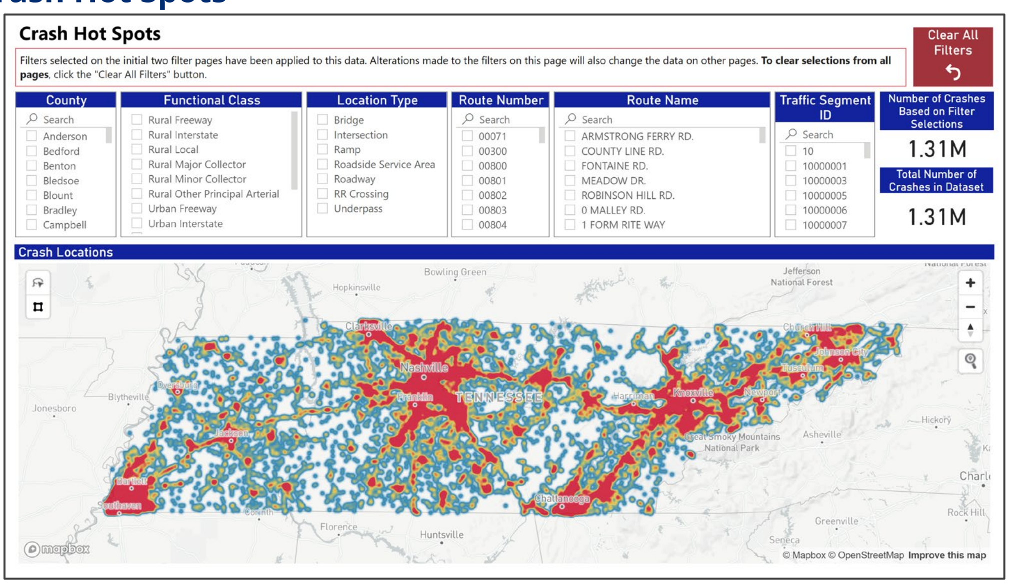


Figure A 4 Crash Hot Spot map and Location filters.

Figure A.4 displays the page that contains a hot spot map and a variety of location-based filters, including county, functional class, location type, route number, route name, and traffic segment ID. The hot spot map will automatically zoom to the appropriate location as different filter selections are made and can also be focused manually. Previous filter selections have already been applied to the data being visualized, and any modifications to filter selections that you make within the filters on this page will be applied to all other pages. See the disclaimer at the top of the Power BI page for additional information and instructions.

A.1.5. Crash Conditions

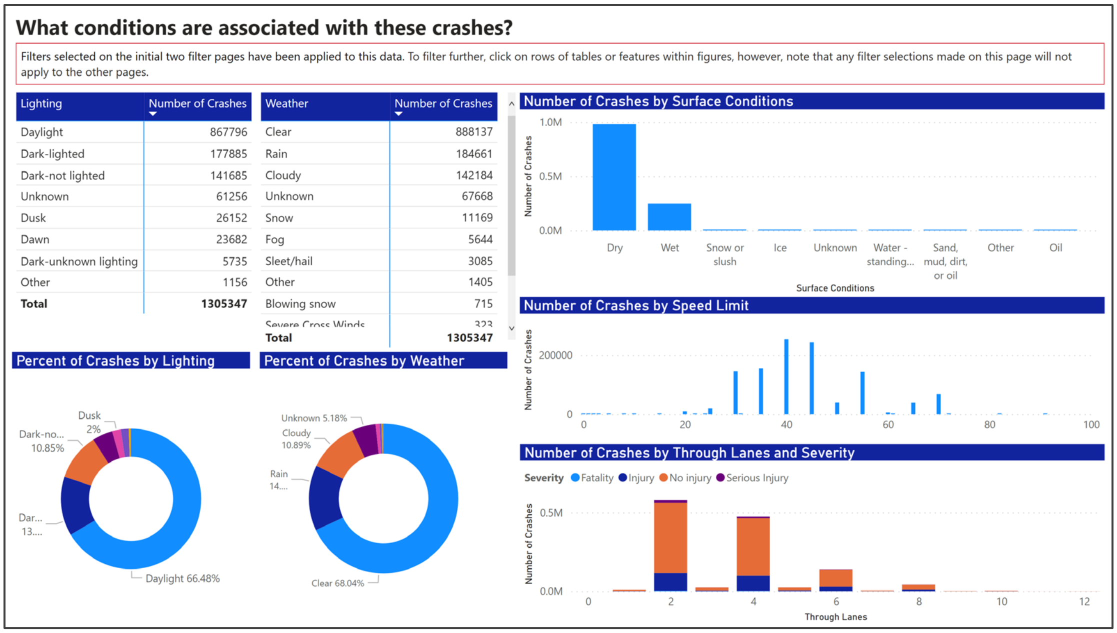


Figure A 5 Crash Conditions associated with different variables.

Figure A.5 displays a page that includes several visuals that show crashes based on the following variables: lighting, weather, surface conditions, speed limit, number of through lanes and severity. See the disclaimer at the top of the Power BI page for additional information and instructions.

A.1.6 Crash Characteristics

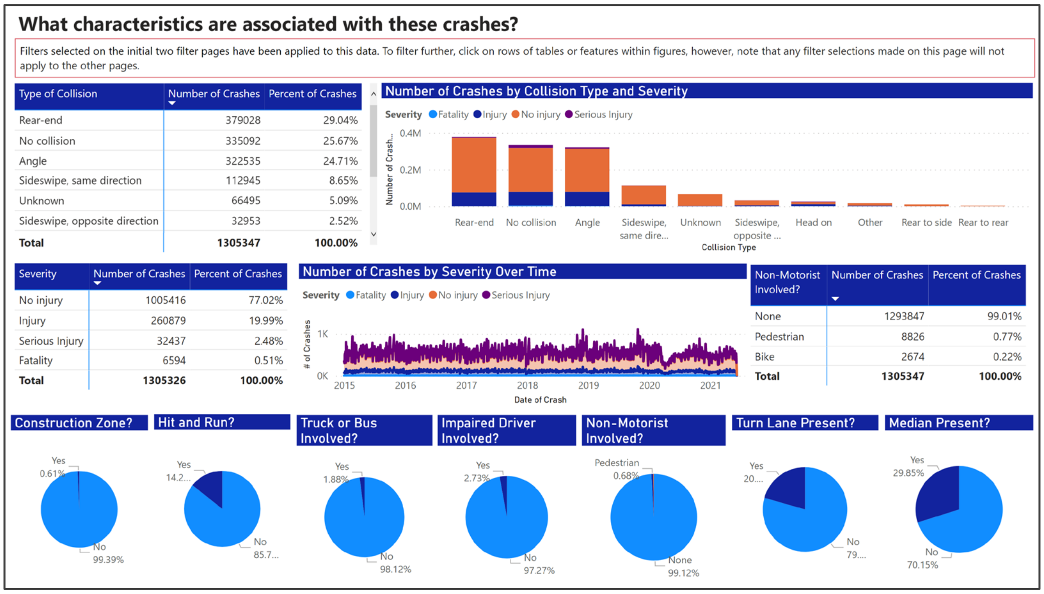


Figure A 6 Crash Characteristics associated with different variables.

Figure A.6 displays a page with several visuals that show crashes based on the following variables: type of collision, severity, non-motorist involvement, construction zone presence, hit and run collisions, truck or bus involvement, impaired driver involvement, turn lane presence, and median presence. See the disclaimer at the top of the Power BI page for additional information and instructions.

A.1.7. Comparisons Between Counties

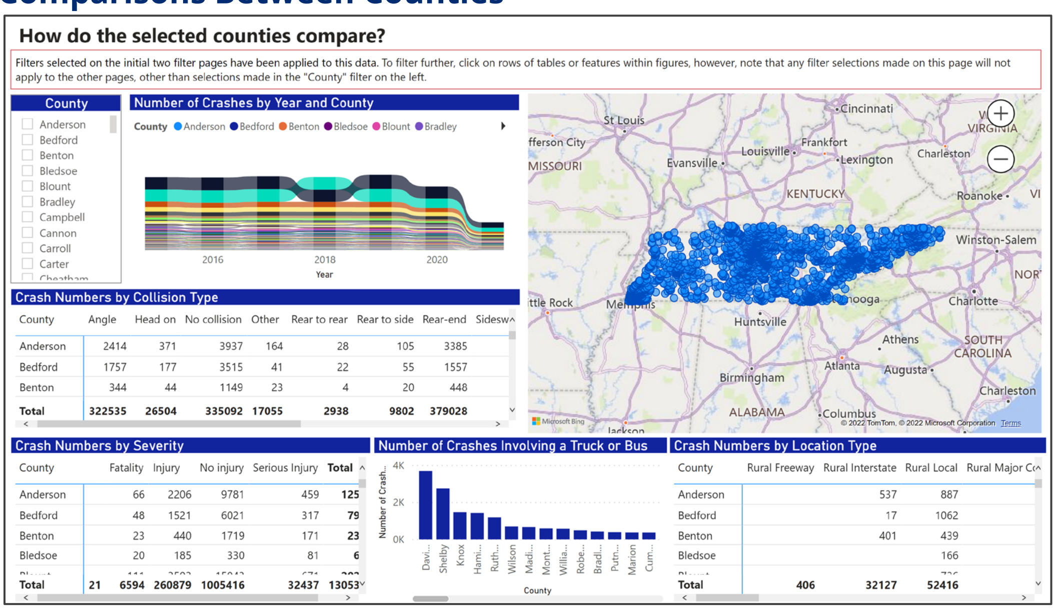


Figure A 7 Comparisons between counties.

Figure A.7 presents the page that allows you to compare crashes in multiple counties, and provides information on crashes by collision type, severity, truck or bus involvement, and location type. There is a map on this page that adjusts automatically when counties are selected and can also be explored manually. The visual on this page under “Number of Crashes by Year and County” can be altered to display crashes by quarter or month instead. You can cycle through these options using the arrow buttons that appear when you hover your cursor over the visual. ***Note*** *that the selections you make to the county filter on this page will be applied to all other pages.* See the disclaimer at the top of the Power BI page for additional information and instructions.

A.1.8. Annual Crash Rate Analysis

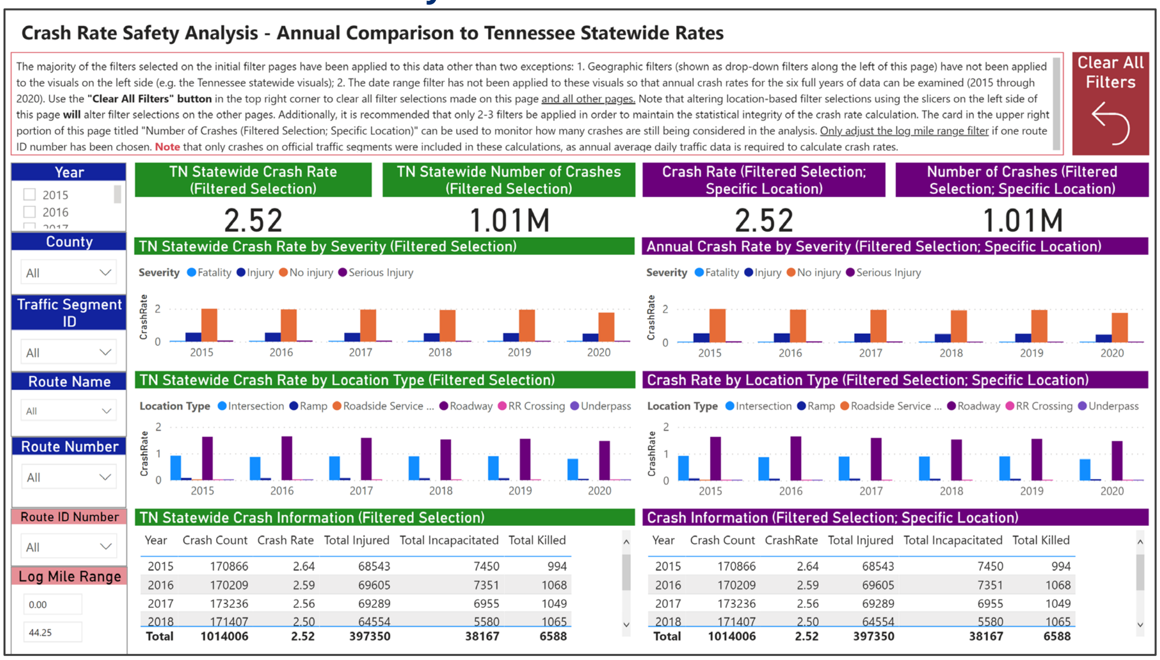


Figure A 8 Annual Crash Rate analysis.

Annual crash rate analysis is performed on the page shown in Figure A.8, in this case for a specific location for the last six full calendar years of data (currently 2015 through 2020 as of 10/18/2021). Location-based filters are present on the left side of the page which allow you to make adjustments to your crash query, in addition to the selection of year(s). Selections can also be made for county, route name, route number, traffic segment ID, route ID number, and log mile range. ***Note*** *that only crashes which occurred on routes designated as traffic segments in the TRIMS traffic table are included in the crash rate calculations*. As explained on the Filters: Crash Time & Location page, adjustments to the log mile range slider should only be made if a single route ID number has been selected.

