THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

**TECHNICAL REPORT 0-7028-01-1**
TxDOT PROJECT NUMBER 0-7028-01

# An Integrated Online Application for SiteManager and Pavement Analyst

Amit Bhasin
Syeda Rahman

August 2024

Published January 2025

https://library.ctr.utexas.edu/ctr-publications/0-7028-01-1.pdf

Technical Report Documentation Page

| 1. Report No. FHWA/TX-25/0-7028-01-1 | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| 4. Title and Subtitle An Integrated Online Application for SiteManager and Pavement Analyst | | 5. Report Date Submitted: June 2024 |
| | | 6. Performing Organization Code |
| 7. Author(s) Syeda Rahman https://orcid.org/0000-0002-7111-0333, Amit Bhasin https://orcid.org/0000-0001-8076-7719 | | 8. Performing Organization Report No. 0-7028-01-1 |
| 9. Performing Organization Name and Address Center for Transportation Research The University of Texas at Austin 3925 W. Braker Lane, 4th Floor Austin, TX 78759 | | 10. Work Unit No. (TRAIS) |
| | | 11. Contract or Grant No. 0-7028-01 |
| 12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Division 125 E. 11th Street Austin, TX 78701 | | 13. Type of Report and Period Covered Technical Report September 2022 – August 2024 |
| | | 14. Sponsoring Agency Code |

15. Supplementary Notes

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

16. Abstract

The objectives of this study were to integrate material, construction, maintenance, and performance information, and to deploy the unified data on a commercial system licensed by TxDOT so that Division and District personnel can access and interact with these data. Data from the SMGR, PA, and DCIS databases were identified, integrated, and processed using Tableau Prep Builder flows. Maintenance activities identified by the four-year project planning records from the PA database were also included. The integrated data-sources were then used to develop Tableau dashboards for easy visualization and tracking of performance of projects, specification Items, and mixture constituents. A text guide and a video guide were developed to demonstrate the utilization and management of the integrated data-sources and developed dashboards. Feedback from TxDOT personnel were sought to identify the needs of various Divisions and Districts and improve dashboard functionality.

With an ability of easy visualization, the online application system incorporates maintenance activities, for the first time, in accounting the total dollar spent on a pavement section, determining the actual age of the pavement surface layers, and tracking the long-term performance of materials and specification Items. The flows and the dashboards developed in this study present the foundational framework for the integration and tracking of performance of materials and construction practices for other design-build projects and pilot projects introducing new specification Items.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| SiteManager, Pavement Analyst, materials, specification Items, performance, maintenance, construction, pavement, distress, Tableau | No restrictions. This document is available to the public through the National Technical Information Service, Alexandria, Virginia 22312; www.ntis.gov. |

| 19. Security Classif. (of report) | 20. Security Classif. (of this page) | 21. No. of pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 86 | |

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

THE UNIVERSITY OF TEXAS AT AUSTIN
CENTER FOR TRANSPORTATION RESEARCH

# An Integrated Online Application for SiteManager and Pavement Analyst

Syeda Rahman
Amit Bhasin


| | |
|---|---|
| CTR Technical Report: | 0-7028-01-1 |
| Report Date: | Submitted: June 2024 |
| Project: | 0-7028-01 |
| Project Title: | Integrated SiteManager and Pavement Analyst Database on an Online Platform |
| Sponsoring Agency: | Texas Department of Transportation |
| Performing Agency: | Center for Transportation Research at The University of Texas at Austin |

Project performed in cooperation with the Texas Department of Transportation and the Federal Highway Administration.

Center for Transportation Research
The University of Texas at Austin
3925 W. Braker Lane, 4th floor
Austin, TX 78759

http://ctr.utexas.edu

# DISCLAIMER

**Author's Disclaimer:** The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation.

**Patent Disclaimer:** There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant, which is or may be patentable under the patent laws of the United States of America or any foreign country.

# ENGINEERING DISCLAIMER

NOT INTENDED FOR CONSTRUCTION, BIDDING, OR PERMIT PURPOSES.

Project Engineer: Amit Bhasin
Professional Engineer License State and Number: Texas No. 126265
P.E. Designation: Research Supervisor

# ACKNOWLEDGMENTS

The authors acknowledge the financial support of the Texas Department of Transportation for project 0-7028-01. The authors would like to thank Tom Schwerdt who served as a project manager. The authors are also thankful to Dr. Enad Mahmoud and Travis Patton for their assistance and support in conducting the project. The research team also extend their thanks to members of the project management committee, Ryan Barborak, Jorge Hernandez, and Sarah Horner. The research team would like to thank Dr. Taehoon Lim from MNT for his help with obtaining pavement condition data from the Pavement Analyst database, Pravat Karki from MTD for seal coat test data, and Benjamin Mcculloch from STR and Kevin Rhinevault from ITD for their advice and support with Tableau. In addition, the research team appreciates Lacy Peters and Kimberly Garner from the Atlanta District for their feedback on the dashboards. Special thanks to Dr. Andre Smit for his insight and assistance with data collection, management, and integration and his support on the development of the dashboards throughout the project.

# PRODUCTS

This report contains Tableau dashboards and Tableau Prep Builder flows that integrate and analyze data from several TxDOT databases. The flows are described in Chapter 2, and the dashboards are described in Chapter 3. The text guide describing the use of the dashboards is provided in Chapter 4.

## ABSTRACT

The objectives of this study were to integrate material, construction, maintenance, and performance information, and to deploy the unified data on a commercial system licensed by TxDOT so that Division and District personnel can access and interact with these data. Data from the SMGR, PA, and DCIS databases were identified, integrated, and processed using Tableau Prep Builder flows. Maintenance activities identified by the four-year project planning records from the PA database were also included. The integrated data-sources were then used to develop Tableau dashboards for easy visualization and tracking of performance of projects, specification Items, and mixture constituents. A text guide and a video guide were developed to demonstrate the utilization and management of the integrated data-sources and developed dashboards. Feedback from TxDOT personnel were sought to identify the needs of various Divisions and Districts and improve dashboard functionality.

With an ability of easy visualization, the online application system incorporates maintenance activities, for the first time, in accounting the total dollar spent on a pavement section, determining the actual age of the pavement surface layers, and tracking the long-term performance of materials and specification Items. The flows and the dashboards developed in this study present the foundational framework for the integration and tracking of performance of materials and construction practices for other design-build projects and pilot projects introducing new specification Items.

# EXECUTIVE SUMMARY

## Research Overview

Texas Department of Transportation (TxDOT) maintains several databases to track material, construction, and performance information for roadway projects: materials and test records in the SiteManager (SMGR) database; construction related information in TxDOT Connect or Design and Constructions Information System (DCIS); in-house maintenance activities in Compass (formerly known as Maintenance Management System (MMS)); and performance measures in the Pavement Analyst (PA) database. In a recent project, 0-7028, data from the SMGR and PA databases were compiled and analyzed to study the influence of material properties on the long-term pavement performance. Several pavement sections were also selected for site visits to validate results obtained from the compiled data. The comparison of the filed observations with the compiled data revealed that there was a need to incorporate maintenance activities to accurately capture the performance of materials and construction practices. Furthermore, currently TxDOT does not have a system to evaluate the performance of materials and assess the effect of modified and new specification Items on the long-term pavement performance. Therefore, the objectives of this study were (i) to integrate material, construction, maintenance, and performance information to accurately determine the total dollar spent on a given section and the age of pavement surfaces; and (ii) to deploy the unified data on a commercial system licensed by TxDOT so that appropriate Division and District personnel can access and interact with these data.

To achieve these goals, the research team extracted material and project related information from the SMGR and DCIS databases, and pavement surface conditions, distress measures, and locations of all contracted and in-house construction and maintenance projects identified for four-year planning cycles from the Pavement Analyst database. The research team queried, integrated, and processed these data on Tableau Prep Builder. The integrated data on Tableau Prep Builder were directly connected to the source SMGR and DCIS databases, which were updated on a regular interval. The integrated data were then utilized to develop Tableau dashboards for easy visualization, analysis, and interaction, and the integrated data-sources and dashboards were published on Tableau-TxDOT. Feedback from TxDOT personnel were sought to identify the specific needs of Divisions and Districts. In addition, a text guide and a video guide were developed to demonstrate how one could use the dashboards to view, study, and compare long-term performance and distresses of projects, specification Items, and mixture constituents. Furthermore, steps to add additional data-sources and create new dashboards utilizing the additional data-sources were provided for future management and expansion.

## Dashboard Design and Functionality

The research team developed a unified online application with multiple dashboards that

- integrate material, construction, maintenance, and performance measures;
- locate projects on a geographical map on a highway section for different Districts and Maintenance Sections;
- visualize long-term pavement conditions and distresses for projects, specification Items and mixes, and material constituents;
- estimate the total dollar value spent on construction and maintenance activities for a given section;
- summarize available material information, material sources, and Quality Control Quality Assurance (QCQA) efforts;
- determine the age of pavement surfaces;
- compares state-wide, district-wide, and maintenance-section-wide performance for projects, specification Items, mixes, and characteristics – including but are not limited to locations, traffic, highway type, and material properties – selected by a user; and
- present pavement performance in the form of pavement condition measures and surface distresses.

An extract of one of the dashboards in Figure ES.1 demonstrates how the application can be used to view the skid score of the specification Items selected from the filter pane highlighted in the yellow box. Divisions and Districts of TxDOT can interact with these dashboards to perform state-wide and district-wide comparison of various projects and specification Items for the following purposes:

- **Planning** – locating roadway sections on a map and summarizing pavement condition, construction history, and material properties for projects constructed on that section. This will allow planning for future projects for that roadway sections.
- **Project level investigation** – analyzing materials and construction practices used in past projects and investigating their effect on the pavement performance.
- **Bench-marking** – aggregating and comparing the performance of items or mixtures, which in turn will provide insights for the modification of specifications.

- **Estimating** – incorporating the cost of the contracted and in-house maintenance activities performed in-between contracted projects and estimating the total dollar value spent on a given section.

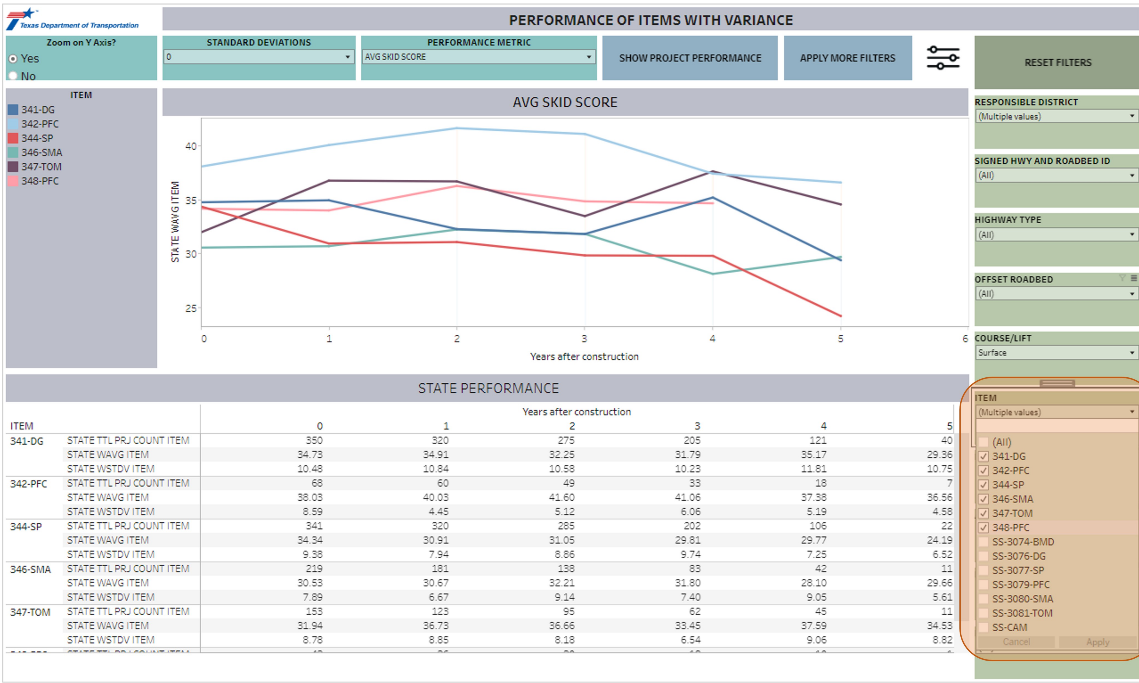


**Figure ES.1. Dashboard showing the skid score of Items selected from the filter pane.**

## Key Achievements

**A first-ever unified system:** The research team developed a unified system that integrates materials, construction, maintenance activities, and pavement surface performance measures for the first time. The developed system incorporates maintenance activities in determining the total dollar value spent on pavement sections and the age of pavement surfaces.
**An online application:** The integrated data-sources and dashboards are published on Tableau-TxDOT server which can be directly accessed by TxDOT personnel from different Divisions and Districts, and the material and project data are updated on regular intervals. Divisions and Districts will be able, in near real time, to evaluate the materials performance, assess the effect of modifying an existing specification Item or introducing a new specification Item on the long-term pavement performance.
**An investigative tool:** The developed system can be used to analyze the historical performance of projects, specification Items or mixes, and constituent materials. The dashboards

can be used to flag unsatisfactory performance, trace back the materials and construction practices associated with such performance, and identify the root cause or initiate further investigation.

**A foundational framework:** The flows and the dashboards developed in this study present the foundational framework for the integration and tracking of performance of materials and construction practices for other design-build projects and pilot projects introducing new or modified specification Items. Such a tool may help in identifying primary modes of pavement distress to be considered in the development or modification of new specifications. Furthermore, this tool may be expanded by adding laboratory test results data, which in turn may be used to relate test results to the field performance and evaluate the appropriateness of laboratory tests.

# TABLE OF CONTENTS

# LIST OF FIGURES

# LIST OF TABLES

# CHAPTER 1. INTRODUCTION

Texas Department of Transportation (TxDOT) maintains several databases to track material, construction, and performance information for roadway projects: materials and test records in the SiteManager (SMGR) database; construction related information in TxDOT Connect or Design and Constructions Information System (DCIS); in-house maintenance activities in Compass (formerly known as Maintenance Management System (MMS)); and performance measures in the Pavement Analyst (PA) database. Data from these databases were compiled in a recent project, performed under the contract number 0-7028, to identify relationships between the materials and construction records and observed long-term performance of hot mix asphalt pavements (Rahman et al., 2022).