The page has visuals that display annual crash rates based on crash severity and location type, and show the number of people injured, incapacitated, and killed in the associated crashes. The visuals with the green headings on the left side of the page are Tennessee statewide crash rate visuals, and do not have geographic filters applied to them, whereas the visuals with the purple headings on the right side of the page have all filters applied to them. This allows you to compare the TN statewide crash rate for your other filter selections (for example crashes that occurred at intersections or in wet conditions) with the same filtered crash rate for a specific location (such as a county or a specific segment of the interstate). See the Crash Calculations Specifics section below for important information on how crash rates were computed and what crashes were included. See the disclaimer at the top of the Power BI page for additional information and instructions.

A.1.9. Crash Rate Date Range Comparison

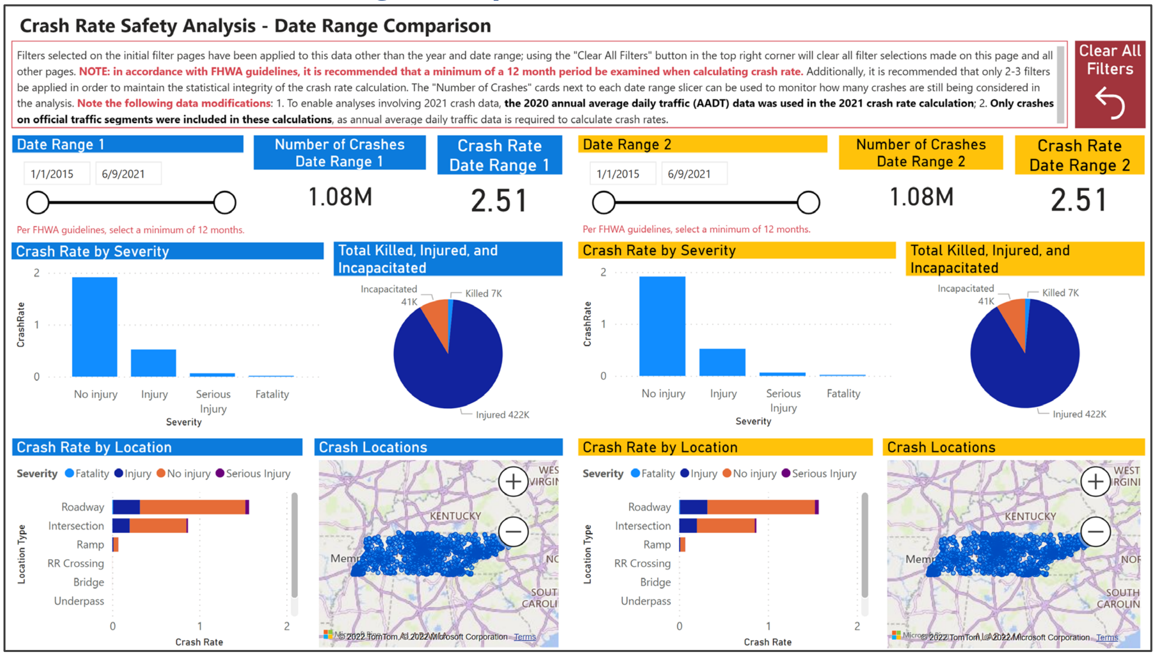


Figure A 9 Crash Rate date range comparison.

Figure A.9 presents the page that allows you to compare crash rates between two different date ranges. All filter selections made on previous filter pages have been applied, and the two date range slicers on this page can be adjusted. ***Note** that it is highly recommended based on FHWA guidelines that a minimum of 12 months are examined in either date range.* After date ranges have been selected, the number of crashes and the associated crash rates are updated next to each date range slider. This page also includes visuals that examine the crash rate by severity and location, as well as the total number of people killed, injured, and incapacitated in the crashes. See the Crash Calculations Specifics section below for important information on how crash rates were computed and what crashes were included. See the disclaimer at the top of the Power BI page for additional information and instructions.

A.2. Additional Important Notes

The "Clear All Filters" button that can be found on several of the pages clear all the filter selections made on any page of the tool (rather than just the current page).

On each page of visuals, you can click on selections within one visual and filter the rest of the visuals on that page. For example, on the Crash Time and Location page, if you click on the "Rural Interstate" row within the functional class table, all of the visuals on the page will adjust accordingly and show you information on crashes within your previously filtered selection that occurred on a rural interstate. Clicking around within a page will not impact how the data is filtered on the subsequent or previous pages, just the current page. For example, if you go to the Crash Conditions page after making initial filter selections on the filter-specific pages, the visualizations on that page will show the data from the filtered selection. On this page, you could then click the "Daylight" option on the table that shows crashes by lighting, and all the visualizations on this page would adjust to show only the information regarding crashes that occurred during daylight. However, if you then clicked on a different page – such as Crash Time and Location – the visualizations would reflect your initial filter selections but would not be filtered to show only crashes that occurred during daylight. If, after clicking around you realize you want all the visualizations to show only crashes during daylight, return to the Filters: Road & Crash Characteristics page and select daylight under the lighting filter. For other examples, see use cases in Section VI of this document.

A.3. Crash Calculations Specifics

Crash rates are commonly calculated as the number of crashes per million vehicle miles traveled (VMT) over a specific period of time. The crash rate calculation used for this application was developed to allow for a dynamically selected range of time. VMT over a period of time distributed unevenly across multiple years is calculated as a weighted sum by the number of days in each year. The formula below was applied to calculate all crash rates in the application:

$$\frac{Crash\ Count * 1{,}000{,}000}{(Sum\ of\ VMT\ 2015 * Days\ in\ 2015) + (Sum\ VMT\ 2016 * Days\ in\ 2016) \ldots + (Sum\ VMT\ 2021 * Days\ in\ 2021)}$$

The "Sum of VMT [YEAR]" variable is the sum of the vehicle miles traveled on all eligible road segments—all those with traffic count data—included in the current filtered selection. Route segments which are selected through the location-based filters but do not have any crash records for the selected time period are still factored into the VMT total. The "Days in [YEAR]" variable is the days in that respective year based on an independent date table that is adjusted based on filter selection. This calculation was designed in Power BI to allow for ultimate end-user flexibility, particularly with respect to adjusting geographic and date filters and immediately seeing accurate updated crash rates.

DISCLAIMERS: As noted on the top of the Crash Rate Date Range Comparison page, the 2020 annual average daily traffic (AADT) data was used in the 2021 crash rate calculation in order to enable analyses involving 2021 crash data. Additionally, in cases where AADT for a specific segment was unavailable for a certain year, but available for others, the AADT for the next closest year was applied. Only crashes that occurred on traffic segments as defined in the TRIMS traffic table were included in the crash rate calculations, since AADT is a required variable for crash rate calculation. These segments were joined by traffic segment/station ID to historic traffic data obtained from TN-TIMES. This exclusion of certain segments and their associated crashes may result in a smaller filtered crash count on the crash rate pages than on the other filter and visualization pages. This is done to ensure the most accurate possible crash rates for all filtered selections. Finally, it is important to note that the route segmentation used for this application exists as an overlay table of the TRIMS Traffic, Road Segment, Geometrics, and Roadway Description tables. Traffic segments can be lengthy in some cases, and variations in attributes such as speed limit, lane count, and median presence produce numerous sub-segments of each traffic segment in the overlay table. AADT from each traffic segment's related traffic station was assigned to all of its sub-segments. It is possible that actual AADT varies across these various smaller segments, but the current method of AADT assignment is appropriate, given the granularity of the available data.

A.4. Background on the Data

All roadway and crash data used for this application was retrieved from the TRIMS SDE database, specifically from the Traffic, Road Segment, Geometrics, Roadway Description, Crash, Crash Driver/Vehicle, and Crash Motorist/Non-Motorist tables. Yearly AADT for traffic segments was obtained from TN-TIMES traffic station counts. GIS geoprocessing tools and Python were used to create the Crash and Roadway Traffic tables. Most crash attributes were obtained from the main TRIMS crash table, with further information on the people and conditions involved in each crash obtained from the other two tables. The Roadway Traffic table contains segmentation and descriptive attribute data as well as traffic counts, where available. The segmentation in this table was created through an overlay of the Road Segment, Geometrics, Roadway Description, and Traffic TRIMS tables. An AADT table downloaded from TN-TIMES was joined to the overlaid TRIMS roadway data table to create a finalized table with both roadway and traffic information.

A.5. Data Dictionary

Below is a list of all attributes that are actively displayed in the current version of the tool along with their source table. Nearly all data used in this application was sourced from TRIMS tables, with the exception of AADT, which was obtained from the TN-TIMES database. The name of the attribute was written to reflect how it is displayed in the filter selections.

Table A 1 TCAST Data Dictionary

Attribute	Source(s)	Brief Description & Relevant Notes
Date	CR_CRASH	Date of crash.
Crash Time	CR_CRASH	Time of crash, displayed in military time.
Year	CR_CRASH	Year of crash, subset of the date attribute.
Urban vs Rural	RD_SGMNT	Derived from the functional class attribute.
County	RD_SGMNT	County name, converted from county number.
Route Number	RD_SGMNT	5-digit alphanumeric route identifier.
Traffic Segment ID	TRAFFIC	Identifier that joins the TRAFFIC segment table to traffic station data from TN-TIMES. Also referred to as traffic station ID, or TN-TIMES ID.
Route Name	RD_SGMNT	Identifying name for a road.
Route ID Number	All TRIMS Tables	10-digit alphanumeric route identifier. Locates route features on TDOT's linear referencing system
Log Mile	CR_CRASH	Used to pinpoint crash locations along routes.
Through Lanes	GEOMETRICS	All travel lanes (both directions). Does not include auxiliary lanes.

Highway Type	GEOMETRICS, RDWAY_DESCR	Used to compare against crash rates by highway type in the Statewide Average Crash Rates for Sections and Spots report.
Access Control	GEOMETRICS	Level of access control on a route segment.
Divider	RDWAY_DESCR	Presence of a turn lane or median on a route segment.
Location Type	CR_CRASH	Route features associated with a crash.
Functional Class	RD_SGMNT	Level of service and capacity provided by a road.
Severity	CR_CRASH	Most severe injury to occur in a crash.
Hit and Run?	CR_CRASH	Suspected hit and run.
Construction Zone?	CR_CRASH	Crashes occurring in construction zones.
Type of Crash	CR_CRASH	Manner of initial collision.
Truck or Bus Involved	CR_TRUCK_BUS	Involvement of at least one truck or bus.
Number of Vehicles Involved	CR_DRIVER_VEH	Total number of vehicles involved in a crash.
Impaired Driver?	CR_DRIVER_VEH	Alcohol involved or a positive driver drug test.
Non-Motorist Involved?	CR_CRASH, CR_MOT_NONMOT, CR_DRIVER_VEH	Involvement of at least one pedestrian, cyclist, or other non-motorist.
Number of People Involved	CR_MOT_NONMOT	Total number of people involved (including passengers) in a crash.
Weather	CR_CRASH	Weather conditions at time of crash
Lighting	CR_CRASH	Lighting conditions at time of crash
Speed Limit	GEOMETRICS, CR_CRASH	Roadway speed limit.
Annual Average Daily Traffic	TN-TIMES	AADT for the year in which a crash occurred.
Surface Conditions	CR_DRIVER_VEH	Roadway surface conditions at time of crash.

A.6. Use Cases

The following examples illustrate a couple ways this tool can be used to explore crashes and crash rates. In this first example, accidents in urban areas involving pedestrians or bicyclists are displayed, and some of the functionalities available on different pages and within individual visualizations are demonstrated.

To start, the “urban” option was selected in the urban vs. rural filter on the Filters: Crash Time and Location page, as seen in Figure 1 below. Notice that the “Number of Crashes Based on Filter Selections” display in the bottom right corner of the screen changed from 1.31 million to 1.07

million when this selection was made, and the map updated to show only the crashes in urban areas.

***Note**: all subsequent pages will now be filtered to show information related to crashes that occurred in urban areas.*

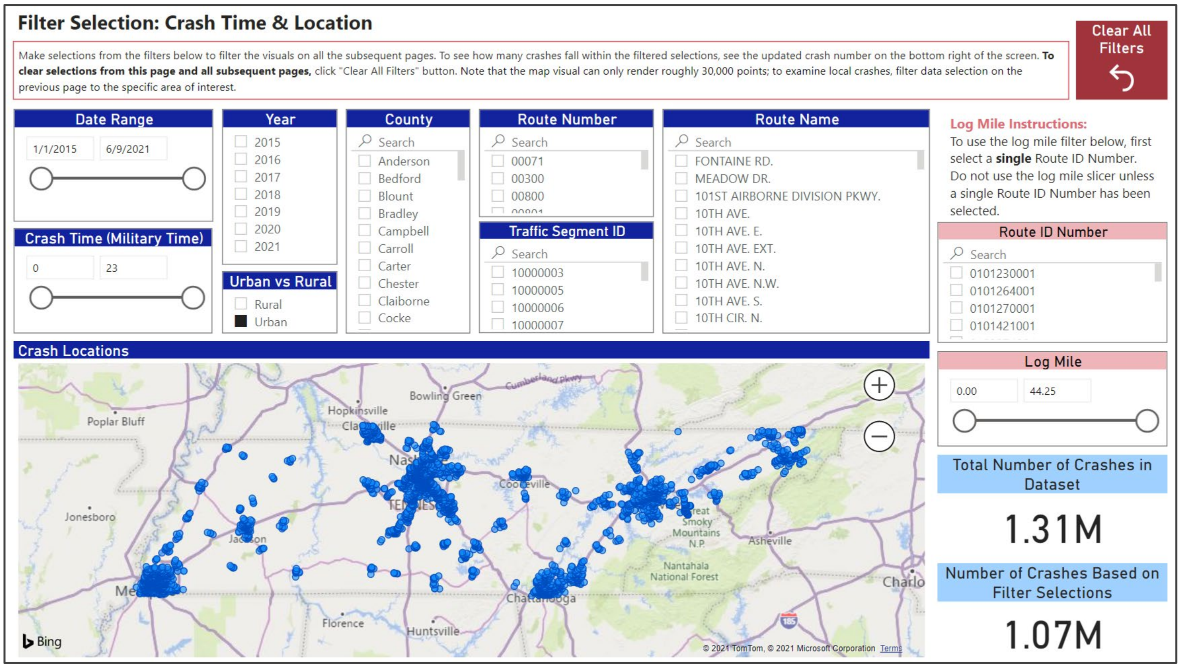


Figure A 10 Filter Selection: Crash Time & Location page with the urban filter applied.

Next, the "pedestrian" and "bike" options were selected from the "Non-Motorist Involved?" filter, as shown below in Figure 2. ***Note** that multiple options from the same filter can be selected by holding down the control key while selecting each relevant option.*

Notice that the "Number of Crashes Based on Filter Selections" was automatically updated, and now shows 10.55 thousand crashes. Also notice that as these selections are made, the other filters update to show the options still available, given your current selection. ***Recall:** these filter selections will impact what information is shown on all other pages of the dashboard.*

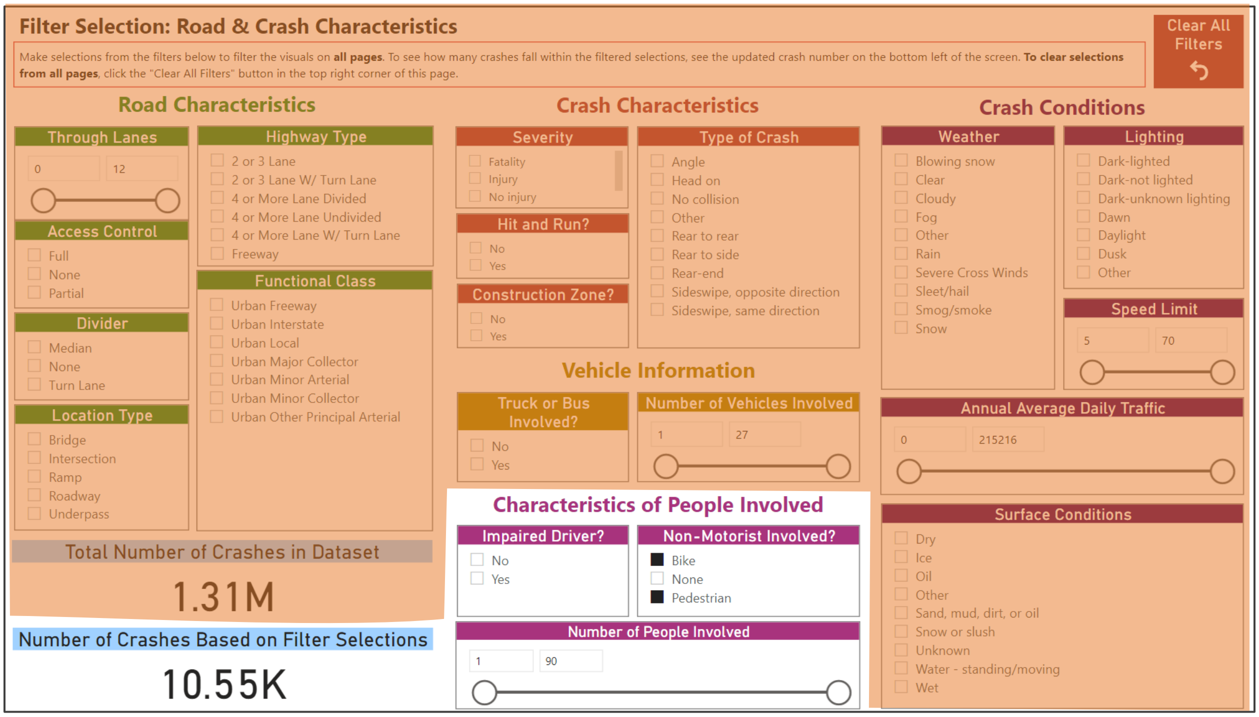


Figure A 11 Filter Selection: Road & Crash Characteristics page with bike and pedestrian options selected.

On the next page, the crash times and locations can be explored, as shown in Figure A.12 below. Tables within Power BI can be reorganized by clicking on the column titles; the tables shown below in Figure 3 have been sorted from highest number of crashes to lowest, by clicking the "Number of Crashes" column titles. The bar graph in the lower right corner shows that the greatest number of crashes within the filtered selection occurred at 17:00 military time (5:00 pm); the number of crashes that occurred at this time can be seen by hovering the mouse over that bar in the bar graph.

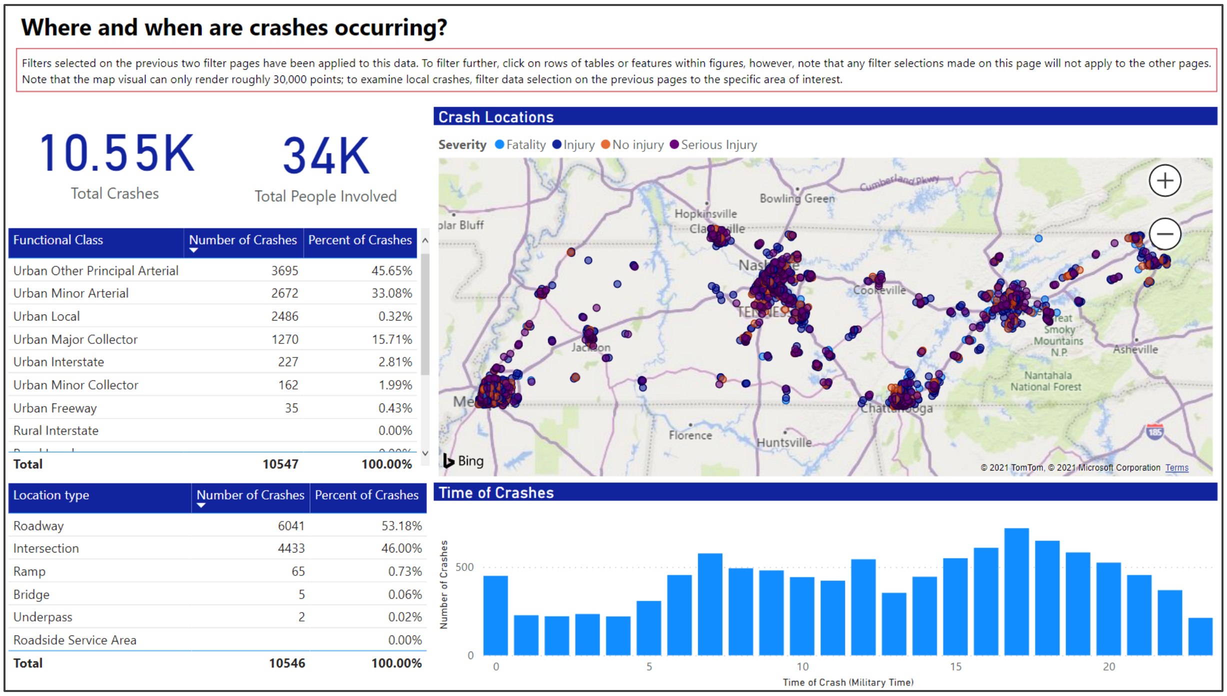


Figure A 12 Crash Time & Location page showing urban crashes involving pedestrians or bicyclists.

On the Crash Hot Spots page, additional filter selections can be applied, and the hot spot map can be maneuvered to explore different locations. In Figure A.13 below, two additional filter selections were made to show urban crashes involving a pedestrian or bicyclist at intersections in Davidson County, reducing the number of crashes being examined to 1,159. The plus and minus controls on the map can be used to zoom in and out on specific locations, and the location at the center of the map can be changed by clicking a location on the map and dragging it to another position. The map in Figure A.13 reveals crash hotspots in downtown Nashville and along 21st Ave and West End Ave near Vanderbilt University's campus. ***Note:*** *adjusting filter selections on this page will adjust the crashes shown on every page;* before continuing to the next page, these two selections (Davidson County and crashes at intersections) were unchecked to return the filtered selection to crashes in urban areas that involve a pedestrian or bicyclist.

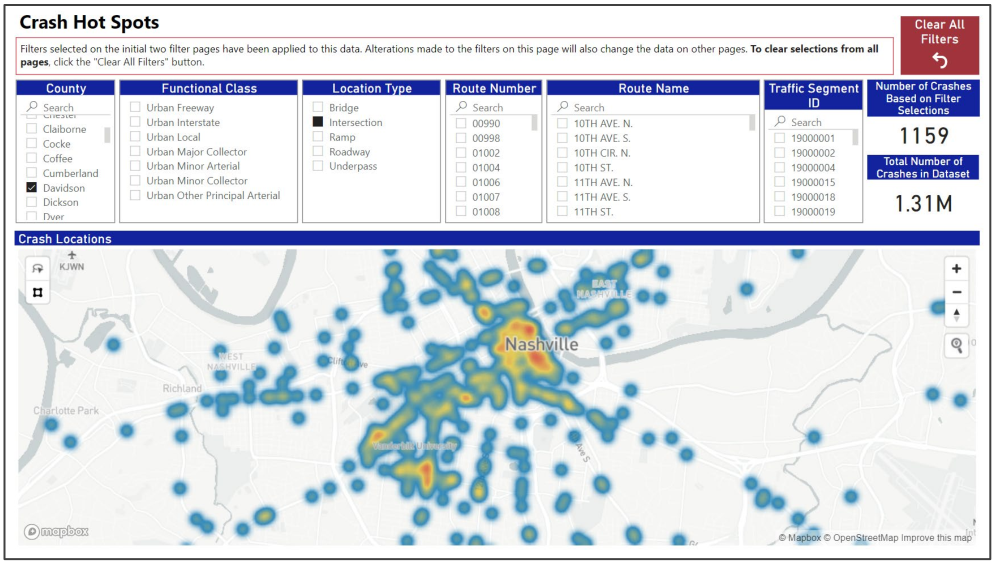


Figure A 13 Crash Hot Spots page showing urban crashes involving a pedestrian or bicyclist at intersections in Davidson County.

On the next page, various visuals display the results for this filtered selection, as can be seen in Figure A.14. ***Note** that the interactivity of the visuals on these pages is a great way to explore the data further.* For example, as can be seen in Figure 6 below, when the "Rain" row of the table of crashes by weather type is selected, the rest of the visuals update accordingly to now show or highlight the data for urban crashes involving pedestrians or bicyclists that also occurred in the rain. Various observations can be made by comparing the visuals for crashes during all weather events (Figure A.14) and crashes during rain events (Figure A.15). For example, the most common lighting for the initial filtered selection (with all weather events included) was daylight, whereas dark-lighted was the most common lighting condition for crashes that occurred while it was raining. ***Note:** clicking components of visuals (rows in a table, bars in a graph, etc.) will filter the other visuals on the page but will not update the overall filtered selection for the other pages.*

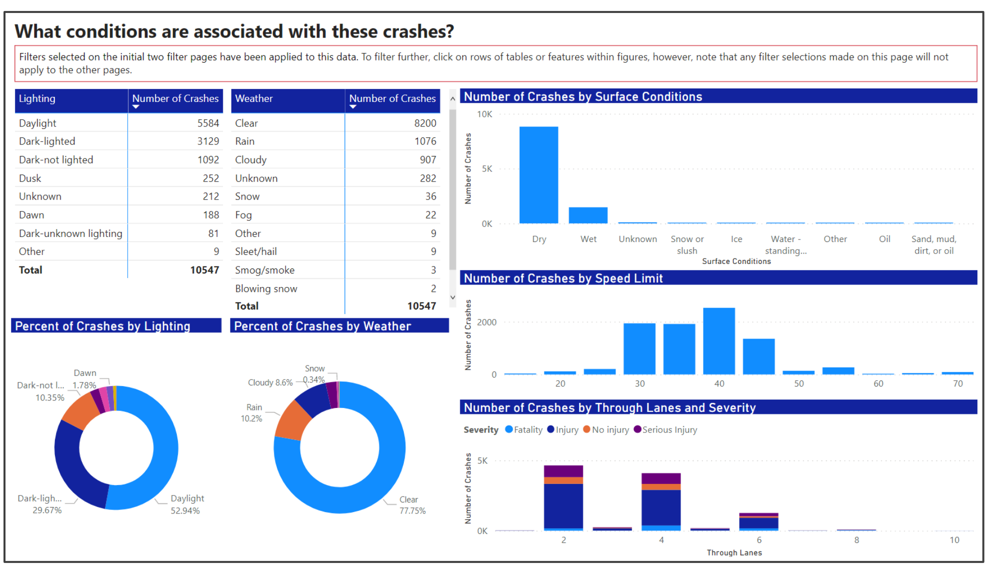


Figure A 14 Crash Conditions page showing urban crashes involving a pedestrian or bicyclist.