In the legacy project, the influence of materials properties including the binder content, binder grade, aggregate absorption, mix type, and recycled binder content on the performance indices such as rutting, cracking, condition score (CS), and international roughness index (IRI) were studied using traditional regression analysis tools as well as new computational data analysis tools. Analysis of the integrated data showed that asphalt content, binder grade, recycled binder content, and aggregate absorption were the notable material characteristics that influenced the long term pavement performance measured in terms of IRI and CS. Based on the material information collected from the SMGR database and performance reported in the PA database, several projects were selected for site inspections in the previous project. Comparison of results from the unified database with field observations revealed that while some of the field observations were consistent with the data retrieved from these two databases, many surfaces were found with crack sealants, chip seal, or overlays indicating that the "well performing" pavement sections were rated high only because of routine maintenance activities that were not captured by the compiled data. Furthermore, currently TxDOT does not have a system to evaluate the performance of materials and assess the effect of modified and new specification Items on long-term pavement performance.

For the aforementioned reasons, there is a need to develop an integrated approach or methodology that incorporates maintenance activities in addition to the construction and performance information to obtain an accurate account of the total cost of pavement sections and the actual period in which pavement surfaces are in service as surface/top layers. Therefore, the objectives of this study were:

- to integrate material, construction, maintenance, and performance information to determine the total dollar spent on a given section and the age of pavement surfaces; and
- to deploy the unified data on a commercial system licensed by TxDOT so that appropriate Division and District personnel can access and interact with these data.

With an easy visualization ability, such a tool will enable accurate accounting of the total dollar spent, determining the actual age of the pavement surface layers, tracking of material, maintenance, and performance history, and ultimately bench-marking the material design factors and QC/QA efforts for improved long-term project performance.

To serve the aforementioned purposes, three major tasks were performed:

- **Task 1: Integrate and process data in Tableau Prep Builder.** Data from the SMGR, PA, and DCIS databases were identified, integrated, and processed in this task using Tableau Prep Builder flows. Maintenance activities were also identified from the four-year project planning from the PA database.
- **Task 2: Develop Tableau Packaged Workbook.** The integrated data-sources were then used to develop Tableau dashboards for easy visualization and tracking of performance of projects, specification Items, and mixture constituents.
- **Task 3: Demonstrate end-to-end functionality.** A text guide and a video guide were developed to demonstrate the utilization and management of integrated data-sources and developed dashboards. In addition, online meetings were held with Divisions and a District to to identify their needs, seek their feedback, and improve the dashboards.

This report documents these tasks in three chapters. Chapter 2 explores various data-sources and demonstrates the integration and processing of these data sources in Tableau Prep Builder. This chapter also provides details of the back-end calculation and analysis of the integrated data that were used to develop the dashboards visualizing the performance of projects and specification Items. Chapter 3 reports on the development of Tableau dashboards and various components of the developed dashboards. Chapter 4 documents the step-by-step process of how one can access the data and interact with the dashboards. The developed dashboards facilitate the state-wide and district-wide analysis as well as comparative analysis for different Districts and Maintenance Sections for viewing the performance of projects, specification Items and mixtures, and material constituents.

# CHAPTER 2. DATA EXTRACTION AND INTEGRATION

## 2.1 INTRODUCTION

A brief description of the data extracted from the SMGR, PA, and DCIS databases is presented in this chapter. The data were queried and processed on Tableau Prep Builder, a commercial software that is already available to TxDOT. This chapter - along with providing a brief account of connections to data sources, queries, data cleaning, processing, and integration techniques - lays the groundwork for the development of Tableau dashboards for further analysis and visualization in the subsequent task.

## 2.2 DATA EXTRACTION AND PROCESSING

TxDOT databases contain as-produced mixture properties and as-constructed pavement quality information as well as the bid and letting related information in the SMGR database and performance related information including ride quality, structural adequacy, and skid resistance in the PA database. The data items extracted from the SMGR and PA databases are summarized in Table 2.1. These data items and the data integration process are further detailed in the subsequent sections.

The material information from the SMGR database was queried using custom SQL queries on Tableau Prep Builder by setting up live connections to the SMGR Oracle Database system. Whereas, pavement performance data from the PA database were imported as comma-separated values (csv) or Microsoft Excel Spreadsheet (xlsx) files to Tableau Prep. An example statement of the SQL query is presented in Figure 2.1. After a connection was set to a data source, a “flow” was created to clean and shape the queried data. Each flow starts from left with the “input” step containing the original data-source and processes to right to the end step, namely the “output” step (see Figures 2.2 to 2.9, for instance). Data from various inputs or connections were combined using the “join” and “union” steps. When needed, a “clean” step was added after an “input” or “union” or “join” step to facilitate data cleaning and shaping. After the data were processed, combined, and cleaned, the curated data were output and published as a data-source on the Tableau-TxDOT server, which was later fed into Tableau to create dashboards for further analysis and visualization.

**Table 2.1. Typical data items extracted from the SMGR and PA database systems**

| Data Source | Data Item |
|---|---|
| SMGR | The following data were extracted for all specification Items (including but not limited to Item 340, 341, 342, 344, 346, 347, and 348) in the 2014* specification book as well as Items for special specifications (items 3074, 3076, 3077, 3079, 3080, 3081, and 3082) to cover HMA mixtures used by TxDOT.<br>• material-related information: mixture type, binder, and recycled material;<br>• volumetric properties: mixture density and related properties as calculated based on the specific gravity of the materials and maximum theoretical density of the mix;<br>• construction cost: information related to quantities, unit costs, and total payment; and<br>• project related information: size of HMA projects in terms of number of tonnage, letting date, and completion date. |
| PA | Performance data records for pavements , including<br>• condition score and each individual component of the condition score (such as distress score, ride score, rut depth, cracking, and roughness), international roughness index;<br>• route, roadbed type, and data collection section;<br>• traffic in terms of 18-kip equivalent single axle load (ESAL), average annual daily traffic (AADT), and maximum speed; and<br>• DCIS and MMS projects and their locations from four-year planning cycles. |

* Projects from 2004 specification Items were not queried because of the missing roadbed and location information that were required to link material properties to the pavement condition. See Section 2.2.2 for further discussion.

### 2.2.1 SiteManager Data

TxDOT's SiteManager database records the mixture properties and project related data as part of the quality control and quality assurance (QCQA) process for all contracted construction and maintenance projects. Hot Mix Asphalt (HMA) information for projects constructed under 2014 specification and special specification Items 340/341/3076 dense-graded, 342/3079 permeable friction course (PFC), 344/3077 performance designed (e.g., Superpave), 346/3080 stone matrix asphalt, 347/3081 thin overlay mixes (TOM), 348/3082 thin bonded wearing courses, and 3074 Superpave mixtures produced using Balanced Mix Design (BMD) were collected from this database. The as-produced mixture properties and as-constructed pavement quality data were captured in the fld_val column from the TX_TST_RSLT_VAL table, and they were referenced by the corresponding fld_nbr column from the same table. Some of the noteworthy QCQA data that were collected from this table were laboratory molded density, in-place air voids, original and substitute binder grades, binder content, and recycled materials. This information was queried for the TX2QCQA14 test method for projects constructed under the specification book 2014. Furthermore, the course information describing the pavement layer and Item information containing the specification Item and mixture type were queried from this table. Since multiple fields were queried from the TX_TST_RSLT_VAL table, several input steps were setup to simplify queries, which were later joined together, as shown in Figure 2.2.

In addition to the material information obtained from the TX_TST_RSLT_VAL, actual and estimated completion dates and start date of constructed projects were queried from the T_SMPL_TST table. The above tables were then joined together using the key fields smpl_id, smpl_tst_nbr, and tst_meth, as shown in the flow presented in Figure 2.2, and output as a data-source, named "SMGR_smpls," and published on the Tableau-TxDOT server. Furthermore, data on material sources, properties, and proportions, such as aggregate and binder sources and producers, were collected via the mixture design form, which was stored as the TX2MIXDE14 test method in the TX_TST_RSLT_VAL table. Figure 2.3 shows the flow that outputs a data-source named "SMGR_mixdes," querying these data from the SMGR database.

The unit price and bid quantity were queried from the T_CONT_ITM table and linked to the T_CONT_SMPL table using the key fields cont_id, proj_nbr, and ln_itm_nbr. These joined tables were then connected to the "SMGR_smpls" and the "SMGR_mixdes" data-sourcesusing smpl_id as the key identifier. The flow joining these tables is presented in Figure 2.4. Table 2.2 provides a list of tables, fields, and their descriptions queried from the SMGR Oracle database system.

Once material information for all samples was tied to the project numbers from the T_CONT_SMPL table, the "Fixed Level of Detail" expression in Tableau Prep Builder was applied over prj_nbr, ln_itm_nbr and tst_meth to calculate the average pay factors, densities, air voids, binder content, and their standard deviations. The same process was used to calculate the total quantity placed and total adjusted pay for each line item number of a project. These calculations and further processing of data including, changing data types and/or trimming empty spaces around data fields were performed in "clean" steps on Tableau Prep Builder.

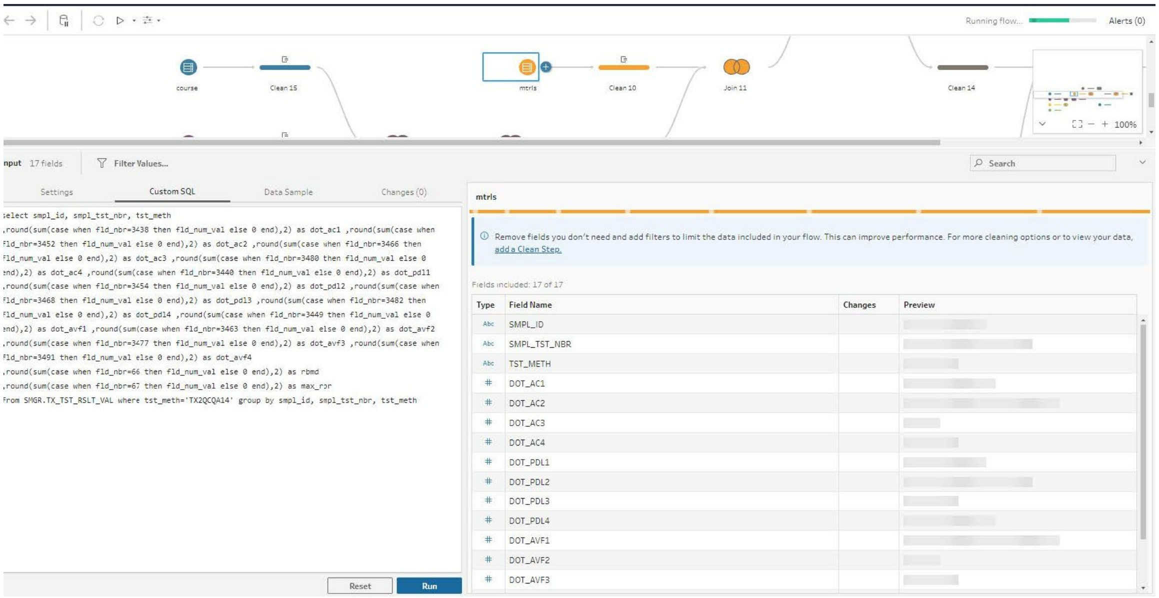


**Figure 2.1. Sample custom query connecting to the SMGR Oracle database system.**

**Table 2.2. Selected tables and fields queried from the SMGR Oracle database.**

| Table | Field | Description |
|---|---|---|
| T_CONT_ITM | cont_id | Contract ID |
| | proj_nbr | Project number (CSJ) |
| | ln_item_nbr | Line item number |
| | itm_cd | Item code |
| | unt_pric | Unit price |
| | spec_yr | Specification year |
| | bid_qty | Bid quantity |
| T_CONT_SMPL | cont_id | Contract ID |
| | proj_nbr | Project number (CSJ) |
| | ln_item_nbr | Line item number |
| | smpl_id | Sample ID |
| T_SMPL_TST | smpl_id | Smple ID |
| | tst_meth | Test method |
| | smpl_tst_nbr | Sample test number |
| | actl_cmpl_dt | Actual completion date |
| | est_cmpl_dt | Estimated completion date |
| | strt_dt | Start date |
| TX_TST_RSLT_VAL | smpl_id | Smple ID |
| | tst_meth | Test method |
| | smpl_tst_nbr | Sample test number |
| | fld_nbr | Field number |
| | fld_val | Field value |

### 2.2.2 Pavement Analyst Data

TxDOT collects annual distress data and records them in the Pavement Analyst (PA) (formerly known as the Pavement Performance Information System) database system to monitor the state-wide road conditions. The Condition Summary Table in the PA database includes annual automated and visual assessments of pavement distresses manifested in the form of 1) rutting; 2) block, alligator, transverse and longitudinal cracking; 3) patching;

4) raveling; and 5) flushing. In addition, this table provides international roughness index, condition scores, and distress scores (DS). DS was calculated from the overall distresses on a pavement surface, which was then further combined with the ride score (RS) and vehicle speed to quantify condition score. Furthermore, this table contains the data collection section information including county, route, and distance to the beginning and ending of the data collection section from the origin of the highway. Information regarding traffic in terms of AADT, current 18 kip ESALS, and maximum speed limit were also present in this table. Table 2.3 lists the data fields extracted from the Condition Summary Table, and Figure 2.5 shows the flow connecting these data.

In addition to the pavement surface condition and distress data, PA tabulates all planned routine maintenance and rehabilitation projects and their locations information. All contracted projects are managed in DCIS and given a unique identifier called control-section-job or CSJ number. While, in-house maintenance and rehabilitation projects undertaken by TxDOT crews are managed with the Compass database system, previously MMS. The planned DCIS and MMS projects along with the location information on a specific route are reported in PA for the four-year planning cycles. Furthermore, these tables report the estimated and actual letting dates, estimated and actual start dates, and construction cost for these projects, and thus can be utilized to locate planned projects on a pavement section.

Locations of projects can be obtained from the DCIS database as an alternate approach, but the process was rather cumbersome. DCIS reports the reference marker extents of projects but it does not always indicate the roadbed on which the project is located. Furthermore, it does not provide Texas reference marker limits for old projects, which need to be manually identified based on textual descriptions of the "from" and "to" limits of a project. While the later issue was addressed recently, these projects cannot be linked to the PA data without knowing the roadbed information. Currently the PA database's Report Dashboard records projects for planning cycles from 2018-2019 up until 2022-2023 in the "DCIS Projects and Locations Archive" and "MMS Projects and Location Archive." Since the DCIS Projects and Locations Archive table only contains projects with the earliest planning year of 2018, only projects constructed under 2014 specification book were queried from the SMGR database. It is possible that a project that is planned in a planning cycle is not constructed under that planning cycle and is carried over to the following cycle. The same project may be listed in multiple four-year planning cycles resulting in unwanted duplicates. To identify and remove these duplicates the "aggregation" step was used on Tableau Prep Builder, as shown in Figures 2.6 and 2.7.