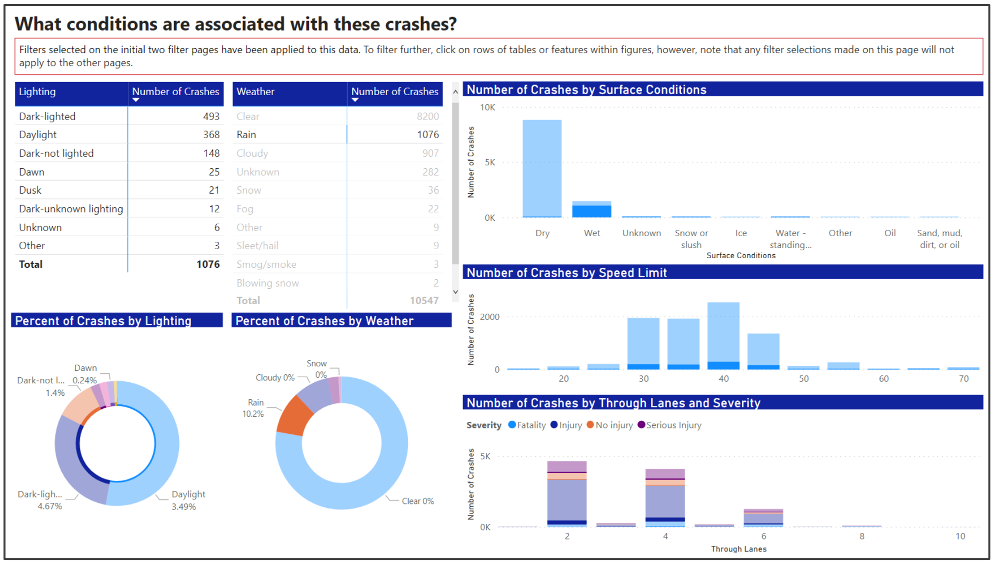


Figure A 15 Crash Conditions page showing urban crashes involving a pedestrian or bicyclist, with crashes occurring during rain events highlighted in the visuals.

Below is another example of utilizing the interaction between visuals, using the Crash Characteristics page. Figure A.16 shows the page based on the overall filtered selection (urban + pedestrian or bicyclist involvement), and Figure A.17 shows the visuals filtered to display crashes that involved a hit and run. This additional filter was applied by clicking on the portion of the pie graph that displays whether the crashes involved a hit and run. By clicking and unclicking that part of the pie graph, the user can effectively compare what we see here in Figures A.16 and A.17 and make related observations. For example, though there are significantly less crashes that involved a hit and run, the percentages of crashes of different severities (fatality, injury, serious injury, no injury) remains fairly similar. **Recall:** clicking components of visuals (rows in a table, bars in a graph, etc.) will filter the other visuals on the page but will not update the overall filtered selection for the other pages.

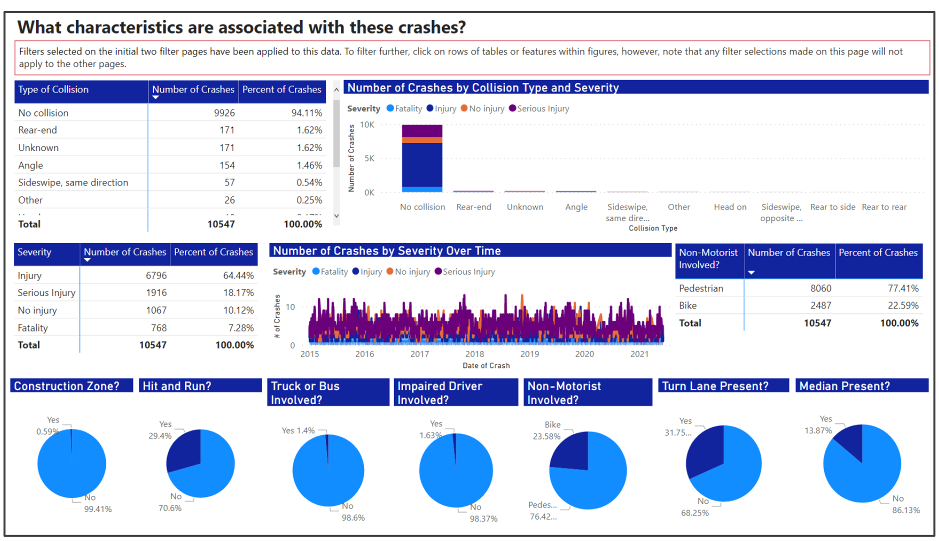


Figure A 16 Crash Characteristics page showing urban crashes involving a pedestrian or bicyclist.

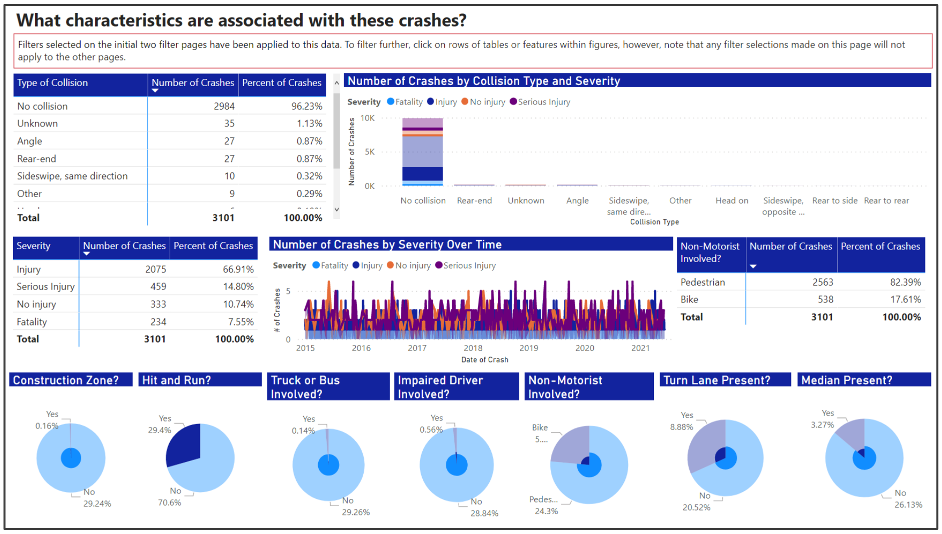


Figure A 17 Crash Characteristics page showing urban crashes involving a pedestrian or bicyclist, with hit and run crashes highlighted in the visuals.

The last crash frequency page before the crash rate pages allows you to compare crashes across different counties. In Figure A.18 below, the counties with the three largest cities in Tennessee were selected using the filter on this page: Davidson, Shelby, and Knox. The ribbon chart in the top left displays the total number of crashes in the filtered selection for each county per year in the darker portions of the “ribbon”, the lighter portion of the ribbon shows the difference between the years on either side of it. By hovering over it, the change in crash frequency of each county can be observed. For example, between 2017 and 2018, there was a decrease in number of urban crashes involving pedestrians/bicyclists in all three counties: Shelby County had a -3.14% decrease, Davidson County had a -5.05% decrease, and Knox had a -14.29% decrease. The other visuals on this page provide additional opportunities to compare counties, and the map can be zoomed in to examine specific locations in more detail.

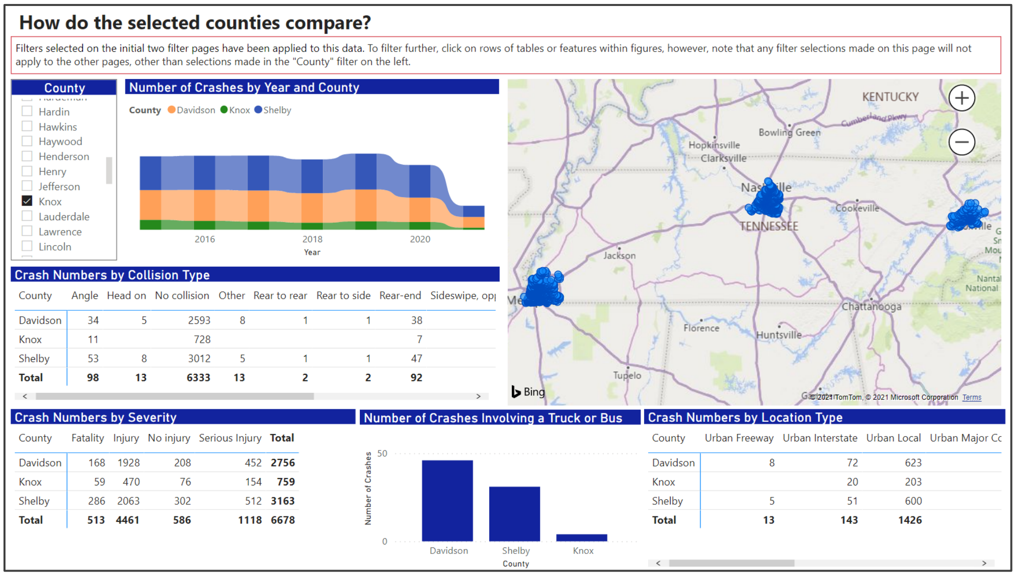


Figure A 18 Comparisons Between Counties page showing urban crashes involving a pedestrian or bicyclist in Davidson, Shelby, and Knox counties.

The Annual Crash Rate Analysis page compares the crash rates based on the filtered selections between a geographically specific area (in the purple visuals on the right) and all of Tennessee (in the green visuals on the left). The example shown below in Figure A.19 displays a comparison of crash rates for all urban traffic segments in Tennessee (green visuals) and crash rates for urban traffic segments in Davidson County (purple visuals). ***Note****: the geographic filters can be updated using the options along the left side of this page, and these filters will impact the data shown on all other pages.* Other filter alterations (lighting, road conditions, etc.) can be made by returning to the initial two filter pages.

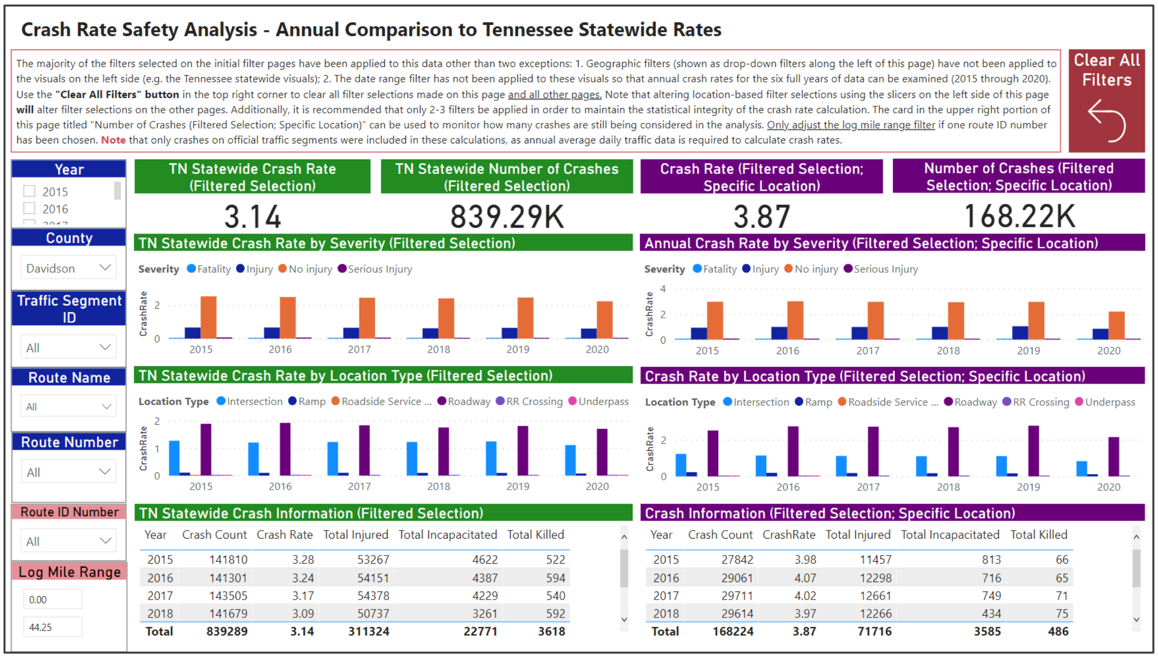


Figure A 19 Annual Crash Rate Analysis page showing crash rates for urban traffic segments for all of Tennessee (green visuals on the left) and for Davidson County specifically (purple visuals on the right).