The DCIS and MMS Projects and Location Archive tables were "union"-ed to gather all contracted and in-house projects planned for the four-year planning projects. The flow showing this connection is shown in Figure 2.8. To facilitate the "union" clause between these two tables, some fields were renamed with a common name, for instance, DCIS Project ID/CSJ and MMS Project ID were renamed to Project ID; DCIS Estimated Letting Date and Compass Estimated Letting Date were renamed to Estimated Letting Date; and Texas DCIS Fiscal Year and Texas MMS Year were renamed to Texas DCIS/MMS Year. The DCIS and MMS projects were then "union"-ed by appending these columns to obtain all contracted and in-house projects planned for construction on a data collection section.

**Table 2.3. Selected fields of the PA Condition Summary Table.**

| Field | Description |
|---|---|
| Fiscal year | The year pavement condition data were collected |
| Signed highway and roadbed ID | Highway name and roadbed type |
| Offset roadbed | roadbed type |
| pa highway system | The broad category of highways used in PA |
| Responsible district | District name |
| County | County name |
| Beginning DFO | The beginning distance from origin of the data collection section |
| Ending DFO | The ending distance from origin of the data collection section |
| Distress score | The overall amount of surface distress on the data collection section |
| Condition score | The overall condition of the data collection section in terms of surface distress and ride quality |
| Ride score | The overall ride quality of the data collection section |
| ACP patching pct | The percentage of lane area with patching in the rated lane of the data collection section |
| ACP failure qty | The number of visually observed failures in the rated lane of the data collection section |

**Continued on next page**

**Table 2.3 continued**

| Field | Description |
|---|---|
| ACP block cracking pct | The percentage of lane area with block cracking in the measured lane of the data collection section |
| ACP alligator cracking pct | The percentage of wheel path length with alligator cracking in the measures lane of data collection section |
| ACP longitude cracking pct | The length in feet per station of visually observed longitudinal cracking on the segment in the rated lane of the data collection section |
| ACP transverse cracking qty | The number of visually observed transverse cracks per station in the measures lane of the data collection section |
| ACP raveling code | The area of pavement raveled |
| ACP flushing code | The area of pavement flushed |
| ACP rut auto shallow avg pct | The average percentage of shallow rutting for all data measured by automated equipment in the data collection section |
| ACP rut auto deep avg pct | The average percentage of deep rutting for all data measured by automated equipment in the data collection section |
| ACP rut auto severe avg pct | The average percentage of severe rutting for all data measured by automated equipment in the data collection section |
| ACP rut auto failure avg pct | The average percentage of failure rutting for all data measured by automated equipment in the data collection section |
| ACP rut left wp dpth (inch) | The average depth of rutting measured in the left wheelpath |
| ACP rut right wp dpth (inch) | The average depth of rutting measured in the right wheelpath |
| ACP rut average wp depth (inch) | The average rut depth of the left and right wheelpaths |

**Continued on next page**

**Table 2.3 continued**

| Field | Description |
|---|---|
| IRI left score (inch/mile) | The average international roughness index in inches per mile for the left wheelpath |
| IRI right score (inch/mile) | The average international roughness index in inches per mile for the right wheelpath |
| IRI average score (inch/mile) | The average international roughness index in inches per mile for the left and right wheelpaths |
| Current 18kip ESALS | Current 18-kip ESAL value obtained for the data collection section |
| AADT current | The published average daily estimate of vehicles for all lanes of traffic on a particular highway over the length of a traffic section |
| Truck AADT pct | The percentage of the current annual average daily traffic classified as trucks |
| Speed limit max | The maximum legal speed limit in miles per hour |

The roadbed information and the beginning and ending DFO were used to join the planned projects from four-year planning cycle to the condition summary table to connect pavement conditions with the corresponding project numbers. Once these projects were located using the projects and locations archive tables from the PA database, the CSJs were then linked to the data from the "SMGR-proj" data-source to identify projects that were contracted and retrieve the construction date, cost, and material properties of the constructed projects. The final flow of data integration combining the material, project, and pavement performance information is shown in Figure 2.9.

The above mentioned flows, shown in Figures 2.2 to 2.9, were linked together and scheduled to run once a week (see Figure 2.10) to update the material and construction information of the ongoing projects that were uploaded to the SMGR Oracle database on a regular basis. The pavement condition information in the PA database is recorded yearly. As such the static csv or xlsx files containing the pavement surface conditions and project locations were planned to be updated annually. The integrated data were then output and published on Tableau-TxDOT server to serve as the primary data-source for further analysis and visualization.

**Table 2.4. Selected fields from the DCIS and MMS projects and location archive table from the PA database.**

| Table | Field |
|---|---|
| DCIS Projects and Locations Archive | Four year plan cycle<br>Texas DCIS fiscal year<br>Highway name<br>Number thru lanes<br>Responsible district<br>County<br>Beginning DFO<br>Ending DFO<br>DCIS project ID/CSJJ number<br>At completion expansion cost<br>DCIS work type<br>DCIS est let date<br>DCIS project class<br>Layman's description |
| MMS Projects and Locations Archive | Four year plan cycle<br>Texas MMS year<br>Highway name<br>Number thru lanes<br>Responsible district<br>County<br>Beginning DFO<br>Ending DFO<br>Activity<br>Compass activity description<br>Compass estimated contract start date<br>Compass estimated letting date<br>Compass actual contract start date<br>Compass actual letting date |

**Continued on next page**

**Table 2.4 continued**

| Table | Field |
|---|---|
| | Compass modified on |
| | Compass labor cost |
| | Compass equipment cost |
| | Compass material cost |
| | Work cost |
| | Original work cost |
| | MMS project ID |
| | MMS project description |
| | MMS Roadbed |

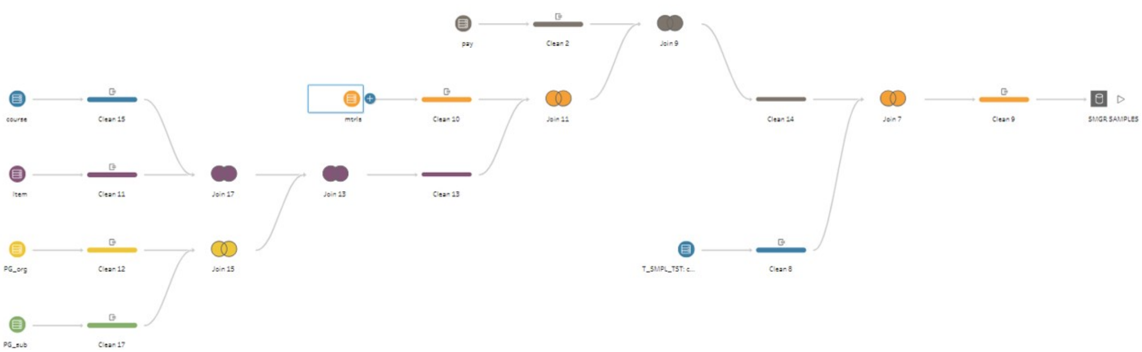


**Figure 2.2. Tableau Prep Builder flow querying and processing material information from the quality control quality assurance records in the SMGR Oracle database.**

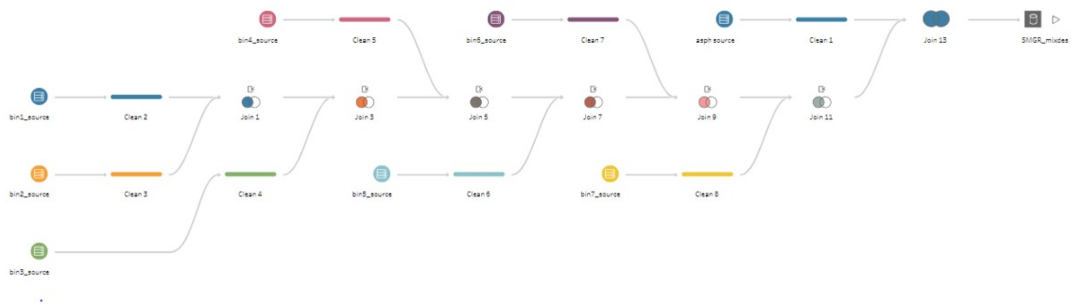


**Figure 2.3. Tableau Prep Builder flow querying and processing material information from the mixture design records in the SMGR Oracle database.**

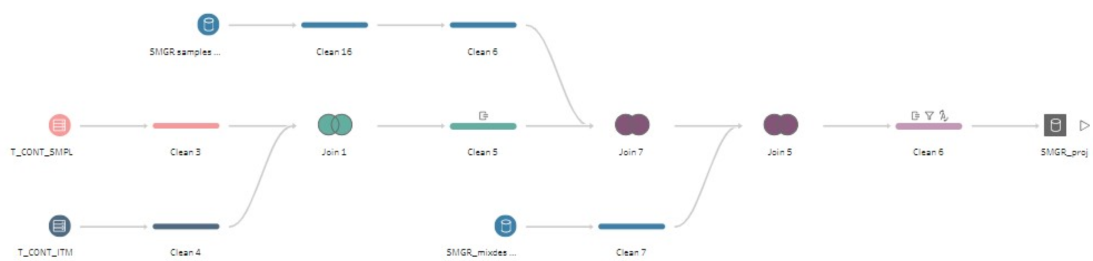


**Figure 2.4. Tableau Prep Builder flow querying and processing project information from the SMGR Oracle database and linking them to the material information from the "SMGR_smpl" (Figure 2.2) and "SMGR_mixdes" (Figure 2.3) data-sources.**

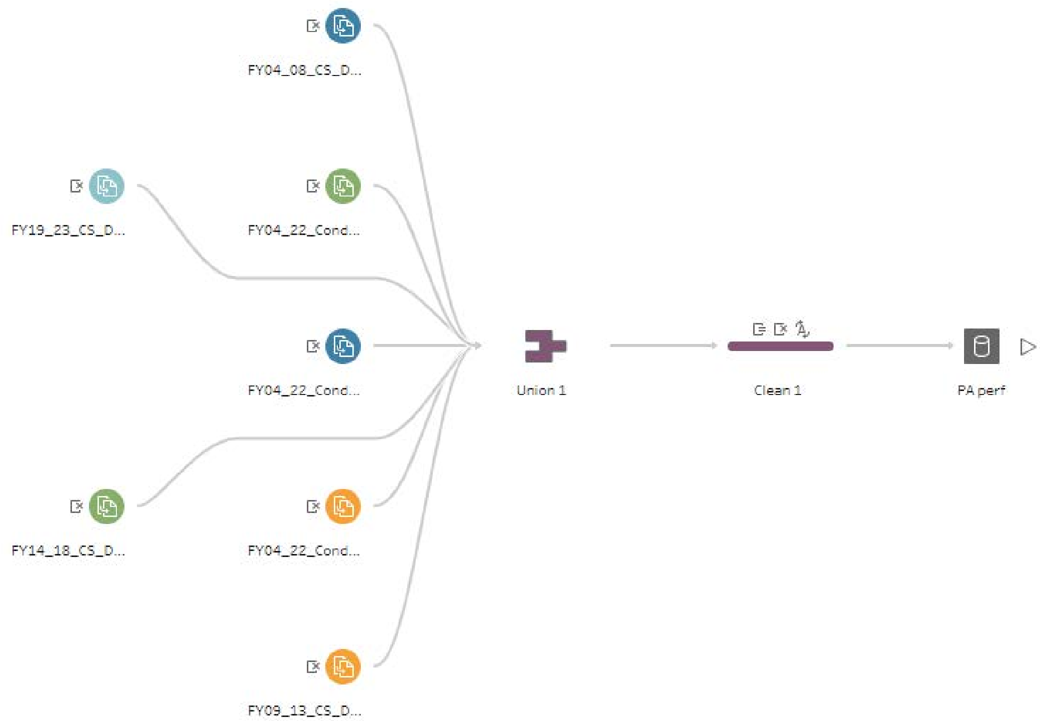


**Figure 2.5. Tableau Prep Builder flow for combining data from the PA Condition Summary Table.**

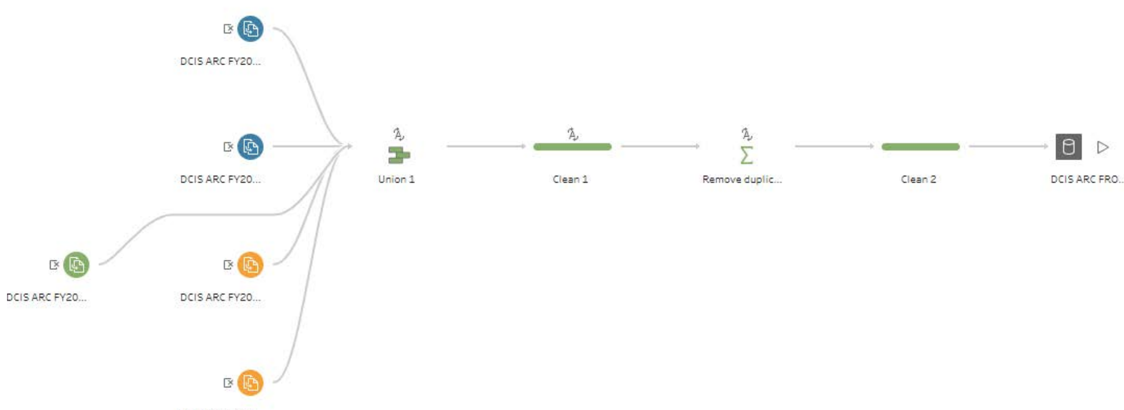


**Figure 2.6. Tableau Prep Builder flow for combining data from the DCIS Projects and Locations Archive table from the PA database.**

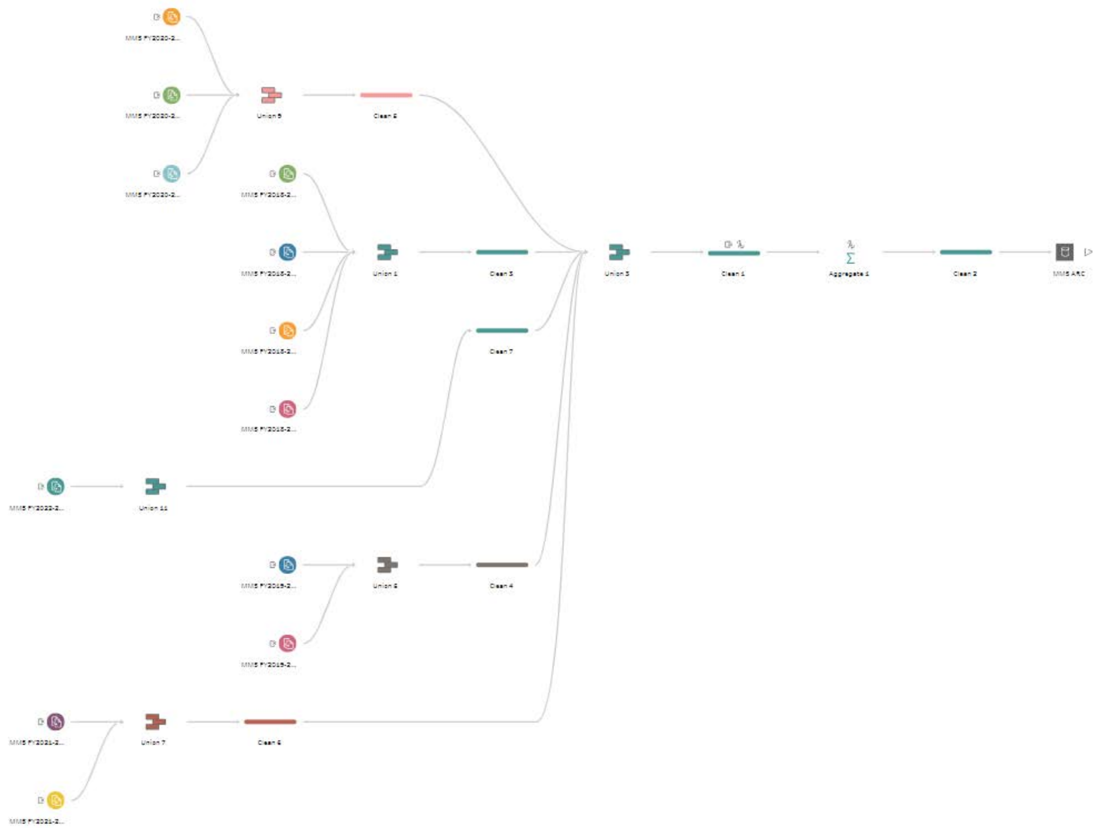

**Figure 2.7. Tableau Prep Builder flow for combining data from the MMS Projects and Locations Archive table from the PA database.**

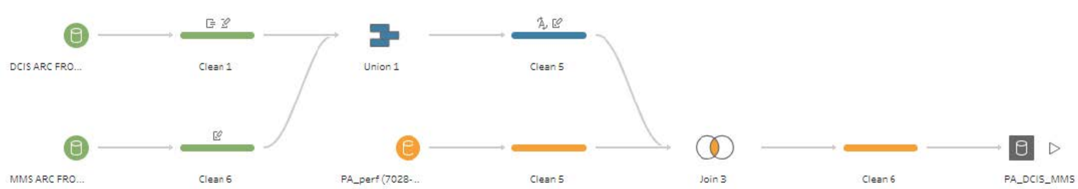


**Figure 2.8. Tableau Prep Builder flow integrating the pavement condition information from the "PA-perf" data-source (Figure 2.5) with the DCIS (Figure 2.6) and MMS (Figure 2.7) project and location information.**

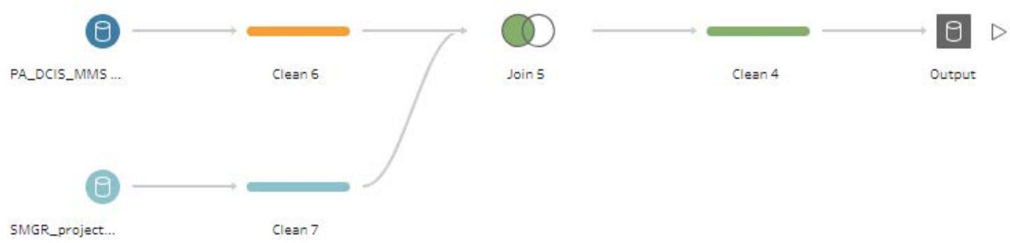


**Figure 2.9. Tableau Prep Builder flow integrating material and project information from the “SMGR_proj” data-source (Figure 2.4) with the pavement condition and project location information from the “PA_DCIS_MMS” data-source (Figure 2.8).**

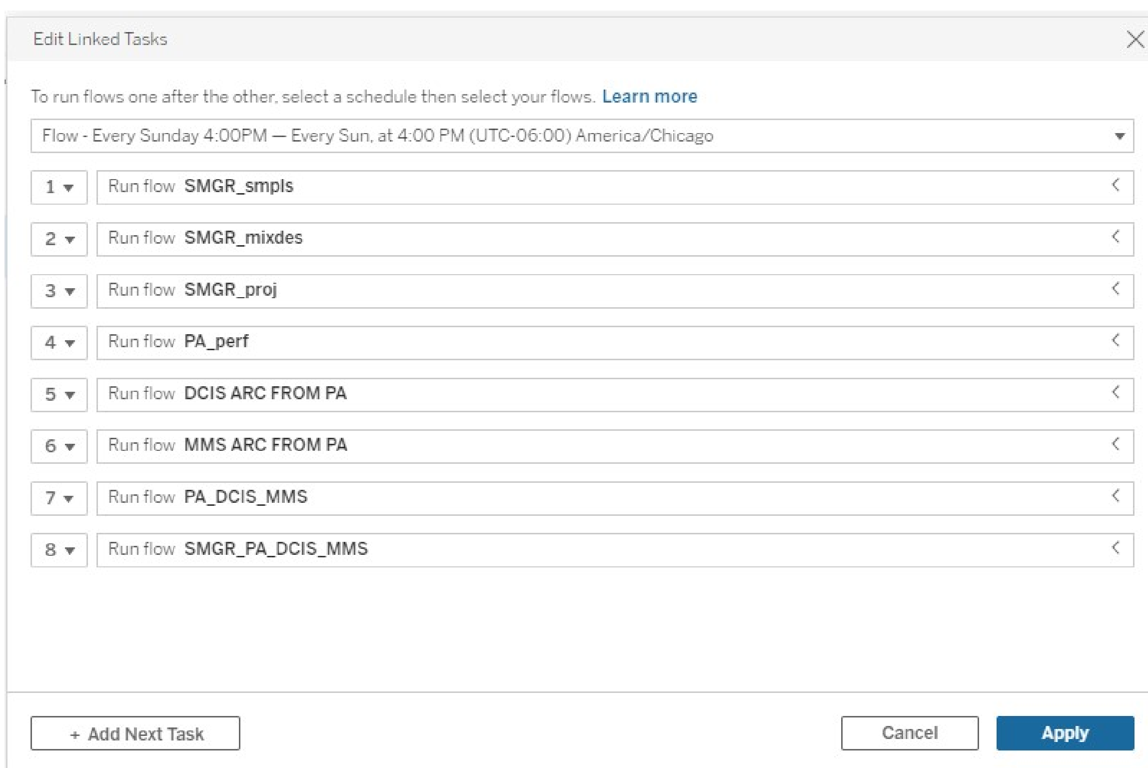


**Figure 2.10. Flow schedule for the integrated material, project, and pavement condition data.**

Based on discussions with TxDOT personnel, it was recognized that cost of maintenance for a pavement section can serve as a surrogate of performance in addition to pavement performance data from PA. This is because the latter may not always reflect the improvements in performance that may be the result of any maintenance activity. To this end, one of the metrics intended for use in the Tableau dashboards is the total cost associated with any seal coat applications on roadbed section. To obtain this metric, all MMS and DCIS projects that involve full-width seal coats and retrieving their construction dates and the associated cost were identified from the four-year project planning from the PA database. The DCIS seal coat construction dates were estimated from letting dates - alternatively by tracking the dates materials were sampled in the field during construction - for a specific CSJ number. Similar approaches were applied to pinpoint the construction dates for MMS projects. Further details on this approach are provided in the following chapter.

## 2.3 SUMMARY

This chapter describes the process used to extract material and project related information from the SMGR database and pavement surface conditions and project locations from the PA database. The data were collected, processed, and combined using a commercially available software, namely Tableau Prep Builder. Data related to materials included the as-produced hot mix asphalt mixture properties, collected as part of QCQA, such as laboratory molded density, in-place air void, mixture type, binder grade and content, and recycled materials. In addition, project related information such as letting and completion date, as well as bidding information such as quantity and unit price of the specification Items involved in a project were extracted. These data were accessed from the SMGR Oracle database by setting up a direct connection through Tableau Prep Builder.

Included in the integrated data were also historical performance measures, such as condition scores, distress scores, ride scores, international roughness index, and surface distresses and data collection section information such as traffic, load, and vehicle speed for the state maintained highway system. These data were extracted from the PA database as csv files. Furthermore, the DCIS and MMS projects and their locations planned for four-year planning cycles were extracted as xlsx files from the PA database and integrated with the pavement surface condition data and material information on Tableau Prep Builder. Finally, the integrated data were published on the Tableau-TxDOT server, which were then fed to Tableau as the principal data-source for the development of the visualization dashboards.

# CHAPTER 3. DEVELOPING TABLEAU PACKAGED WORKBOOK

## 3.1 INTRODUCTION

The previous chapter describes the process of extracting and integrating the materials, bid, and project related information collected from the SMGR database and pavement surface conditions and project location information collected from the PA database. These data were processed and integrated on Tableau Prep Builder. The as-produced hot mix asphalt mixture properties were collected from the QCQA test method, and material sources were collected from the mixture design test method.

Furthermore, project related information such as letting and completion date, as well as bidding information such as quantity and unit price of the specification items were extracted. These data were accessed from the SMGR Oracle database by setting up a direct connection through Tableau Prep Builder. Included in the integrated data were also historical performance measures, such as condition scores, distress scores, ride scores, international roughness index, and surface distresses and data collection section information such as traffic, load, and vehicle speed for the state maintained highway system. These data were extracted from the PA database as csv files. Furthermore, the DCIS and MMS projects and their locations planned for four-year planning cycles were extracted as xlsx files from the PA database and integrated with the pavement surface condition data and material information on Tableau Prep Builder.

This chapter describes the integrated data published on the Tableau-TxDOT server, which were then fed to Tableau as the principal data-source and used to develop several dashboards. These dashboards can be utilized by a user for the following purposes:

- Planning – locating roadway sections on a map and summarizing pavement condition, construction history, and material properties for projects constructed on that section. This will allow planning for future projects for that roadway sections.
- Project level investigation – analyzing materials and construction practices used in past projects and investigating their effect on the pavement performance.
- Benchmarking – aggregating and comparing the performance of items or mixtures, which in turn will provide insights for the modification of specifications.
- Estimating – incorporating the cost of the contracted and in-house maintenance activ-

ities performed in-between contracted projects and estimating the total dollar value spent on a given section.

## 3.2 DASHBOARD DESIGN

To serve the aforementioned purposes, the current dashboards were designed to perform analyses in three levels (Figure 3.1)

- Project level analysis – to compare and analyze the performance of projects from the same section or different sections with the same traffic and weather condition;
- Mixture level analysis – to analyze and benchmark the performance of different specification items used under similar traffic and weather condition; and
- Material level analysis – to determine the effect of selecting specific materials and their proportions and to improve mixture design.

The dashboards can be used by different divisions and districts of TxDOT to perform all three levels of analyses. State-wide and district-wide analyses as well as comparative analysis for different districts and maintenance sections were facilitated. The following subsections detail the data processing and development of the dashboards that perform each of these analyses.

### 3.2.1 Dashboard performance and continuity

The time it takes to load a workbook usually combines the time it takes to query the data from the data source and to render the visuals and create the tables. Since this workbook contains complex data from multiple data-sources, two separate Tableau workbooks with nine dashboards with same functionalities were developed for the state-wide and district-wide use to maintain optimum performance and necessary continuity in the analyses. Each workbook shows project level, Item level, and mixture level analyses for the target entity – the state of Texas or the individual district.

### 3.2.2 Feedback from TxDOT personnel

Feedback from different divisions of TxDOT and a district were sought at different stages of the development of the dashboards to identify the needs of target users. The current design reflects the interests and intended use of different divisions and districts where the user can perform comparative analysis for reponsible districts and maintenance sections, as well as identify projects and specification items with performance challenges/benefits.

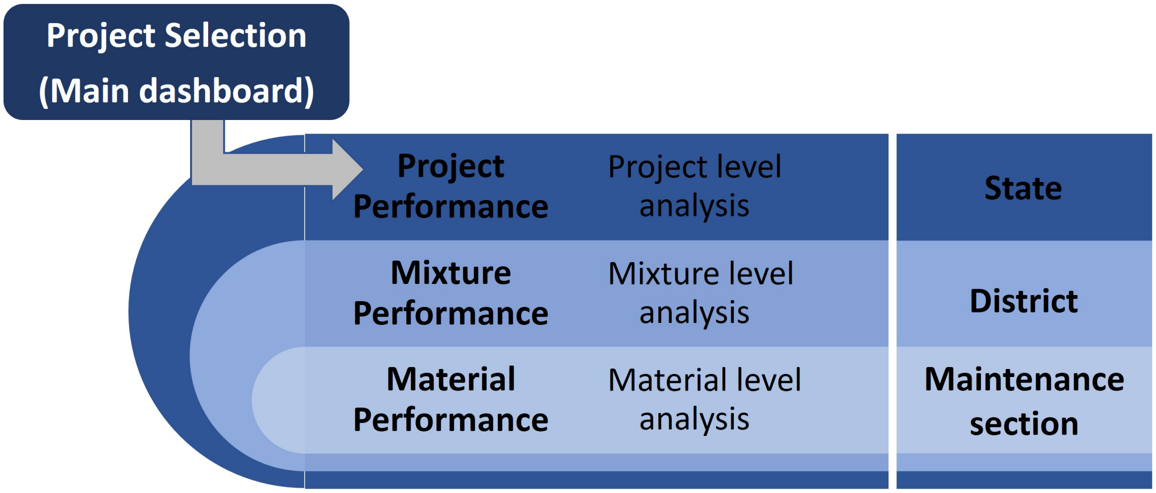


**Figure 3.1. Levels of analysis handled by the dashboards**

### 3.2.3 Project Level Analysis

The first dashboard comprises filters consisting several options, a map locating highway sections, and a plot summarizing construction history of the highway sections. On this dashboard a user can select projects based on their district, county, highway type, and other material characteristics as shown in Figure 3.2. The current filters consist of district, county, highway types, route, project number, Item, binder grade, course, current AADT and the percentage of the recycled binder. Once the desired route or projects were selected, the map in the middle pane shows the geographic location of the highway sections and the projects. The figure on the left pane shows all projects and their locations and length on the roadbed section in a chronological order presented in the vertical axis.