While this tool is effective for querying and analyzing large sets of crash data, it can also be used for targeted crash rate analyses at specific locations. The final page of the tool, Crash Rate Date Range Comparison, can be coupled with the ID Number and Log Mile filters on the initial filter page to directly compare crash rates and statistics before and after the completion of specific countermeasures. This provides the user with the ability to assess the impacts of road improvement projects on safety. Two example projects were selected to illustrate this functionality and are illustrated below.

The project under the identification number (PIN) 115547.00 involved the installation of an intelligent transportation system on portions of I-65. A section in Davidson County was examined using the tool. A project report obtained from the Program Development and Scheduling Office (PDSO) indicates that the project coincides with route ID 19I0065001 from log miles 0.000 to 1.815 in the TRIMS roadway network, and the project was completed on February 28, 2018. The TRIMS termini information can be input into the ID Number and Log Mile filters on the first filter page to isolate that road segment, as shown in Figure A.20 below.

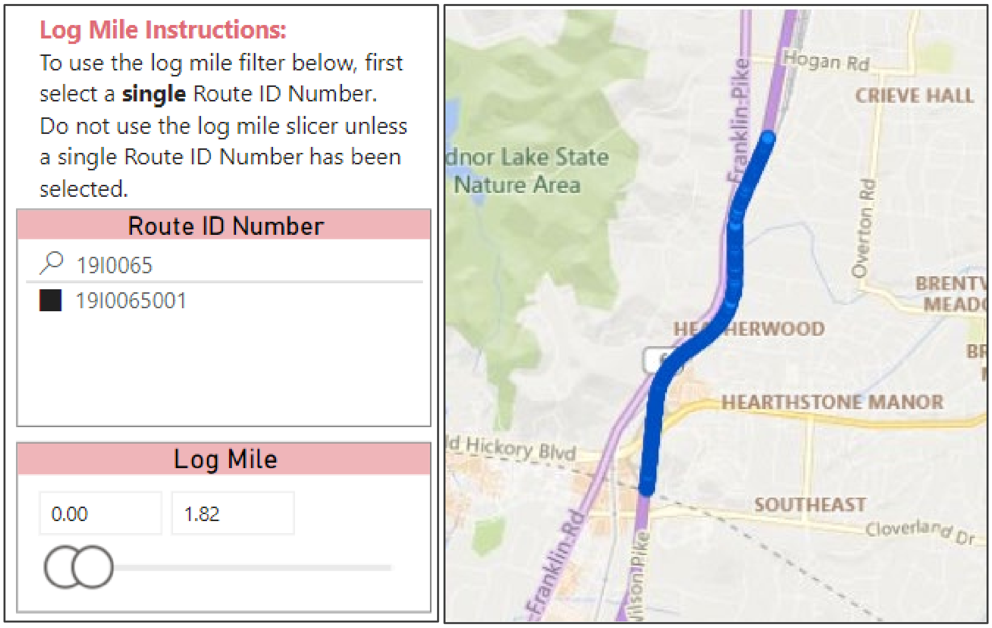


Figure A 20 Log mile filter located on the Filter Selection: Crash Time and Location Page, after a selection has been made for a specific project (PIN: 115547.00) (left) and updated map displaying the queried crashes (right).

The project completion date can then be applied to the Crash Rate Date Range Comparison Page to assess crash rates three years before and after that date, as shown in Figure A.21 below. This reveals that there was a significant decrease in both crash rate and total crashes after the completion of the project.

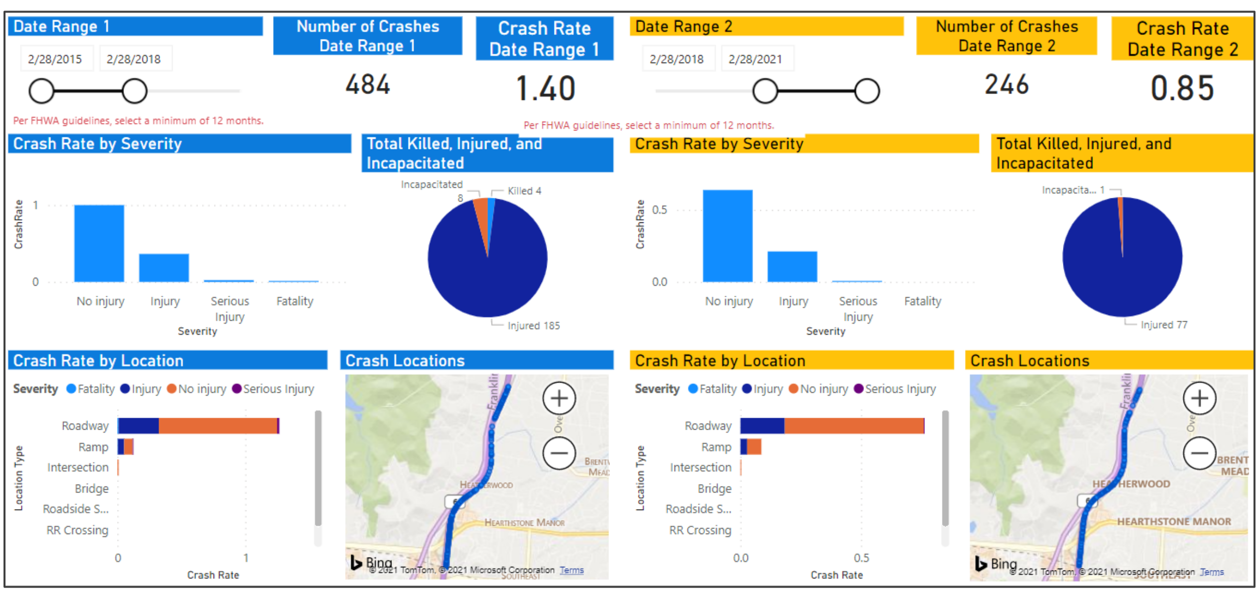


Figure A 21 Crash Rate Date Range Comparison page showing data for a specific project (PIN: 115547.00) with two date ranges selected, displaying crash rate data before and after project completion.

A second project under PIN 117367.02 was also assessed. This involved various safety improvements on several roads, including State Route 57 in Fayette County, on ID number

24SR057001 from log miles 6.000 to 9.000 in the TRIMS network. The project was completed on April 27, 2018. The linear referencing filter values and query output are shown below in Figure A.22.

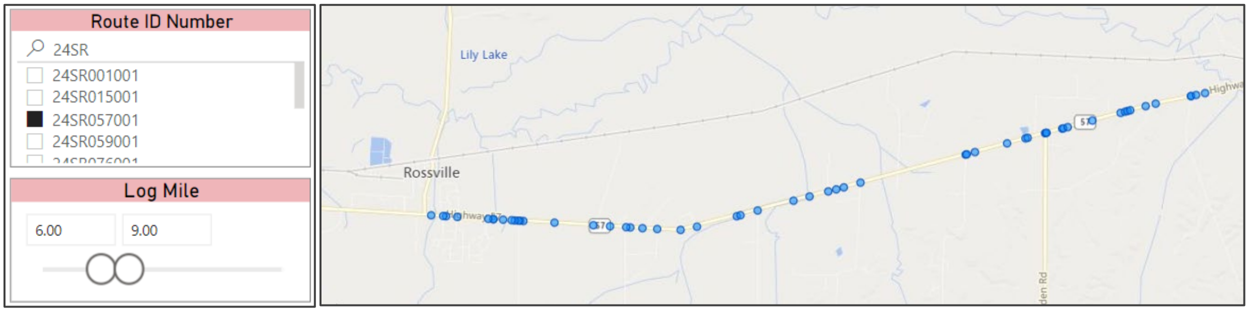


Figure A 22 Log mile filter located on the Filter Selection: Crash Time and Location Page, after a selection has been made for a specific project (PIN 117367.02) (left) and updated map displaying the queried crashes (right).

The crash rate results for this project shown below in Figure A.23 demonstrate how safety improvements at a specific location do not necessarily lead to lower crash rates. However, the injury and fatality statistics reveal that although a greater number of crashes occurred after the completion of the project, there were fewer total injuries and fatalities.

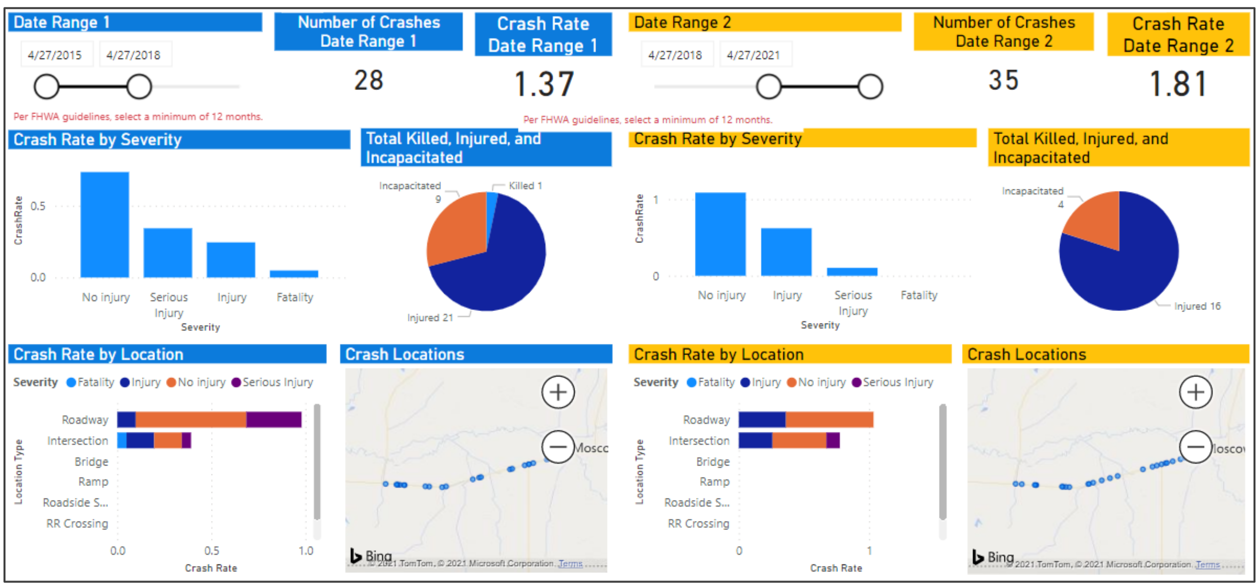


Figure A 23 Crash Rate Date Range Comparison page showing data for a specific project (PIN 117367.02) with two date ranges selected, displaying crash rate data before and after project completion.

Appendix B - Tennessee Pavement Analytics Tool (TPAT) User Guide

Version 1.0, Last Updated: August 2022

B.1. Tour of the Tool

The TDOT Pavement Analytics Tool (TPAT) can be used to explore the impact of pavement projects on roadway safety for Tennessee roadways. The tool enables the user to perform batch analyses on any number of projects and provides the user with crash rate analyses for 1-, 2-, and 3-years before and after pavement projects. Pavement quality data from HPMA, pavement project data from PPRM, roadway and crash data from TRIMS, and traffic count data from TN-TIMES are included in the tool's database. All pavement projects since 2013 and crashes since 2012 are included, and regularly updated with new data. The tool interface includes an initial overview page, followed by six pages of filters and visualizations, and a glossary of pavement indices, as described below.

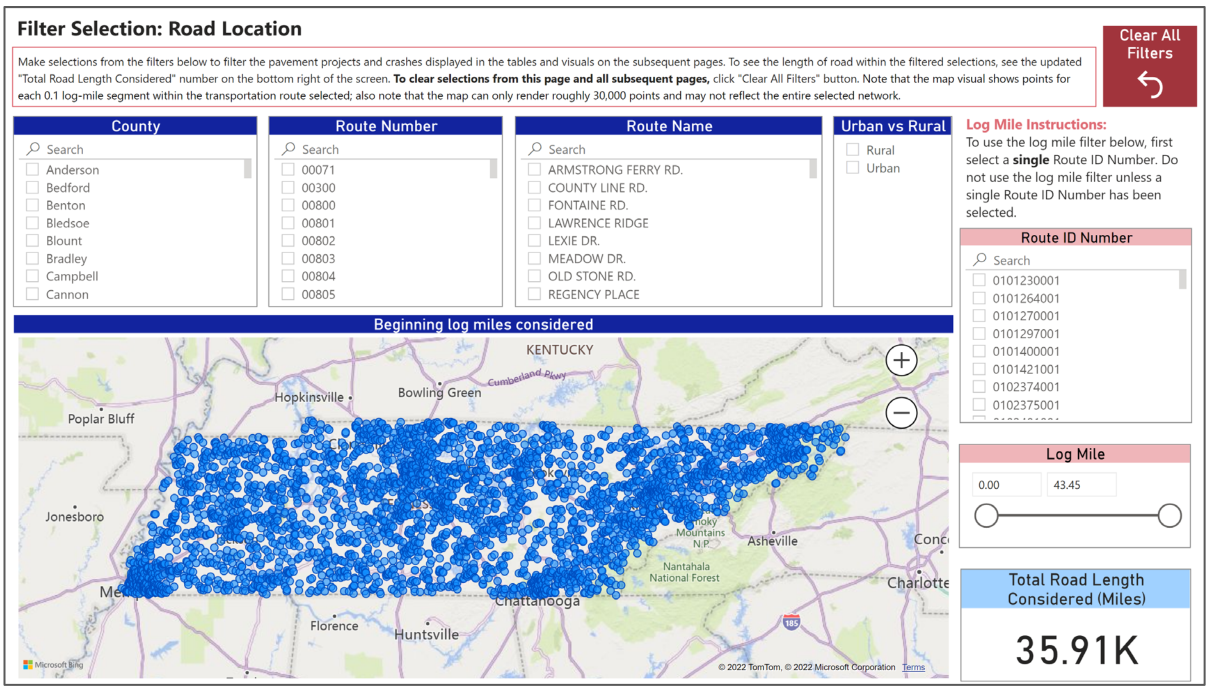


Figure B 1 Filtering by Location of pavement projects.