The performance history and project materials summary can then be seen from the project performance and materials summary dashboard as shown in Figure 3.3. The performance history diagram has two components – the component on the top left shows the weighted average of pavement surface condition for the selected "PERFORMANCE METRIC" as a function of the year data were collected; and the bottom part shows the local performance for all data collection sections within the highway section for the selected fiscal year. DFO refers to the distance from origin of the selected highway section.

The "PERFORMANCE METRIC" is a drop-down list of several pavement surface conditions that include condition score, distress score, IRI, alligator cracking, rut depth, skid score, and ride score.

The weighted average of the performance metrics were calculated in the “clean” step of a flow that integrated pavement condition data with the project location information from the four-year planning cycle. The weighted average of pavement conditions was calculated for the entire project section on a route for each fiscal year.

The table at the bottom of the dashboard summarizes all materials used in the project. This table includes bid item, quantity, and price from the contract table; mixture item, binder grade, average field air-voids, binder content, placement pay factors and their standard deviation, average recycled binder percentage, and the total adjusted pay from the QCQA form, and asphalt source and aggregate source from the mixture design form within the SMGR database. In addition to the hot mix asphalt items recorded by the SMGR database, in-house and contracted seal coats projects were identified from the four-year planning cycles. The construction dates for these seal coat projects were estimated from various data sources. TxDOT’s Materials and Tests Division performs quality management tests for all seal coat projects. These test dates were obtained and used to estimate approximate construction dates for the projects by matching the corresponding CSJ numbers. In addition, some contracted overlay and seal coat projects were managed under the controlling CSJ (CCSJ) at the DCIS database. Construction dates for these projects were estimated from the “DCIS Estimated Construction Date” from the “Project Details Data for TxDOTCONNECT Self Service Analytics” data-source from the Tableau-TxDOT server. CSJs/project numbers were used to identify the CCSJs for these projects and their construction dates. Construction dates for some in-house seal coat projects were obtained from the “Compass Actual Contract Start Date” available from the “MMS Projects and Locations Archive” table from the “Reports” section of Pavement Analysts. This field was sparsely populated – there were projects that were actually completed but the dates were not updated. Among these, projects that were prioritized to be constructed during the first year of the four-year planning cycles were assumed to be completed. This assumption was drawn after discussions with several TxDOT personnel involved with project planning, prioritizing, and construction.

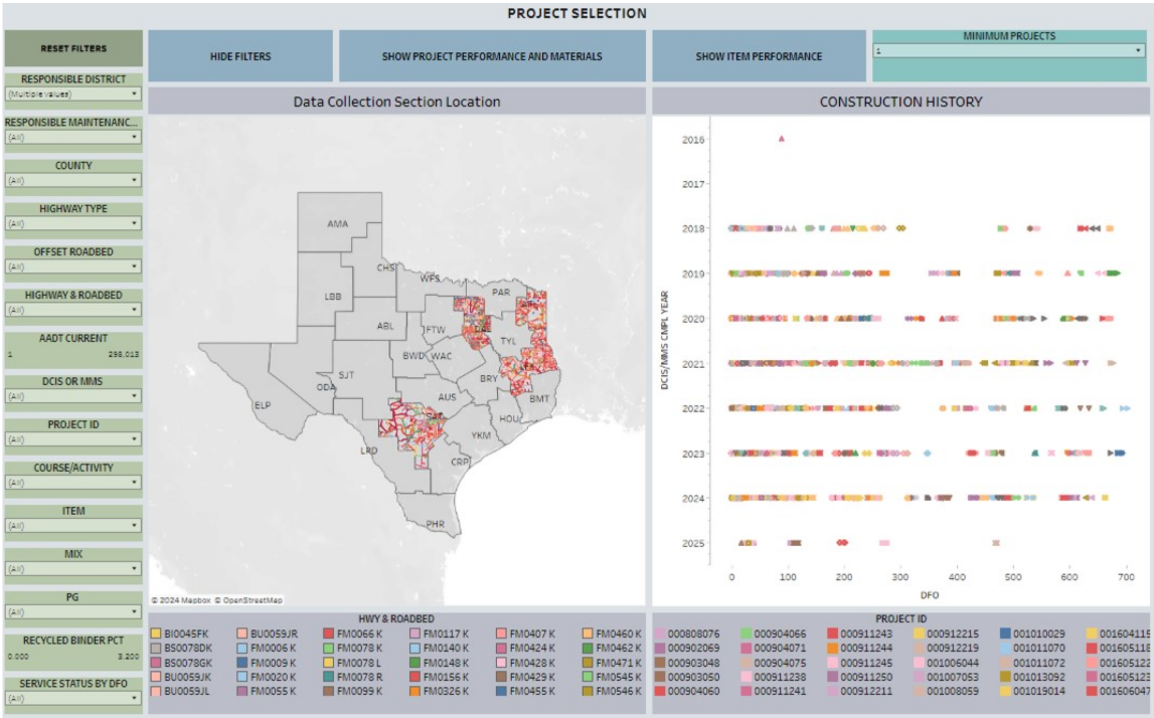

**Figure 3.2. Project selection dashboard**

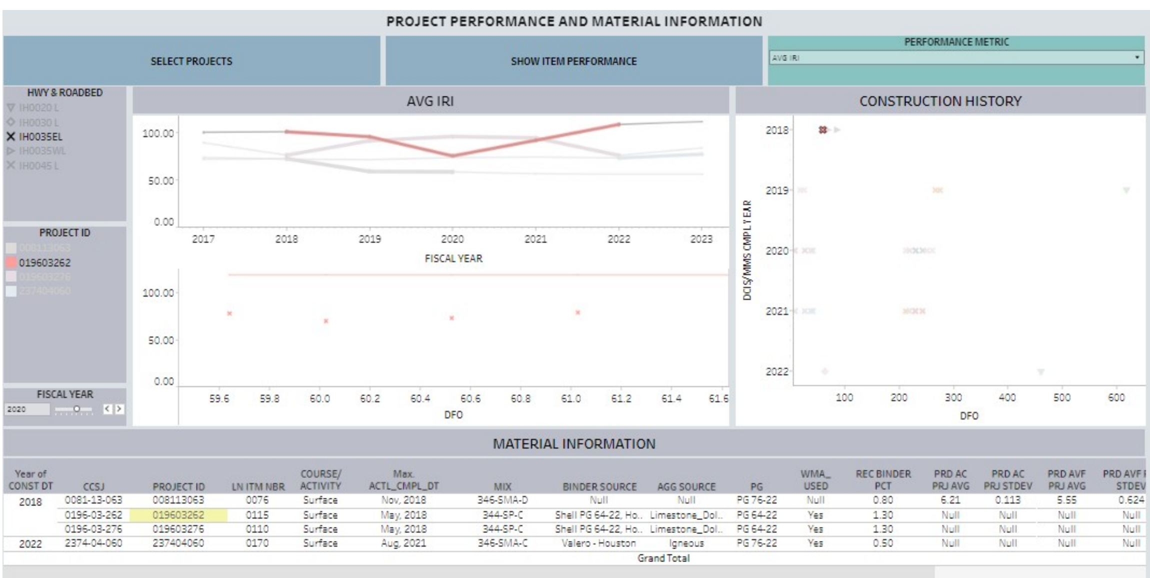

**Figure 3.3. Project performance and material summary dashboard.**

### 3.2.4 Item and Mixture Level Analysis

The dashboards involving the Item level analysis are shown in Figures 3.4 to 3.6. Figure 3.4 shows the dashboard with weighted average percentage of alligator cracking for Item 341, the dense graded (DG) mixtures, and Item 344, the Superpave (SP) mixtures for the surface course. The user can see the state-wide variation for the selected performance metrics as shown in Figure 3.5. The tables underneath the plots in Figures 3.4 to 3.6 list the plotted values for the items. For instance, the table in Figure 3.4 shows the state-wide total number of projects that used Item 341 and 344 along with the weighted average and weighted standard deviation of the percentage of alligator cracking. The STATE TTL PRJ COUNT ITEM gives the total project count using the Item within the entire state, the STATE WAVG ITEM is the state-wide weighted average of the performance measure for an Item, and STATE WSTV ITEM is the weighted standard deviation of all projects using that Item. These values are fixed calculated values for a given Item and course.

Additional filters can also be applied. For instance, if one wants to narrow down the performance for a range of traffic load or for particular material constituent, one can do so by clicking the "APPLY MORE FILTERS" button and navigating to the dashboard shown in Figure 3.6. On this dashboard the user can analyze performance for different items by selecting the desired filters from the filter pane on the right side of the window. Similar to the project performance dashboard, it has the capability of processing and presenting the pavement surface conditions manifested in the form of alligator cracking and rutting in addition to the condition score, IRI, ride score, and skid score for the specification items. The performance metric of interest can be selected from the “PERFORMANCE METRIC” filter. Different colors of the curves present different items. The solid lines represent the weighted average of the performance matrix for the selected filters, and the dashed lines show the weighted average for the entire state as a reference. The table at the bottom tabulates these values – the PROJECT COUNT is the total number of projects that satisfies the selected filters and WTD AVG is the weighted average of the performance measure for those selected criteria. The table also shows the state-wide project counts, weighted average, and standard deviations as a reference.

On the horizontal axis the plot shows the years in the service – zero on this axis presents the construction year, one presents the first year of service after construction, and so on. The percentage of alligator cracking is high during the construction year, probably because the pavement condition data were collected prior to completion of the project. This value decreases the following year implying that the data were collected on a new surface. The dashboard in Figure 3.4 shows that the cracking progression for the dense graded (Item 341) and Superpave (Item 344) is comparative and follows a similar trend for the selected filters. The dashboard in Figure 3.7 suggests that porous friction courses of items 342 and 346 have superior skid performance than Item 344 for the selected districts, route, and traffic conditions. However, it is very important to recognize that such conclusions should only be drawn after carefully considering local factors and number of roadway sections.

Figure 3.5 shows the variation in the performance metric when the "STANDARD DEVIATIONS" from the top pane is selected. The variation is displayed as a shaded band above and below the line of weighted average and calculated as weighted average $\pm n$ weighted standard deviations, where $n$ is the number of standard deviations of interest. The dashboards have the capability of doing similar analysis for various mixtures and constituent materials as shown in Figures 3.8 and 3.9. Figure 3.9 shows the comparative performance of the D mixture for Items 341 and 344 for the district of San Antonio and Dallas, marked by different markers.

The dashboard in Figure 4.13 shows the average age of all items from the 2014 specification and special specification items. The colored circles denote individual projects using the items, and the thick solid line denotes the average age of those mixtures in years. The shaded band shows the average age $\pm 1$ standard deviation for each Item.


**Figure 3.4. Tableau dashboard showing the average alligator cracking for different items over time.**

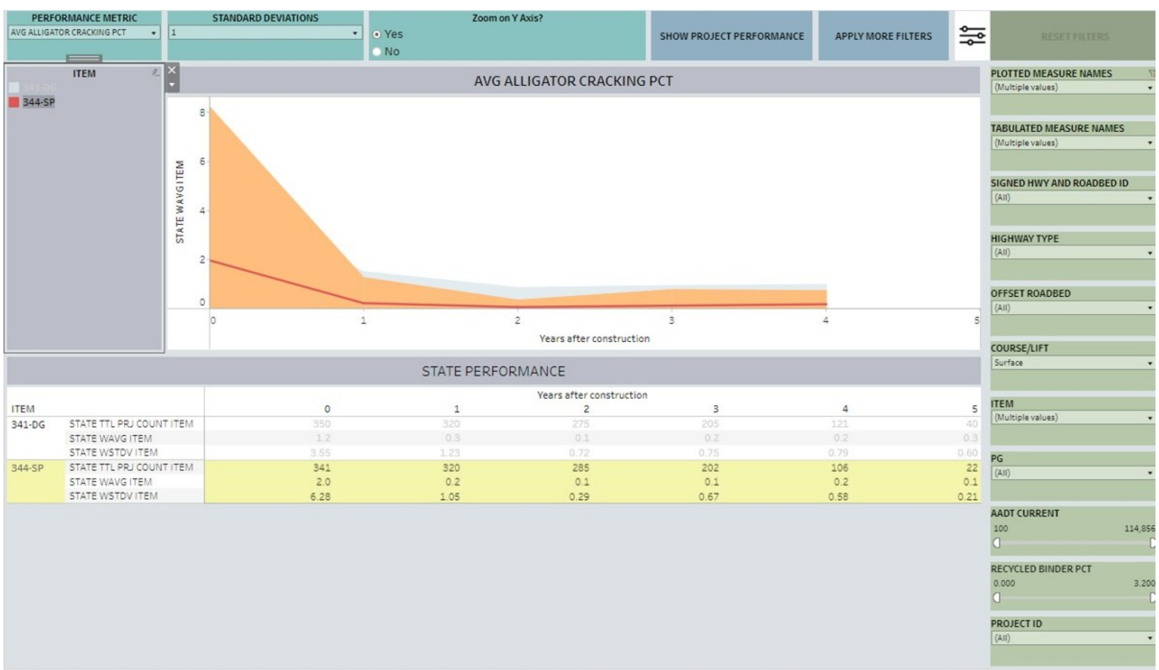


**Figure 3.5. Tableau dashboard showing the average of alligator cracking with one standard deviation for different items over time.**