B.1.1. Filters: Road Location

The page presented in Figure B.1 allows you to filter by location-related variables, including county, route number, route name, urban vs rural, and route ID number. Additionally, the user has the ability to filter by log mile range, which should be done only after a single route ID number has been selected. As you make filter selections on this page, tables and visuals on all subsequent pages are automatically updated, so when a selection is made (e.g., a single county is selected), all the other filters show the remaining filter options (e.g., only traffic segment IDs that are located in that county will be displayed). The number on the bottom right corner of the page under "Total

Road Length Considered (Miles)" allows you to monitor the length of road included in the filtered data. Since there is currently no way within Power BI to display roadways as lines on a map, the map on this page displays beginning log miles considered instead. The user should keep in mind that the map can only render roughly 30,000 points, and merely serves as a helpful tool for refining geographic selections. See the disclaimer at the top of the Power BI page for additional information and instructions.

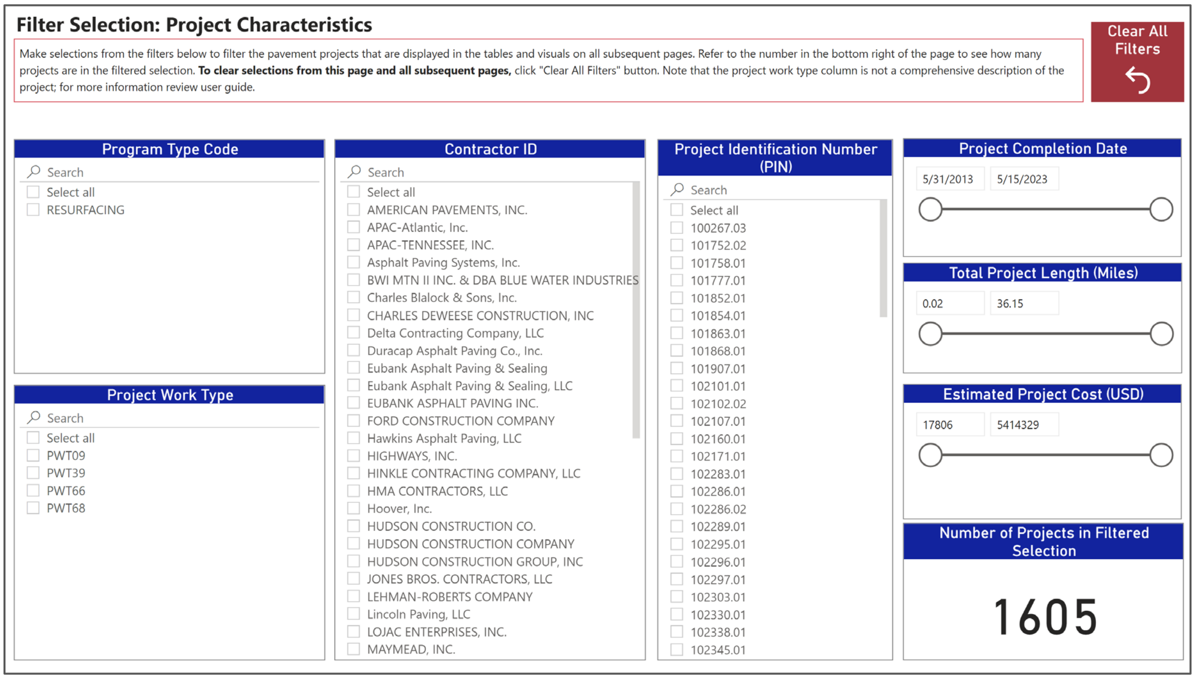
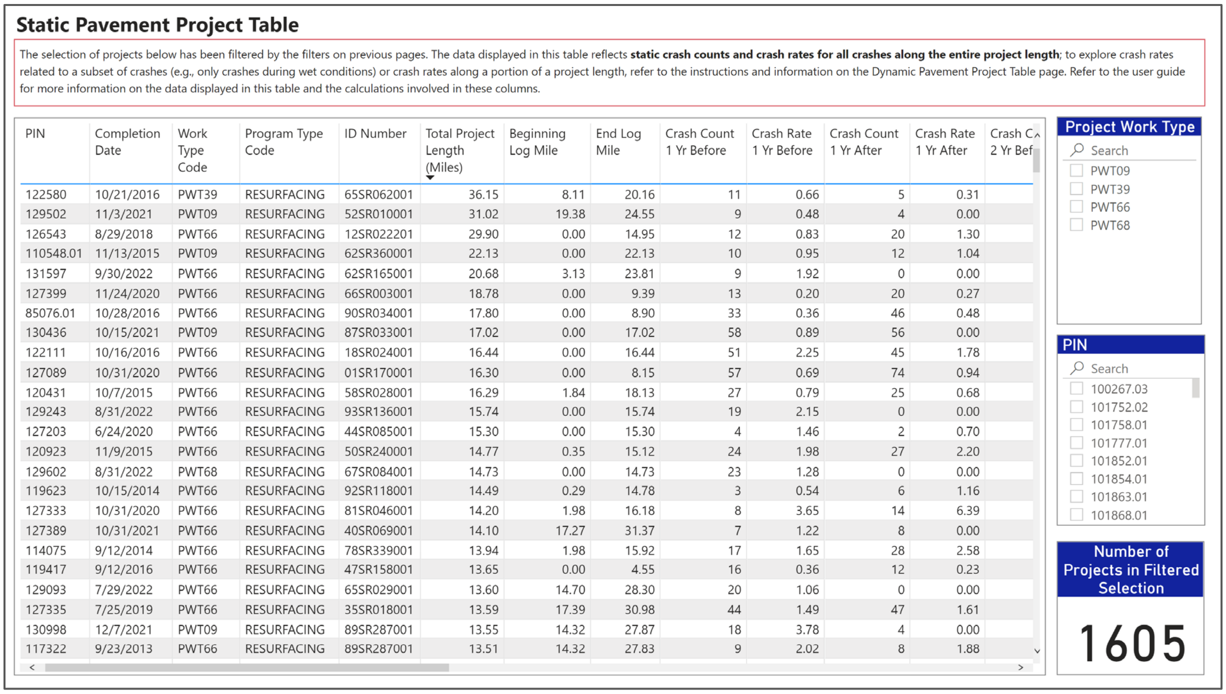


Figure B 2 Filtering by Project Characteristics.

B.1.2. Filters: Project Characteristics

The page displayed in Figure B.2 allows you to filter by project characteristics, including program type code, project work type, contractor ID, project identification number (PIN), project completion date, total project length, and estimated project cost. To see how many projects are within the filtered selection, see the updated number in the bottom right of the screen under "Number of Projects in Filtered Selection." As on the previous filter page, tables and visuals on all subsequent pages are automatically updated as you make filter selections. See the disclaimer at the top of the Power BI page for additional information and instructions.



Static Pavement Project Table

The selection of projects below has been filtered by the filters on previous pages. The data displayed in this table reflects **static crash counts and crash rates for all crashes along the entire project length**; to explore crash rates related to a subset of crashes (e.g., only crashes during wet conditions) or crash rates along a portion of a project length, refer to the instructions and information on the Dynamic Pavement Project Table page. Refer to the user guide for more information on the data displayed in this table and the calculations involved in these columns.

PIN	Completion Date	Work Type Code	Program Type Code	ID Number	Total Project Length (Miles)	Beginning Log Mile	End Log Mile	Crash Count 1 Yr Before	Crash Rate 1 Yr Before	Crash Count 1 Yr After	Crash Rate 1 Yr After	Crash C 2 Yr Bef
122580	10/21/2016	PWT39	RESURFACING	65SR062001	36.15	8.11	20.16	11	0.66	5	0.31	
129502	11/3/2021	PWT09	RESURFACING	52SR010001	31.02	19.38	24.55	9	0.48	4	0.00	
126543	8/29/2018	PWT66	RESURFACING	12SR022201	29.90	0.00	14.95	12	0.83	20	1.30	
110548.01	11/13/2015	PWT09	RESURFACING	62SR360001	22.13	0.00	22.13	10	0.95	12	1.04	
131597	9/30/2022	PWT66	RESURFACING	62SR165001	20.68	3.13	23.81	9	1.92	0	0.00	
127399	11/24/2020	PWT66	RESURFACING	66SR003001	18.78	0.00	9.39	13	0.20	20	0.27	
85076.01	10/28/2016	PWT66	RESURFACING	90SR034001	17.80	0.00	8.90	33	0.36	46	0.48	
130436	10/15/2021	PWT09	RESURFACING	87SR033001	17.02	0.00	17.02	58	0.89	56	0.00	
122111	10/16/2016	PWT66	RESURFACING	18SR024001	16.44	0.00	16.44	51	2.25	45	1.78	
127089	10/31/2020	PWT66	RESURFACING	01SR170001	16.30	0.00	8.15	57	0.69	74	0.94	
120431	10/7/2015	PWT66	RESURFACING	58SR028001	16.29	1.84	18.13	27	0.79	25	0.68	
129243	8/31/2022	PWT66	RESURFACING	93SR136001	15.74	0.00	15.74	19	2.15	0	0.00	
127203	6/24/2020	PWT66	RESURFACING	44SR085001	15.30	0.00	15.30	4	1.46	2	0.70	
120923	11/9/2015	PWT66	RESURFACING	50SR240001	14.77	0.35	15.12	24	1.98	27	2.20	
129602	8/31/2022	PWT68	RESURFACING	67SR084001	14.73	0.00	14.73	23	1.28	0	0.00	
119623	10/15/2014	PWT66	RESURFACING	92SR118001	14.49	0.29	14.78	3	0.54	6	1.16	
127333	10/31/2020	PWT66	RESURFACING	81SR046001	14.20	1.98	16.18	8	3.65	14	6.39	
127389	10/31/2021	PWT66	RESURFACING	40SR069001	14.10	17.27	31.37	7	1.22	8	0.00	
114075	9/12/2014	PWT66	RESURFACING	78SR339001	13.94	1.98	15.92	17	1.65	28	2.58	
119417	9/12/2016	PWT66	RESURFACING	47SR158001	13.65	0.00	4.55	16	0.36	12	0.23	
129093	7/29/2022	PWT66	RESURFACING	65SR029001	13.60	14.70	28.30	20	1.06	0	0.00	
127335	7/25/2019	PWT66	RESURFACING	35SR018001	13.59	17.39	30.98	44	1.49	47	1.61	
130998	12/7/2021	PWT09	RESURFACING	89SR287001	13.55	14.32	27.87	18	3.78	4	0.00	
117322	9/23/2013	PWT66	RESURFACING	89SR287001	13.51	14.32	27.83	9	2.02	8	1.88	

Figure B 3 Static Pavement Project Table.

B.1.3. Static Pavement Project Table

Figure B.3 displays a table showing the results of a batch analysis completed on all the projects in the filtered selection. The main content in the table includes Crash counts and crash rates for 1-, 2-, and 3-years before and after each project, as well as a 3-year percent change. Refer to the section below on Crash Calculation Specifics for more information on how these calculations were performed. Other data in the table includes PIN, completion date, work type code, program type code, ID number, total project length, beginning and end log miles, and scope of work. ***Note*** that this table is static, in that it includes all crashes on the roads in the filtered project selection regardless of other geographic or crash filters; this is in contrast to the dynamic pavement project table described below. There are two filters included on this page - project work type and PIN; note that modifying selections within these filters will impact the filtered selection on all other pages. Refer to the number at the bottom right of the screen for the updated number of projects in filtered selection. See the disclaimer at the top of the Power BI page for additional information and instructions. Also ***note*** that the information in this table allows the user to easily explore crash rates further for a specific project using the Tennessee Crash Analytics and Safety Tool (TCAST), by plugging the ID number and beginning and end log miles into the "Filters: Crash Time & Location" page of TCAST and exploring the following pages of visuals.

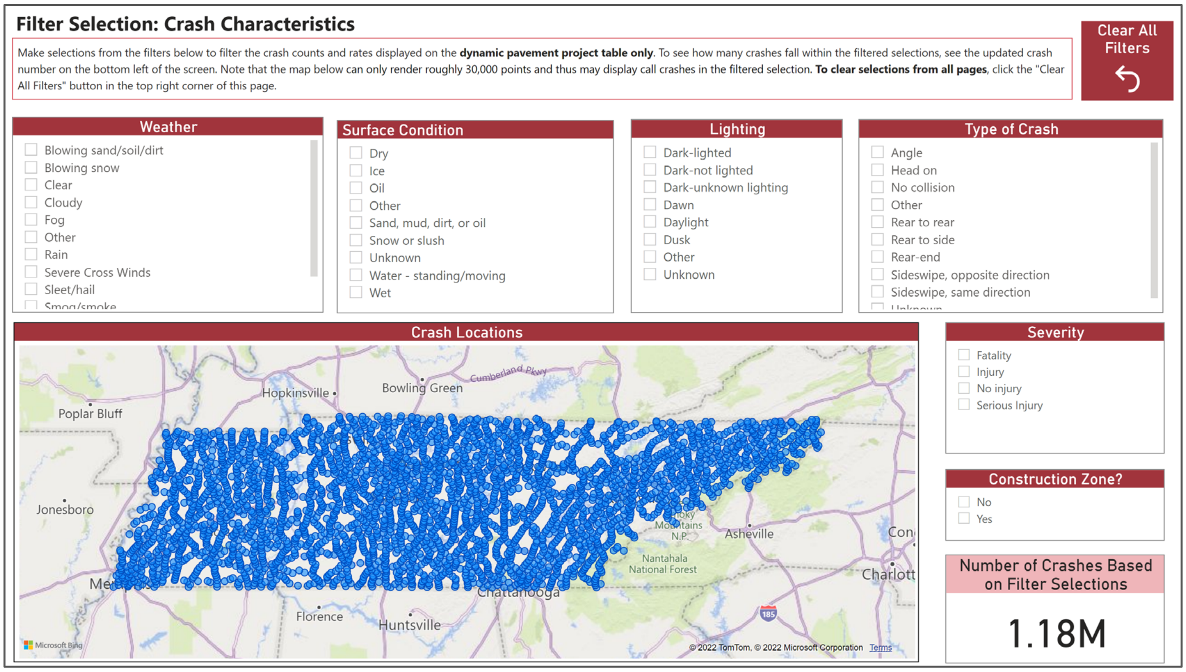
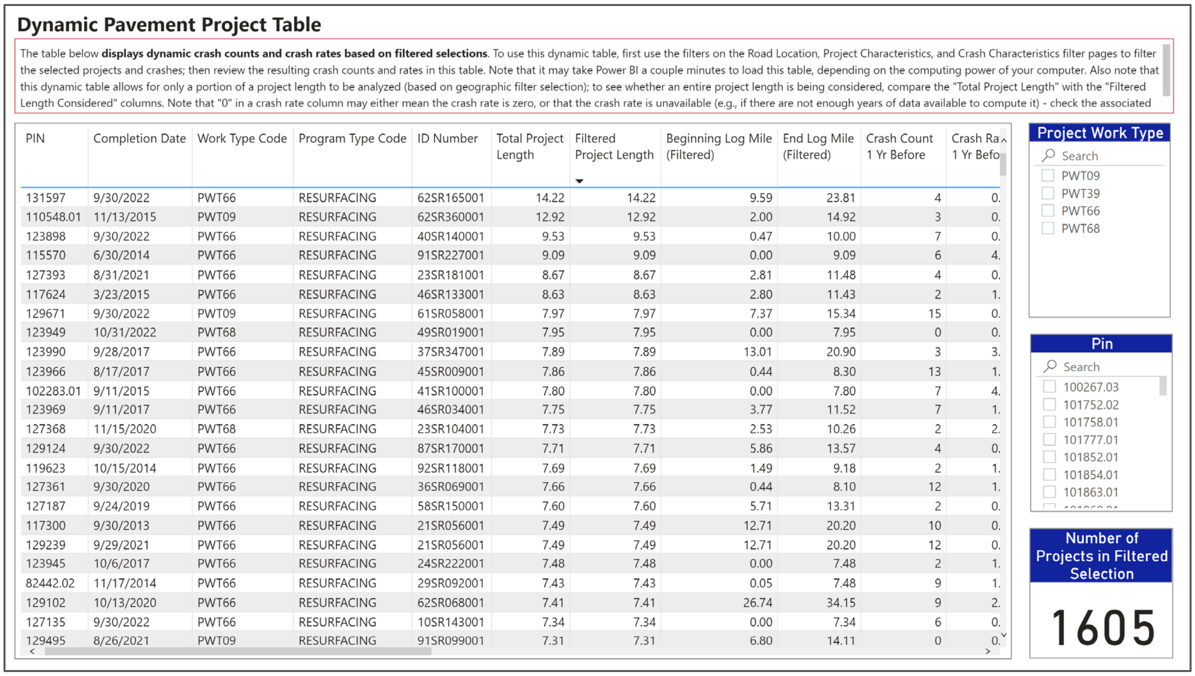


Figure B 4 Filtering by Crash Characteristics.

B.1.4. Filters: Crash Characteristics

The page that allows you to filter by crash characteristics is shown in Figure B.4, including characteristics of weather, surface conditions, lighting, type of crash (e.g., angle, head on, etc.), severity, and construction zone. To see how many crashes are within the filtered selection, see the updated number in the bottom right of the screen under “Number of Projects in Filtered Selection.” As on the previous filter pages, tables and visuals on the other pages are automatically updated as you make filter selections, though recall that selections made on this page have no impact on the Static Pavement Project Table. See the disclaimer at the top of the Power BI page for additional information and instructions.



Dynamic Pavement Project Table

The table below **displays dynamic crash counts and crash rates based on filtered selections**. To use this dynamic table, first use the filters on the Road Location, Project Characteristics, and Crash Characteristics filter pages to filter the selected projects and crashes; then review the resulting crash counts and rates in this table. Note that it may take Power BI a couple minutes to load this table, depending on the computing power of your computer. Also note that this dynamic table allows for only a portion of a project length to be analyzed (based on geographic filter selection); to see whether an entire project length is being considered, compare the "Total Project Length" with the "Filtered Length Considered" columns. Note that "0" in a crash rate column may either mean the crash rate is zero, or that the crash rate is unavailable (e.g., if there are not enough years of data available to compute it) - check the associated

PIN	Completion Date	Work Type Code	Program Type Code	ID Number	Total Project Length	Filtered Project Length	Beginning Log Mile (Filtered)	End Log Mile (Filtered)	Crash Count 1 Yr Before	Crash Ra 1 Yr Befo
131597	9/30/2022	PWT66	RESURFACING	62SR165001	14.22	14.22	9.59	23.81	4	0.
110548.01	11/13/2015	PWT09	RESURFACING	62SR360001	12.92	12.92	2.00	14.92	3	0.
123898	9/30/2022	PWT66	RESURFACING	40SR140001	9.53	9.53	0.47	10.00	7	0.
115570	6/30/2014	PWT66	RESURFACING	91SR227001	9.09	9.09	0.00	9.09	6	4.
127393	8/31/2021	PWT66	RESURFACING	23SR181001	8.67	8.67	2.81	11.48	4	0.
117624	3/23/2015	PWT66	RESURFACING	46SR133001	8.63	8.63	2.80	11.43	2	1.
129671	9/30/2022	PWT09	RESURFACING	61SR058001	7.97	7.97	7.37	15.34	15	0.
123949	10/31/2022	PWT68	RESURFACING	49SR019001	7.95	7.95	0.00	7.95	0	0.
123990	9/28/2017	PWT66	RESURFACING	37SR347001	7.89	7.89	13.01	20.90	3	3.
123966	8/17/2017	PWT66	RESURFACING	45SR009001	7.86	7.86	0.44	8.30	13	1.
102283.01	9/11/2015	PWT66	RESURFACING	41SR100001	7.80	7.80	0.00	7.80	7	4.
123969	9/11/2017	PWT66	RESURFACING	46SR034001	7.75	7.75	3.77	11.52	7	1.
127368	11/15/2020	PWT68	RESURFACING	23SR104001	7.73	7.73	2.53	10.26	2	2.
129124	9/30/2022	PWT66	RESURFACING	87SR170001	7.71	7.71	5.86	13.57	4	0.
119623	10/15/2014	PWT66	RESURFACING	92SR118001	7.69	7.69	1.49	9.18	2	1.
127361	9/30/2020	PWT66	RESURFACING	36SR069001	7.66	7.66	0.44	8.10	12	1.
127187	9/24/2019	PWT66	RESURFACING	58SR150001	7.60	7.60	5.71	13.31	2	0.
117300	9/30/2013	PWT66	RESURFACING	21SR056001	7.49	7.49	12.71	20.20	10	0.
129239	9/29/2021	PWT66	RESURFACING	21SR056001	7.49	7.49	12.71	20.20	12	0.
123945	10/6/2017	PWT66	RESURFACING	24SR222001	7.48	7.48	0.00	7.48	2	1.
82442.02	11/17/2014	PWT66	RESURFACING	29SR092001	7.43	7.43	0.05	7.48	9	1.
129102	10/13/2020	PWT66	RESURFACING	62SR068001	7.41	7.41	26.74	34.15	9	2.
127135	9/30/2022	PWT66	RESURFACING	10SR143001	7.34	7.34	0.00	7.34	6	0.
129495	8/26/2021	PWT09	RESURFACING	91SR099001	7.31	7.31	6.80	14.11	0	0.

Figure B 5 Dynamic Pavement Project Table.

B.1.5. Dynamic Pavement Project Table

Figure B.5 shows the page that provides a table displaying the results of a batch analysis completed on all the projects in the filtered selection, **including only the crashes included in the geographic and crash characteristic filtered selection** (e.g., if the user selected "Wet" on the Surface Condition filter on the previous page, the resulting crash counts and crash rates in this table would only include crashes that occurred during wet conditions). The table includes crash counts and crash rates for 1-, 2-, and 3-years before and after each project, as well as a 3-year percent change. Refer to the section below on Crash Calculation Specifics for more information on how these calculations were performed. Other data in the table includes PIN, completion date, work type code, program type code, ID number, total project length, filtered project length, filtered beginning and end log miles, and scope of work. Note that the since this table is dynamic, geographic filters applied may result in only a portion of a project length being analyzed (e.g., if a project spanned two counties but only one county was selected on the road location filter page, then only the portion of the project in that one county would be analyzed in this table). To check whether the full project length is being considered, compare the total project length and filtered project length columns. There are two filters included on this page - project work type and PIN; note that modifying selections within these filters will impact the filtered selection on all other pages. Refer to the number at the bottom right of the screen for the updated number of projects in filtered selection. See the disclaimer at the top of the Power BI page for additional information and instructions. ***Note*** that due to the dynamic nature of this table, it may take Power BI a few minutes to load the table depending on the computing power of the computer being used.

Also ***note*** that the information in this table allows the user to easily explore crash rates further for a specific project using the Tennessee Crash Analytics and Safety Tool (TCAST), by plugging the ID number and beginning and end log miles into the “Filters: Crash Time & Location” page of TCAST and exploring the following pages of visuals.

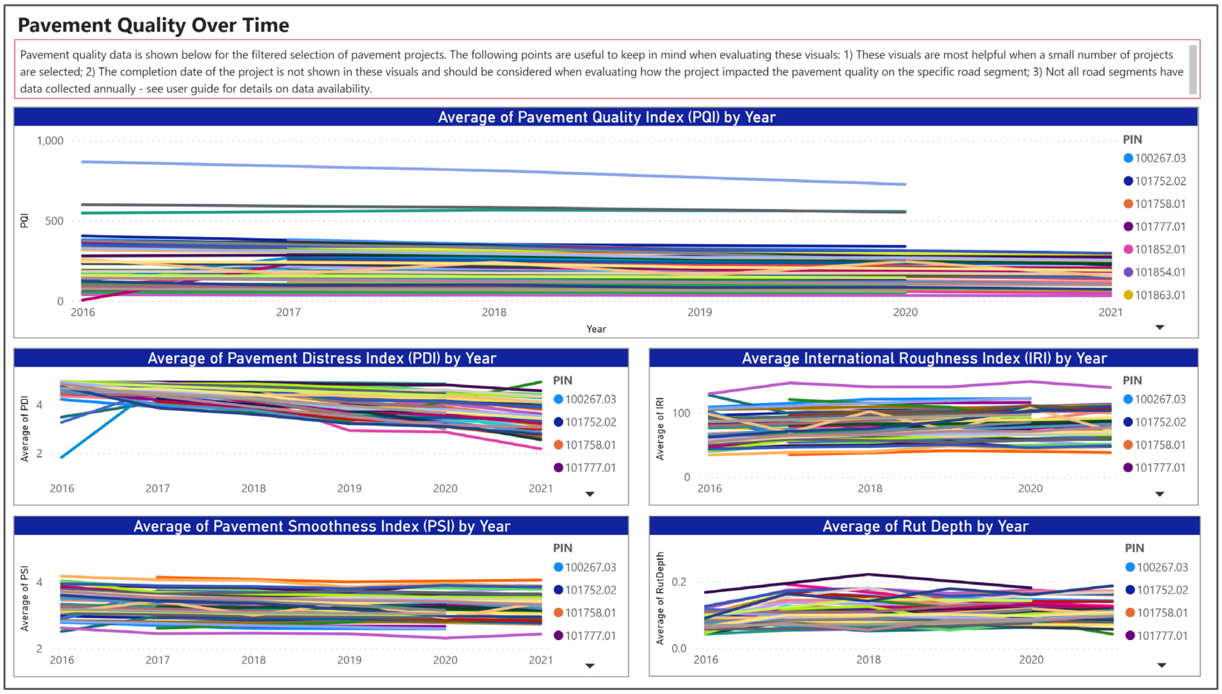


Figure B 6 Analyzing Pavement Quality over Time.