**Figure 3.6. Tableau dashboard showing the average alligator cracking for different items over time.**

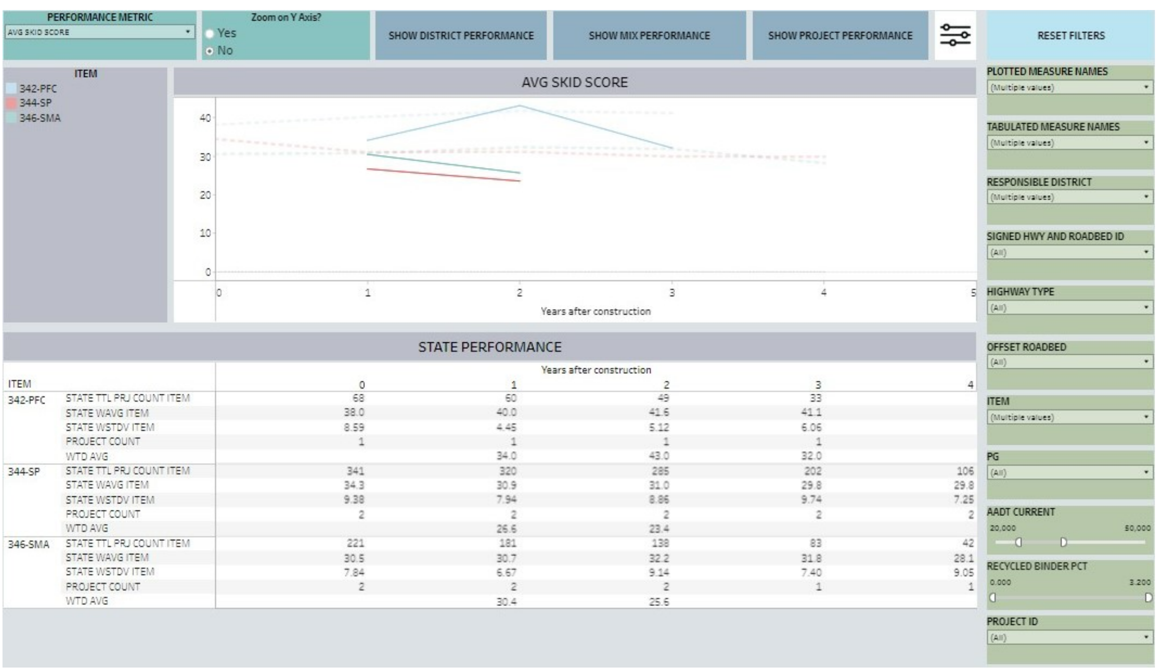

**Figure 3.7. Tableau dashboard showing the skid performance for different items.**


**Figure 3.8. Tableau dashboard showing the weighted average percentage of alligator cracking for different mixes.**

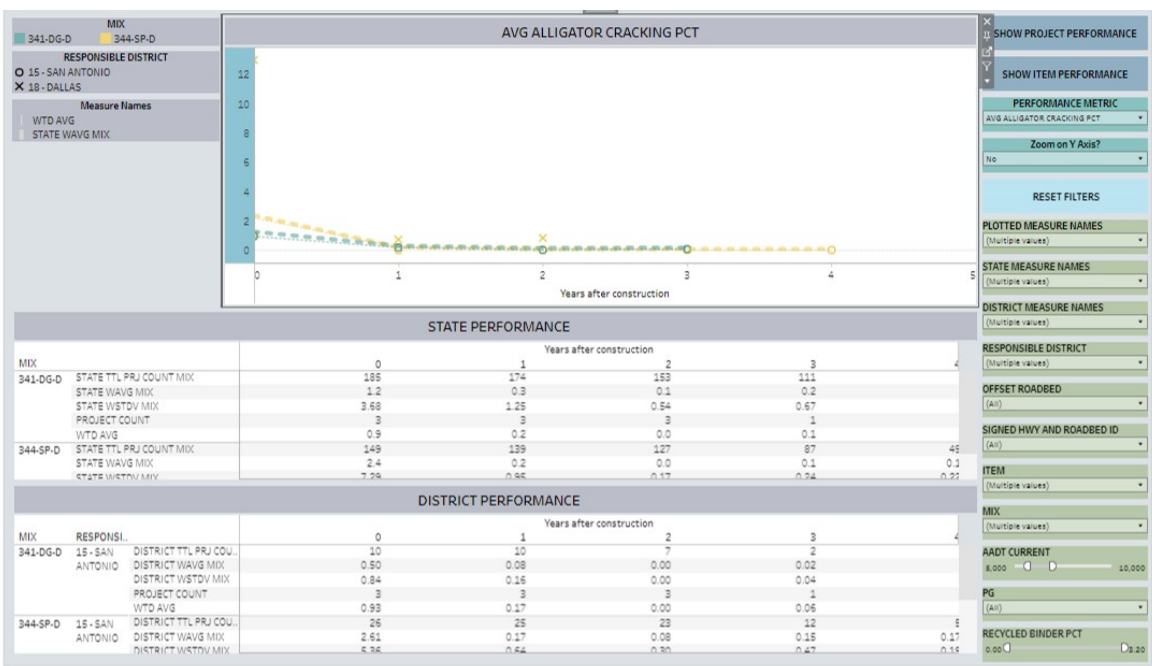


**Figure 3.9. Tableau dashboard showing the weighted average percentage of alligator cracking for different mixes for different districts.**

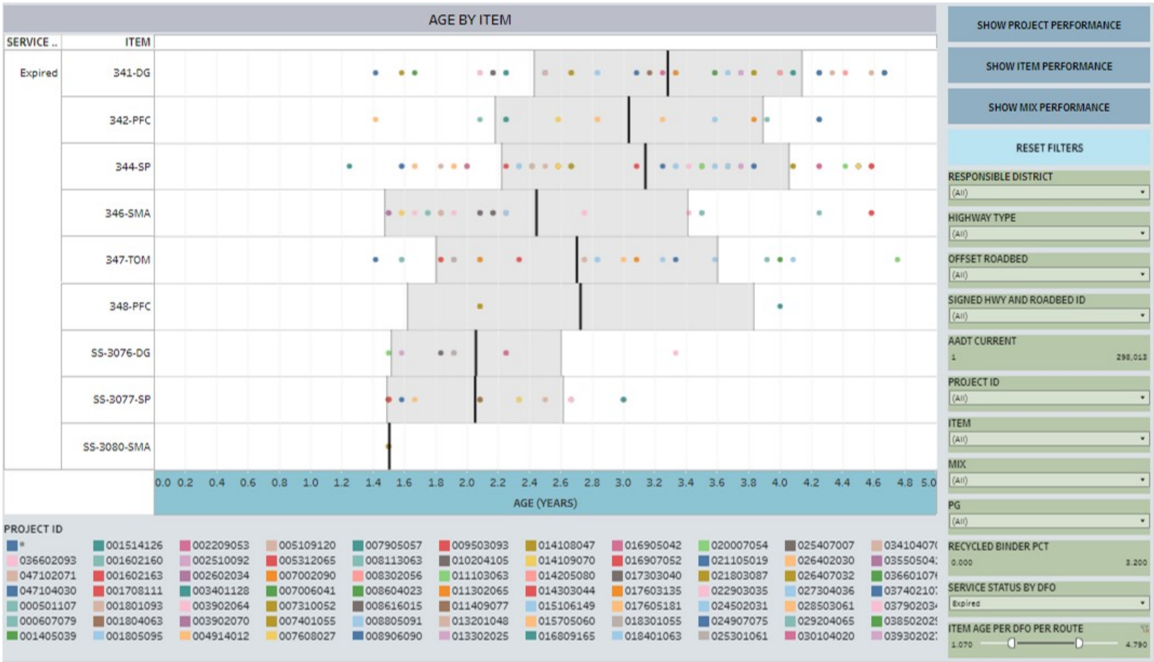


**Figure 3.10. Tableau dashboard showing the age of mixtures in years.**

## 3.3 ADDITIONAL IMPROVEMENTS

In Task 2, data from the PA database for all data collection sections were integrated with all sampled test and material information from all lots of a project. The integration of the data collection sections with the SiteManager sampled data for all lots created unexpected multiplications producing millions of rows. As a result, further integration of the contracted or in-house maintenance data involving the construction dates and cost of the seal coat projects was found to be computationally cumbersome. In addition, hundreds of millions of rows contributed to the slowing down of the dashboard performance when the state wide data were analyzed. The researchers improved the performance of the Tableau dashboards by

- filtering unused data rows and fields, aggregating sampled data from the SiteManager;
- reducing the lot level information to project level by only taking the average, standard deviations, maximum and minimum values of the test results for a project; and
- separating the workbook into two for the state-wide and district-wide use.

These steps reduced the row numbers significantly by eliminating the lot level information as well as reduced the number of worksheets with visualization. This in turn allowed the joining of further data, especially the construction date and cost of the contracted and in-house seal coat projects. The researchers gathered additional data-sources that include quality management data containing test samples from the contracted seal coat projects and DCIS CCSJ information managing some of contracted seal-coat projects. Additionally, zone information were incorporated to the existing data-source to facilitate future analyses for different zones – similar to the ones developed for the state and districts. Furthermore, the researchers worked with the project management team and sought feedback from the District of Atlanta to identify the district need and finalize the layout and target features of the dashboards.

### 3.4 SUMMARY

The integrated data from the previous task were further processed and imported to Tableau and several dashboards were developed. The dashboards have the capability to perform analysis for projects and mixture items whereby performances of the projects, mixtures, and constituent materials can be visualized, studied, and compared. The dashboards also offer several filters allowing a user to select projects based on the desired characteristics including district, county, responsible maintenance section, highway type, route, traffic, mixture and material properties. The dashboards analyze pavement surface conditions, e.g. condition score, distress score, IRI, ride score, alligator cracking, rut depth, and skid score. These dashboards can be applied by districts or divisions as an investigative tool for analyzing the historical performance of the past projects and materials used in those projects. The comparative analysis visualized by the dashboards shows the effect of changes in specifications on the long-term performance. The use of these dashboards is expected to help improve mixture design, benchmark mixtures with superior performance, and modify specifications toward long lasting pavements.

# CHAPTER 4. OPERATING AND MANAGING THE DASHBOARDS

## 4.1 INTRODUCTION

The previous chapter describes the developed dashboards and descriptions of the components of the dashboards including plots, tables, filters, and parameters. This chapter illustrates the steps for operating and managing the dashboards. It also includes steps to create and add new data sources to the existing data source and steps to create new dashboards using the added data source. The examples presented here are not exhaustive, but are intended to serve as a guide to help beginners with little knowledge of Tableau Workbook operate and manage the dashboards.

Two sets of dashboards were developed to improve the processing time – one for the State's use and one for the Districts' use. This chapter provides guidelines on the dashboards intended for the use by the entire State. One can follow this guide to operate the dashboards for the Districts' use with a few differences. One main difference is that the Districts can view the comparative analysis for the Item/Mix performance for different Maintenance Sections, while the State's dashboards show the Item/Mix performance for different Districts.

This chapter is divided into two sections. The first section describes how to operate the dashboards. The second section describes how to add new data sources and dashboard items to the existing workbook and is intended for users with administrative privileges with permission to modify the dashboards.

## 4.2 OPERATING THE DASHBOARDS

The dashboards analyze long term performance for projects, Items, and mixes for HMA pavements. This section provides a general guideline for performing analysis for each of these analysis levels in the form of case studies:

- Case 1: Analyze Project Performance,
- Case 2: Analyze Item/Mix Performance, and
- Case 3: Track Projects and Materials from Item/Mix Performance.

### 4.2.1 Case 1: Analyzing Project Performance

One can analyze project performance for any given section for any District or multiple sections for multiple Districts on the dashboards labeled as "D1_Project Selection" (Figure 4.1) and "D2_Project performance and material information" dashboards (Figure 4.2). "D1_Project Selection" provides the geographic locations for projects and construction history along with the project length, and "D2_Project performance and material information" provides the local performance and material information of the specification items for those projects.

As an example, a section of IH0035 within the San Antonio, Austin, Waco and Dallas Districts is selected. The steps for selecting projects and showing performance parameters are given below.

#### 4.2.1.1 Steps to operate the project performance dashboard

1. Select Waco, Austin, San Antonio, and Dallas from the drop-down list of the "RESPONSIBLE DISTRICT" filter and hit the "Apply" button. Since multiple Districts are selected, it will show "(Multiple values)" in the input field. Note: If one doesn't hit the apply button, the selection will not be saved (Figure 4.1).
2. Select IH from the "HIGHWAY TYPE". The subsequent filters will only show data relevant to the above selected values.
3. Select all roadbeds for IH0035 from the drop-down list of "HIGHWAY & ROADBED". Now on the "Data Collection Section Location" map one will see all projects belonging to IH0035 for the selected responsible Districts. The "Construction History" plots the location and construction year of all the projects constructed on the selected section (Figure 4.1).
4. One can see the sections with more than one project by selecting the "MINIMUM PROJECTS" parameter to 2.
5. To further narrow down the selection, one can pick "AADT CURRENT" values as 50,000-100,000 and select "PRJ BEGINNING DFO" from 200 to 220 miles (Figure 4.2).
6. Once done with the selection, click on the "SHOW PROJECT PERFORMANCE AND MATERIALS" button to navigate to the "D2_Project performance and material information" dashboard. For these selected criteria the project performance dashboard appears as Figure 4.2.

7. To highlight the performance of a project, one can highlight the Project ID from the legend card on the left side and use the left and right arrow under the “FISCAL YEAR” field to navigate through the years of performance to view the local deformation for that year.