B.1.6. Pavement Quality Over Time

The page provided in Figure B.6 includes five line graphs displaying four pavement quality indices and average rut depth over time. The four indices displayed are: Pavement Quality Index (PQI), Pavement Distress Index (PDI), International Roughness Index (IRI), and Pavement Smoothness Index (PSI). For information on the indices, see the following glossary page, described below. ***Note*** that 1) these visuals are most helpful when a small number of projects are selected; 2) the completion date of the project is not shown in these visuals and should be considered when evaluating how the project impacted the pavement quality on the specific road segment; and 3) not all road segments have data collected annually (see Additional Important Notes section below).

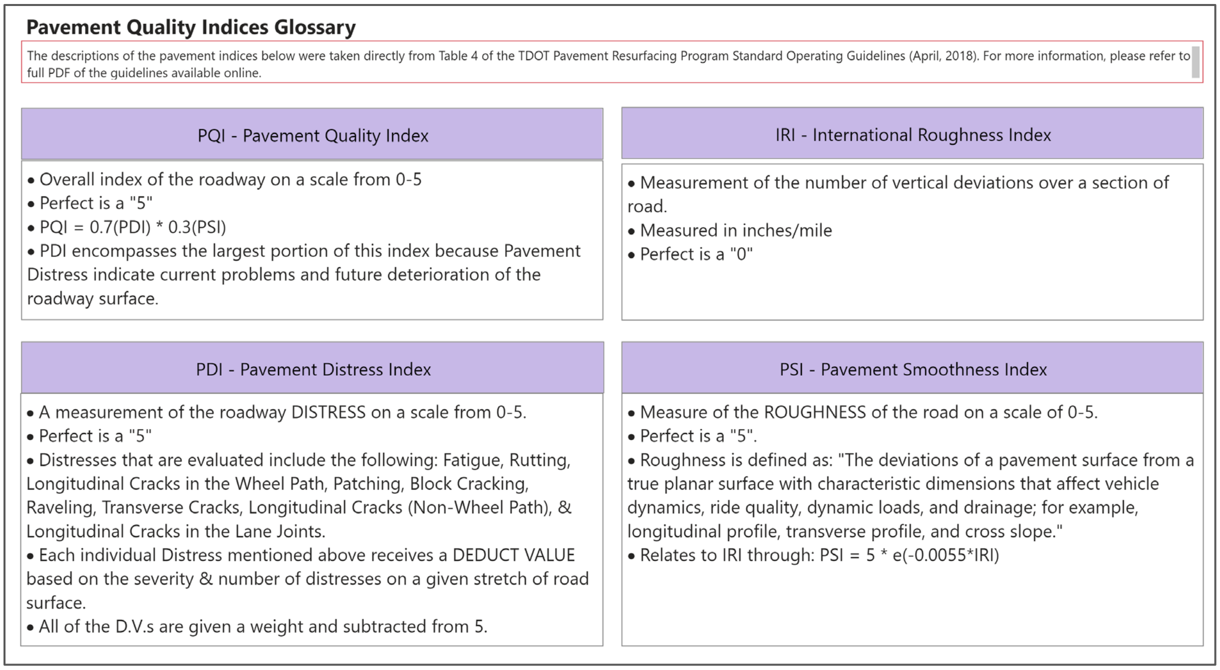


Figure B 7 Pavement quality glossary page.

B.1.7. Pavement Quality Glossary

Also included in the tool is a pavement quality glossary page (see Figure B.7). This page includes definitions and relevant information on the four pavement quality indices shown on the previous page. The definitions were taken directly from Table 4 of the TDOT Pavement Resurfacing Program Standard Operating Guidelines published in April, 2018; for more detailed information on the indices, please refer to the full PDF of the guidelines available online at: https://www.tn.gov/content/dam/tn/tdot/maintenance/pavement-office/TDOT-ResurfacingGuidelines-27April2018.pdf.

B.2. Additional Important Notes and Disclaimers

- The “Clear All Filters” button that can be found on several of the pages clear all the filter selections made on any page of the tool (rather than just the current page).
- Not all pavement data is collected annually; Data is collected in both directions every year only on interstates. Pavement quality on other road types, such as state routes or local roads, is collected on an alternating schedule. For these roads, pavement quality data is typically available for either only even or odd years.
- The 2021 AADT data was used in the 2022 crash rate calculation in order to enable analyses involving 2022 crash data. Only crashes that occurred on traffic segments as defined in the TRIMS traffic table were included in the crash rate calculations, since AADT is a required variable for crash rate calculation.

B.3. Crash Calculations Specifics

Crash rates are commonly calculated as the number of crashes per million vehicle miles traveled (VMT) over a specific period of time. The crash rate calculation used for this application was developed to allow for a dynamically selected range of time. VMT over a period of time distributed unevenly across multiple years is calculated as a weighted sum by the number of days in each year.

The formula below was applied to calculate crash rates in the application over 0.1 log mile:

$$\frac{Crash\ Count * 1{,}000{,}000}{(Sum\ of\ VMT\ 2012 * Days\ in\ 2012) + (Sum\ VMT\ 2013 * Days\ in\ 2013) \ldots + (Sum\ VMT\ 2021 * Days\ in\ 2021)}$$

The "Sum of VMT [YEAR]" variable is the sum of the vehicle miles traveled on all eligible road segments—all those with traffic count data—included in the related project segment length (and – for the dynamic table – for the length of the project still within the filtered geographic area).

The formula below was applied to calculate crash rates in the application under 0.1 log mile:

$$\frac{Crash\ Count * 1{,}000{,}000}{(\ AADT\ 2012 * Days\ in\ 2012) + (AADT\ 2013 * Days\ in\ 2013) \ldots + (AADT\ 2021 * Days\ in\ 2021)}$$

The project start date was defined as 120 days before project completion date since PPRM often times did not have an official start date listed. The crash counts and crash rates for 1-, 2-, and 3-years before and after were set up in such a way that they included the crash counts and related AADT or VMT measurements for 1-, 2-, or 3-years before project start date and 1-, 2-, or 3-years after project completion date. ***Note*** that for projects that occurred either very early or very late within our data window, some of these crash counts and crash rates may not be available, and will display as zeroes in the table (e.g., a pavement project that was completed in 2020 would have crash counts and crash rates for 1-, 2-, and 3-years before the project, but would not have a 3-year after crash count or crash rate (and, depending on when the project was completed in 2020, may not have a 2-year after).

The 3-year percent change calculation was computed using the following formula:

$$\frac{Crash\ Rate\ 3\ Year\ After - \ Crash\ Rate\ 3\ Year\ Before}{Crash\ Rate\ 3\ Year\ Before} * 100\%$$

Note that due to the way this equation is set up, if the result is a negative percentage (e.g., -70%), that means the 3-year crash rate was reduced by that percentage.

B.4. Background on the Data

All pavement project data was retrieved from PPRM from 2013 to present. The projects included in this tool represent a variety of work types. These include resurfacing projects, as well as other project types which could have altered a road's pavement. These project types include, but are not limited to widening, new construction, and realignment. The pavement quality data was retrieved from HPMA from 2016 to present. All roadway and crash data used for this application was retrieved from the TRIMS SDE database, specifically from the Traffic, Road Segment, Crash, and Crash Driver/Vehicle tables. Yearly AADT for traffic segments was obtained from TN-TIMES traffic station counts.

The data model behind the TPAT interface consists of a database of related tables containing pavement, projects, roadway, and traffic data. The relationships between these tables are defined by where their features intersect on TDOT's linear referencing network (see Figure B.8). To effectively connect all of these tables, which contain data obtained from multiple different databases, a pre-processing script was developed in Python to generate the tables for the data model. The process performed by the script heavily relies on ArcGIS linear referencing tools to overlay route feature tables and identify relationships between features. The script was developed so that the tool's database could be updated with new data through a repeatable process, which can accept a standardized set of inputs, and produce a new set of tables which can be directly connected to the tool's database.

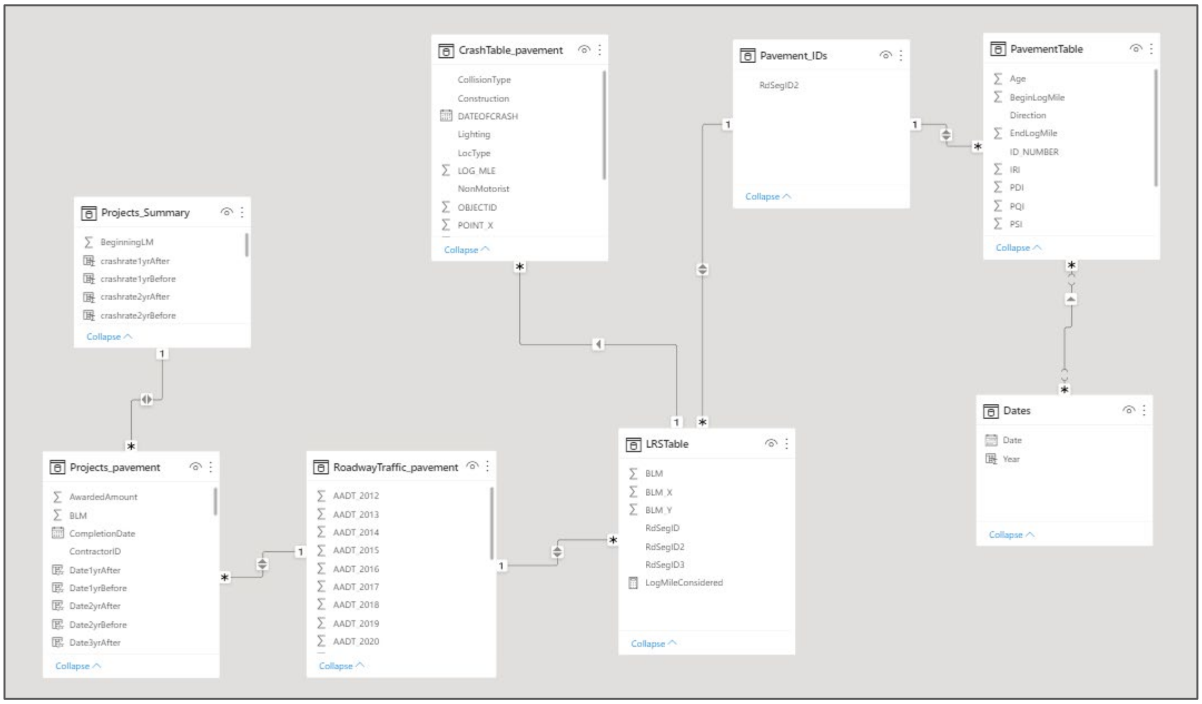


Figure B 8 TPAT data table relationships.

B.5. Data Dictionary

Below is a list of all attributes that are actively displayed in the current version of the tool along with their source table. Nearly all data used in this application was sourced from TRIMS tables, with the exception of AADT, which was obtained from the TN-TIMES database. The name of the attribute was written to reflect how it is displayed in the filter selections.

Table B 1 TPAT Data Dictionary

Attribute	Source(s)	Brief Description & Relevant Notes
Urban vs Rural	RD_SGMNT	Derived from the functional class attribute.
County	RD_SGMNT	County name, converted from county number.
Route Number	RD_SGMNT	5-digit alphanumeric route identifier.
Route Name	RD_SGMNT	Identifying name for a road.
Route ID Number	All TRIMS Tables	10-digit alphanumeric route identifier. Locates route features on TDOT's linear referencing system

Log Mile	CR_CRASH	Used to pinpoint crash locations along routes.
Severity	CR_CRASH	Most severe injury to occur in a crash.
Construction Zone?	CR_CRASH	Crashes occurring in construction zones.
Type of Crash	CR_CRASH	Manner of initial collision.
Weather	CR_CRASH	Weather conditions at time of crash
Lighting	CR_CRASH	Lighting conditions at time of crash
Surface Conditions	CR_DRIVER_VEH	Roadway surface conditions at time of crash.
Program Type Code	PPRM	Program type code describing type of project, e.g., resurfacing, local programs, safety
Project Work Type Code	PPRM	5-digit alphanumeric work type identifier
Contractor ID	PPRM	Name of contractor for each project
Project Identification Number (PIN)	PPRM	8-digit numeric project identifier
Project Completion Date	PPRM	Date of project completion
Total Project Length	PPRM	Project length in miles
Estimated Project Cost	PPRM	Project cost in USD
Beginning Log Mile (of project)	PPRM	Beginning log mile of project
End Log Mile (of project)	PPRM	End log mile of project
Scope of Work	PPRM	Description of the scope of work; some entries contain information on materials used, and additional location information
Pavement Quality Index (PQI)	HPMA	See glossary for description
Pavement Distress Index (PDI)	HPMA	See glossary for description
Pavement Smoothness Index (PSI)	HPMA	See glossary for description
International Roughness Index (IRI)	HPMA	See glossary for description
Rut Depth	HPMA	Rut depth of road segment