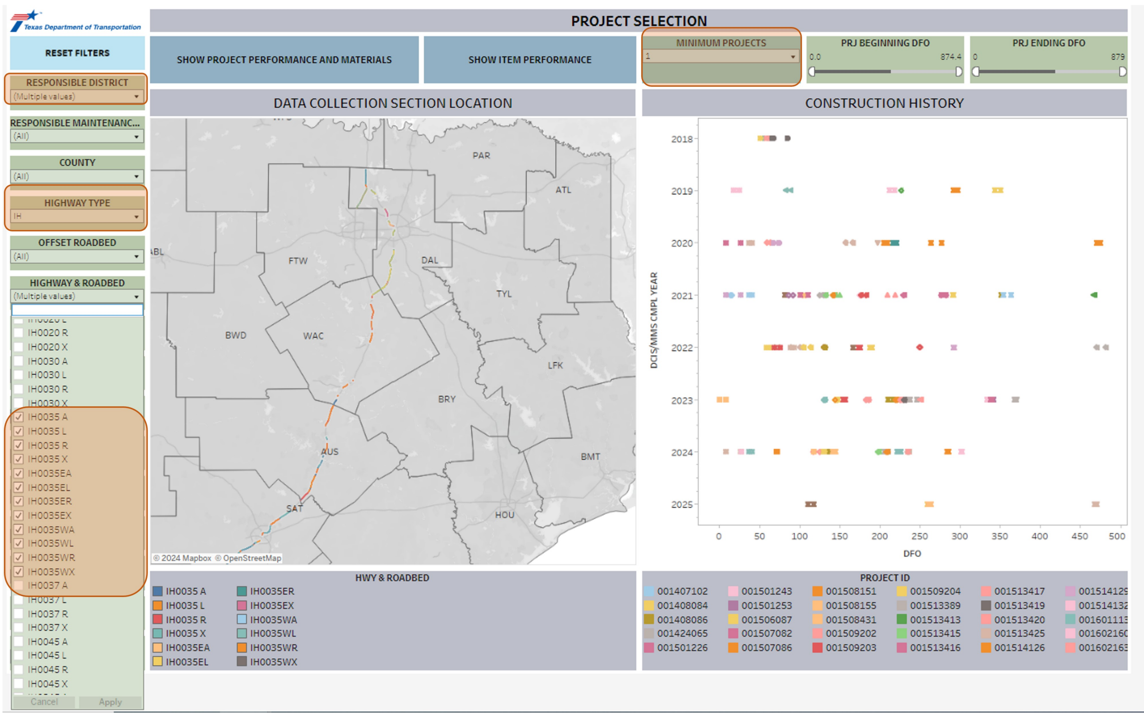


**Figure 4.1. Project selection dashboard: selecting projects for project performance analysis.**

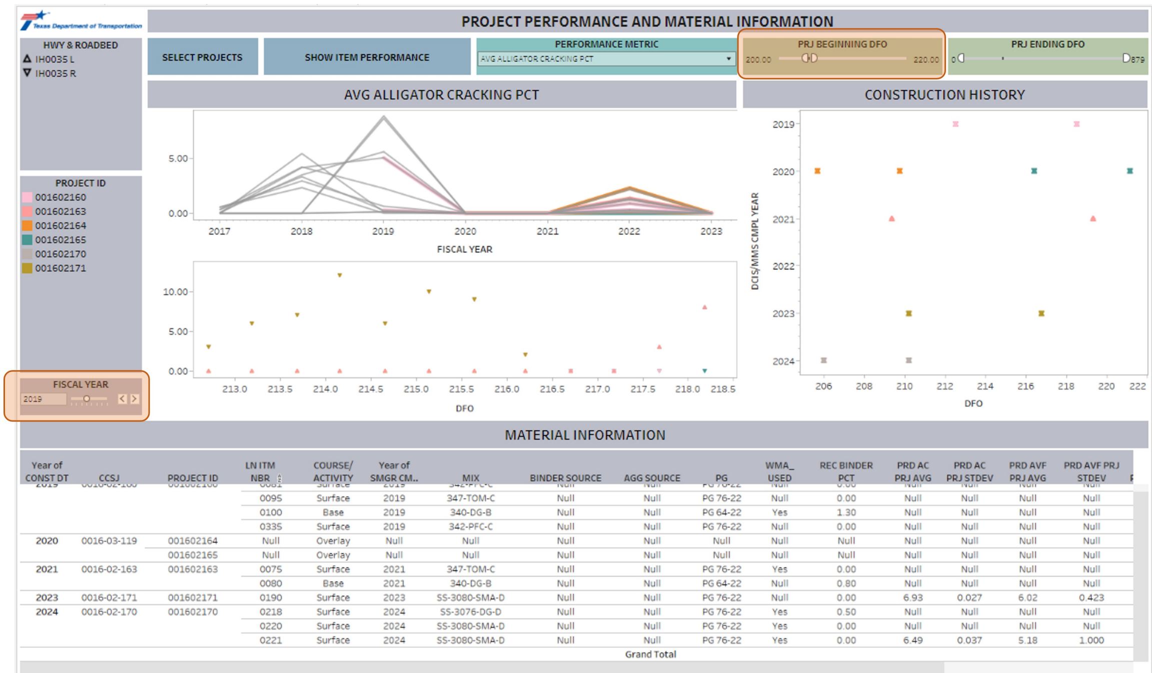


**Figure 4.2. Project performance and material information dashboard: project performance and material information for sections of IH0035 in the Waco, Austin, San Antonio, and Dallas Districts.**

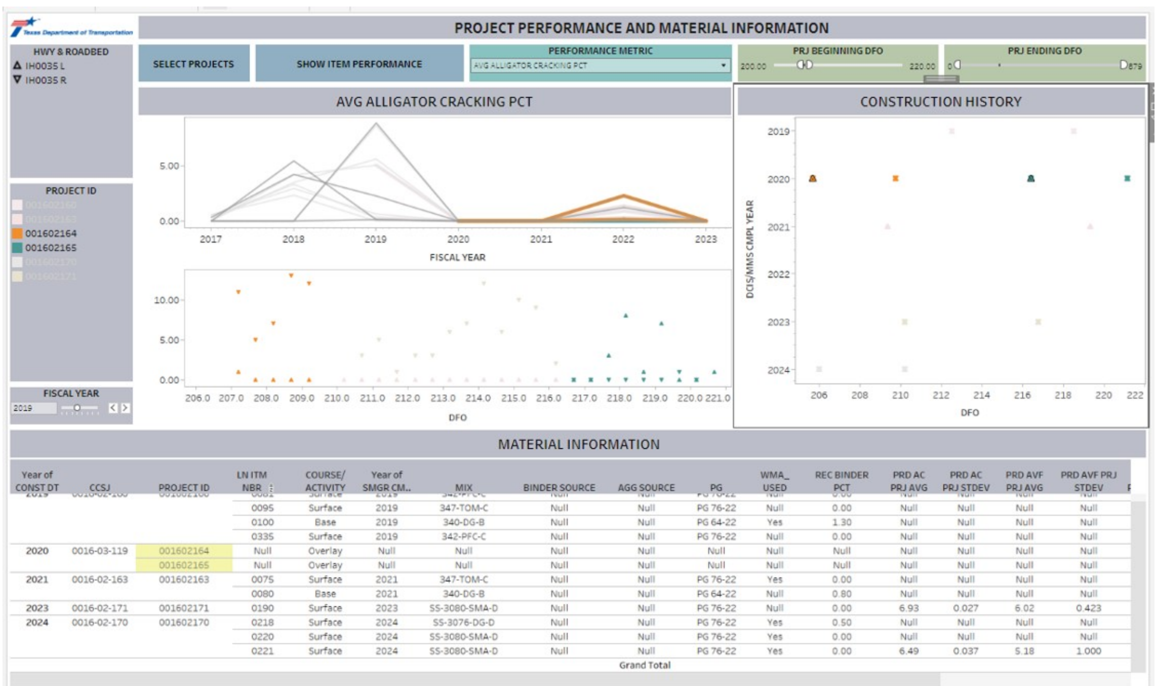


**Figure 4.3. Project performance and material information dashboard: overlay projects with highlighted local deformation**

#### 4.2.1.2 Understanding the dashboard information

The performance history diagram on the "D2_Project performance and material information" dashbard has two components – the component on the top left shows the weighted average of pavement surface condition for the selected "PERFORMANCE METRIC" as a function of the year data are collected; and the bottom part shows the local performance for all data collection sections within the highway section for the selected fiscal year. DFO refers to the distance from origin of the selected highway section.

The "PERFORMANCE METRIC" is a drop-down list of several pavement surface conditions that include condition score, distress score, IRI, alligator cracking, rut depth, skid score, and ride score. The weighted average of pavement conditions is calculated for the entire project section on a route for each fiscal year.

The table at the bottom of the dashboard summarizes all materials used in the project. This table includes bid item, quantity, and price from the contract table; mixture item, binder grade, average field air-voids, binder content, placement pay factors and their standard deviation, average recycled binder percentage, and the total adjusted pay from the QCQA form, and asphalt source and aggregate source from the mixture design form within the SMGR database.

The earliest project constructed on the selected section dates back to 2019. This project, with CSJ 0016-02-160, was about 8 mile long and used Item 342-PFC-C mix. About a 4 mile long section from DFO 212.5 miles to 216.4 miles, the R roadbed was in service for 4 years till 2023, whereas the same section on the L roadbed has a service life of 2 years. On this section, a new surface with Item 347-TOM-C was laid in 2021. Sections from 216.4 from 218.5 on both the L and R roadbed had a service life of approximately 1 year. This project provides a variety of service life for the different Items.

For the selected section, there are a couple of overlay projects that are located from the 4-Year Project Planning Pavement Analyst database and are managed under the CCSJ 0016-03-119, which is confirmed from the DCIS database. These projects, highlighted in Figure 4.3, costed about $ 4 M and were constructed on both L and R roadbeds. Projects similar to these overlay projects that are not registered in the SMGR database are important to locate to accurately determine the age of prior projects and to estimate the total money spent on the selected section. In total, over the last five years since 2019, about $15.8 M worth of construction has been done on this 20-mile long section of IH0035.

If one looks at the cracking performance of project 0016-02-0160 constructed in 2019

(Figure 4.2), one may think that the project was performing well. However, if one selects the average rut depth as “PERFORMANCE METRIC”, one will see that this particular section potentially showed some level of rutting. This observation indicates that this section may need further investigation to determine if there are any pre-existing issues affecting the performance of new surfaces.

The recent projects on this particular section use SMA mixes, whereas a combination of PFC and TOM mixes was used in the older projects. The project constructed in 2019 used a combination of PFC and TOM surface layers with dense graded base mixture with recycled binder percentage of 1.3 of the total binder content. Thus, this section is used to demonstrate how the dashboards can be used to analyze historical performance of different Items/Mixes, which is presented in the following section.

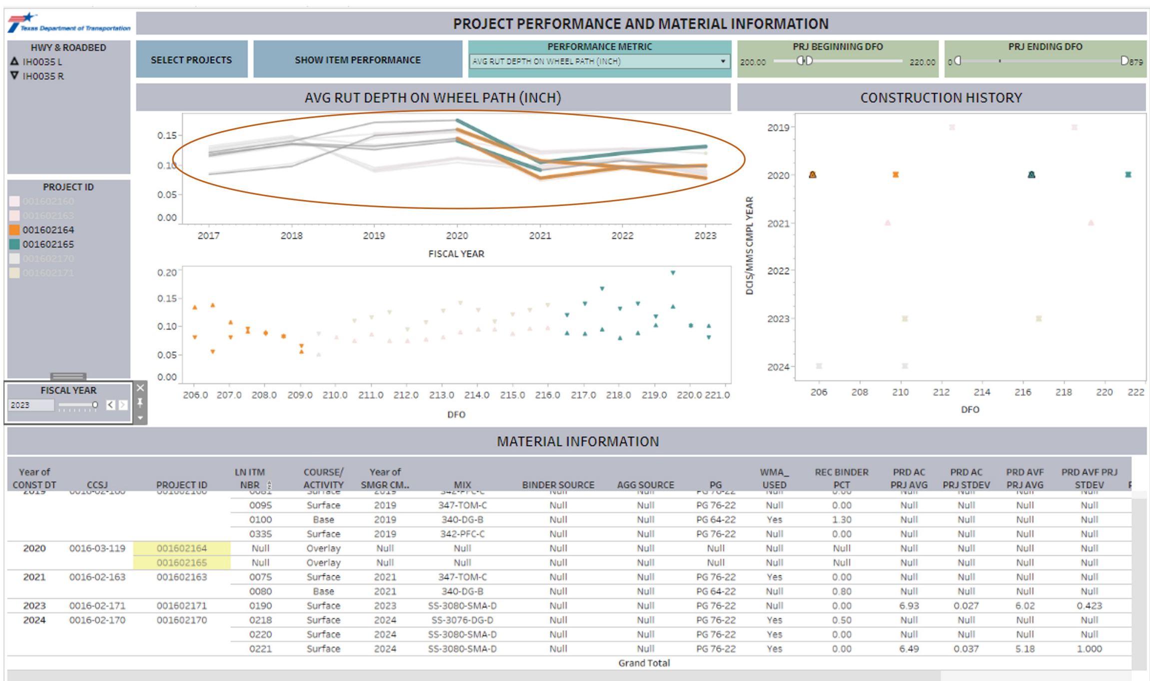


**Figure 4.4. Project performance and material information dashboard: project performance in terms of average rut depth.**

### 4.2.2 Case 2: Analyzing Item/Mix Performance

For this particular section, one can use the “D3_State: item perf with stdv”, “D4_State: item perf dynm” and “D5_State: dist item perf dynm” dashboards to analyze the performance of Items further. Similar analyses for mixes can be viewed on the “D6_State: mix perf with stdv", "D7_State: mix perf dynm" and "D8_State: mix item perf dynm" dashboards. Below are the steps that one can follow to do such an analysis.

#### 4.2.2.1 Steps to operate the Item/Mix performance dashboards

1. Select the surface mixes with Item 341, 342, 344, 346, 347, and 348, from the "ITEM" filter. This will show the weighted average performance for the entire state (Figure 4.5).
2. Select "STANDARD DEVIATIONS" to 1 to see the variation of performance metric to 1 standard deviation (Figure 4.6).
3. Select "Yes" to zoom on the Y axis or "No" to zoom out.
4. To apply more filter, click on the button "APPLY MORE FILTERS" to navigate to "D4_State: item perf dynm" (Figure 4.7).
5. To view District performance, click on "SHOW DISTRICT PERFORMANCE" on the "D4_State: item perf dynm" to navigate to the "D5_State: dist item perf dynm" dashboard (Figure 4.9).
6. Similar analysis can be viewed for different mixes on dashboards "D6_State: mix perf with stdv" (Figure 4.10), "D7_State: mix perf dynm" (Figure 4.11), and "D8_State: dist mix perf dynm" (Figure 4.12). Navigate to "D7_State: mix perf dynm" by clicking on the "SHOW MIX PERFORMANCE" button to view the performance of mixes.
7. Navigate to the "D9_Avg age" dashboard (Figure 4.13) to view the service life for the Items and mixes for the selected sections.

#### 4.2.2.2 Understanding the Item/Mix performance dashboards

Figure 4.5 shows the dashboard with weighted average skid score for Items 341, 342, 344, 346, 347, and 348 for the surface course. The user can see the state-wide variation along with the weighted average for the selected performance metrics as shown in Figure 4.6. On the horizontal axis the plot shows the years in the service – zero on this axis presents the construction year, one presents the first year of service after construction, and so on.

The tables underneath the plots in Figures 4.5 to 4.9 list the plotted values for the items. For instance, the table in Figure 4.5 shows the state-wide total number of projects along with the weighted average and weighted standard deviation of the skid score for different Items. The STATE TTL PRJ COUNT ITEM gives the total project count using the item within the entire state, the STATE WAVG ITEM is the state-wide weighted average of the performance measure for an item, and STATE WSTV ITEM is the weighted standard deviation of all projects using that item. These values are fixed calculated values for a given item and course.

On the dashboard shown in Figure 4.7, the user can analyze performance for different items by selecting the desired filters from the filter pane on the right side of the window. Similar to the project performance dashboard, it has the capability of processing and presenting the pavement surface conditions manifested in the form of alligator cracking and rutting in addition to the condition score, IRI, ride score, and skid score for the specification items. Different colors of the curves present different items. The solid lines represent the weighted average of the performance matrix for the selected filters, and the dashed lines show the weighted average for the entire state as a reference. The table at the bottom tabulates these values – the PROJECT COUNT is the total number of projects that satisfies the selected filters and WTD AVG is the weighted average of the performance measure for those selected criteria. The table also shows the state-wide project counts, weighted average, and standard deviations as a reference.

Figure 4.9 shows the comparative analysis for the Waco and Austin Districts for Item 342. These items are from projects that were constructed on IH0035 sections with traffic between 50,000 to 100,000 AADT. The square markers show the alligator cracking percentage for the Austin District and the triangular marker shows the same for the Waco District. The thin line shows the weighted average of alligator cracking for these two Districts for the selected projects. Whereas, the thick dashed line shows the weighted average for the entire state. These values are tabulated for the state and Districts in the tables in Figure 4.9.

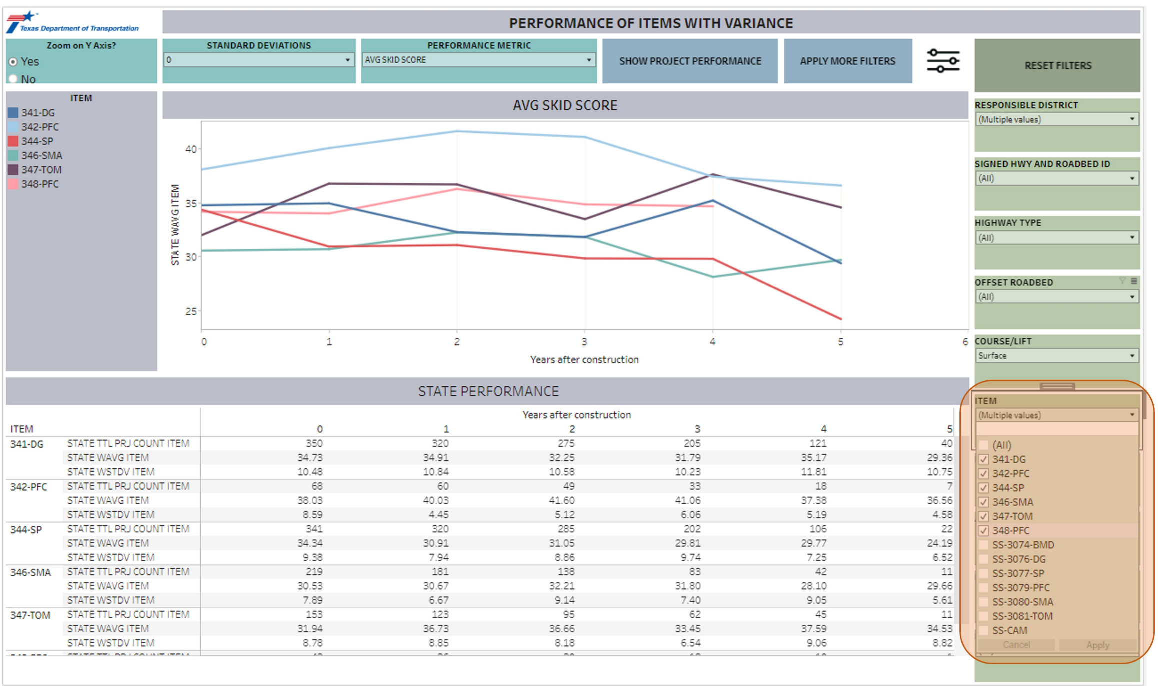


**Figure 4.5. Statewide weighted average of skid score for 2014 specification Items 341, 342, 344, 346, 347 and 348.**

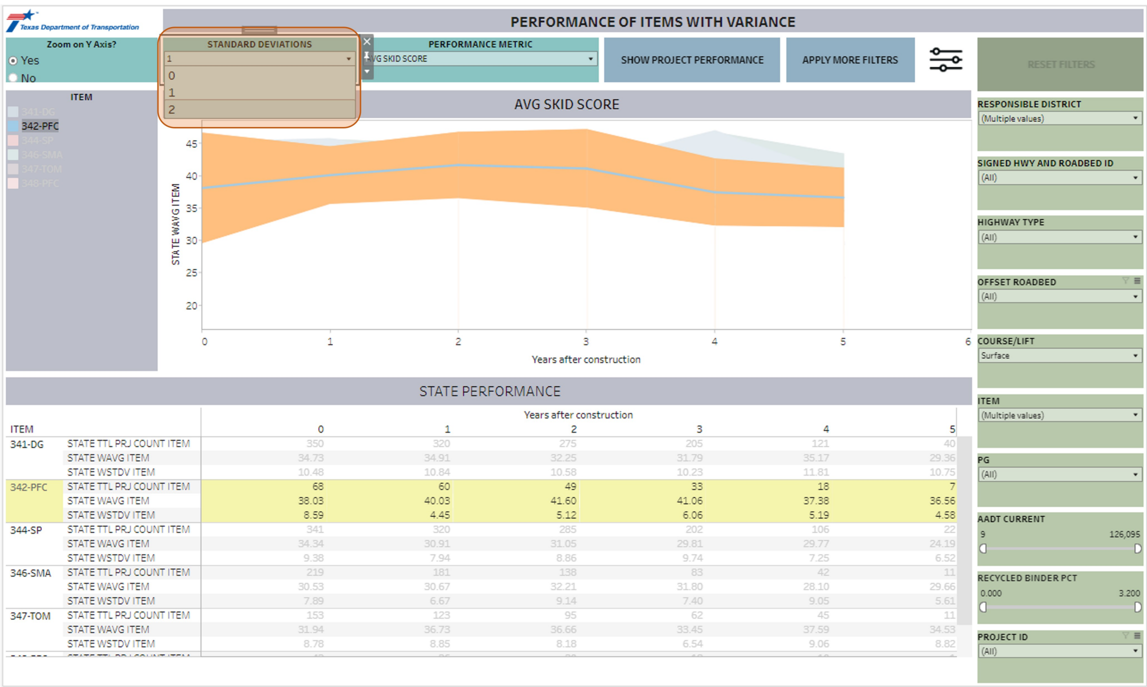

**Figure 4.6. Statewide weighted average of skid score along with one standard deviation for Item 342.**

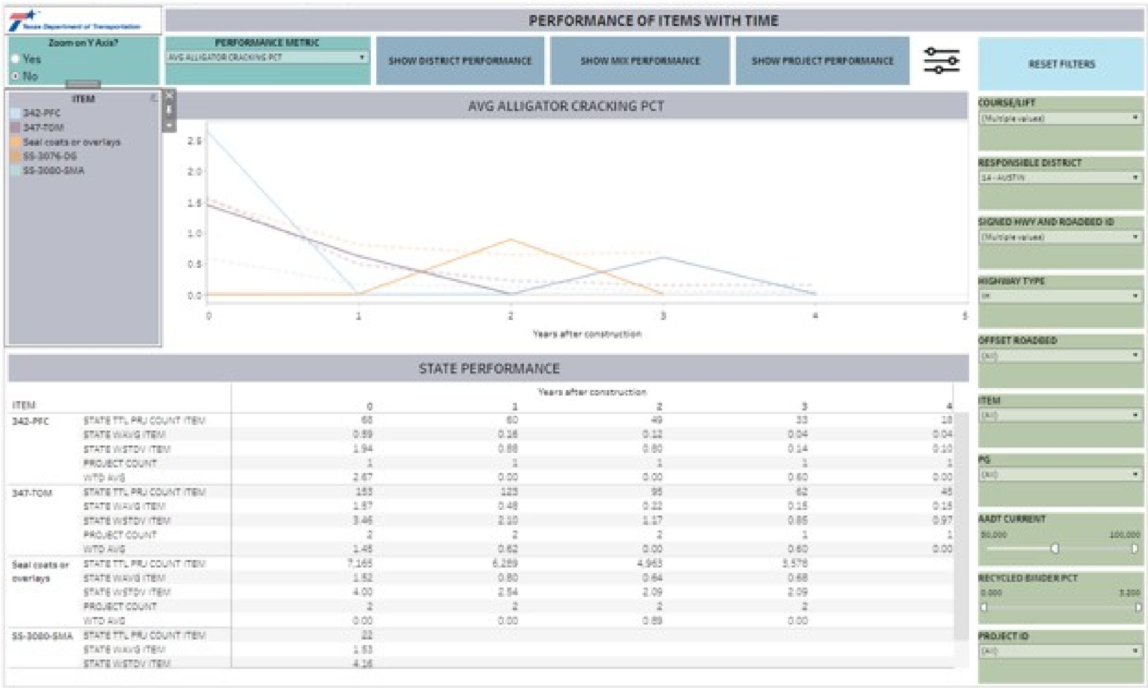


**Figure 4.7. Cracking performance of selected Items along with seal coats and overlays.**

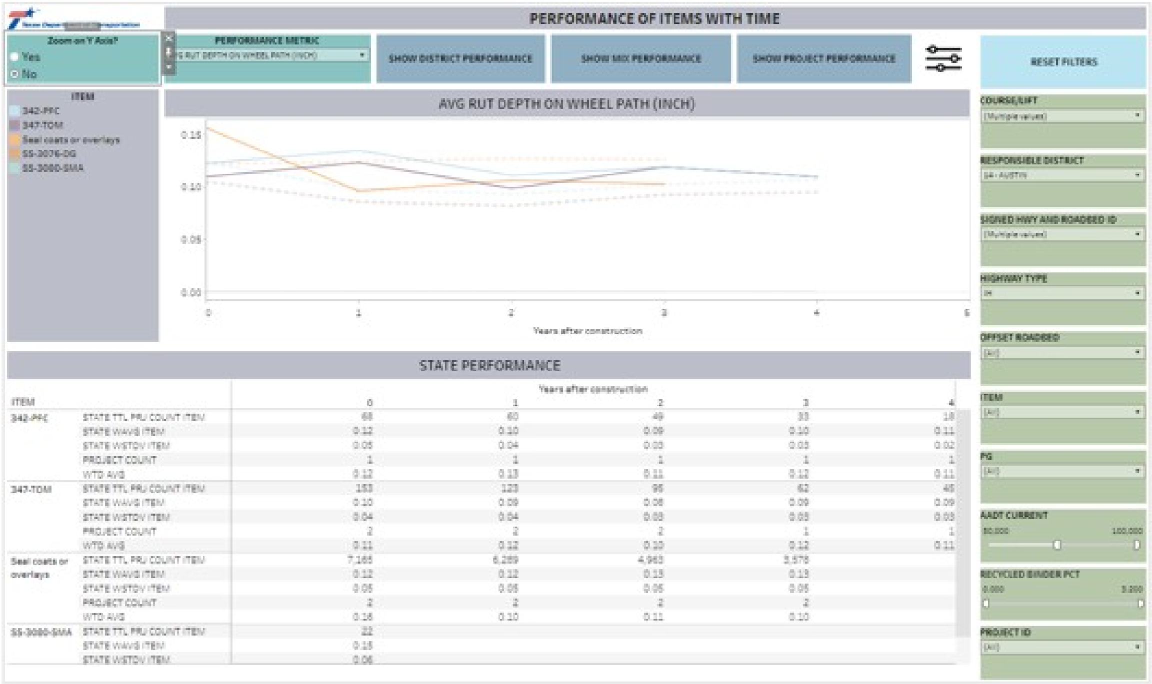


**Figure 4.8. Rutting performance of the selected Items.**

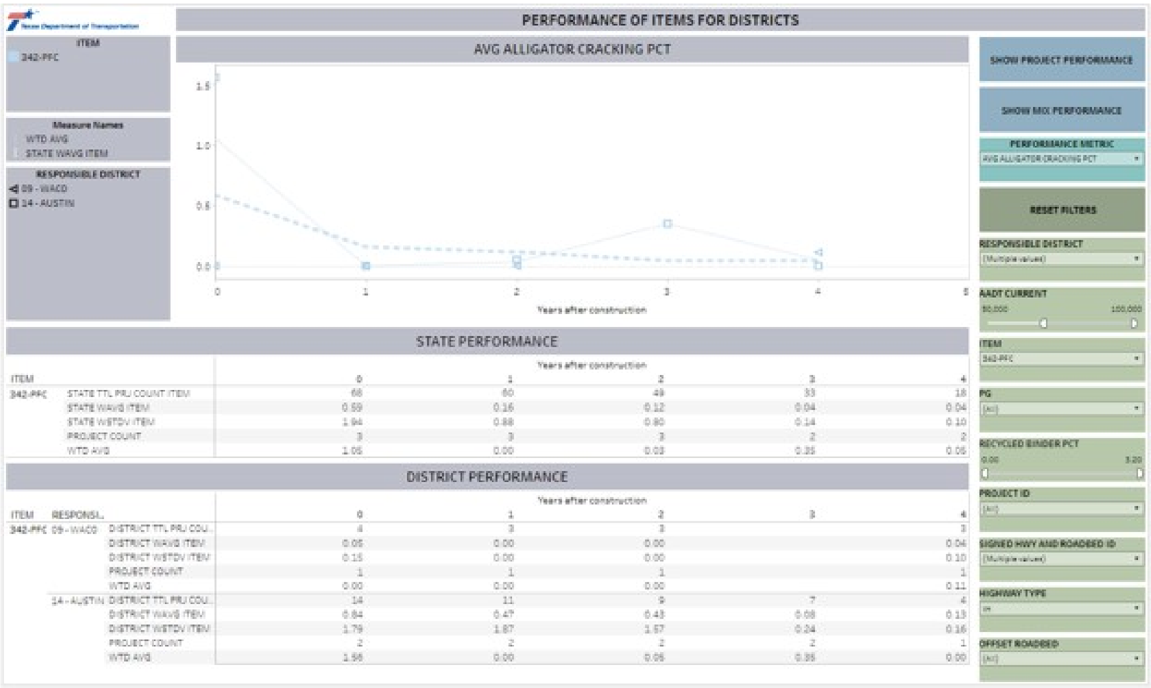


**Figure 4.9. Analyzing District performance for Item 342.**


Figure 4.10. State-wide mix performance dashboard.


Figure 4.11. Mix performance dashboard.


**Figure 4.12. Mix performances for different districts dashboard.**


**Figure 4.13. Age of Items and mixes.**

### 4.2.3 Case 3: Tracking Projects and Materials from Item/Mix Performance

For the same selected section of IH0035 stretching over the four Districts, if we view the skid score of all items, we see that the skid performance of Item 341-DG dropped to about 22.23 from around 27.7 in two years. The following steps show how the dashboards can be used to obtain project and material information from the Item performance.

#### 4.2.3.1 Steps to track project and material information from Item/Mix performance

For this particular example, to obtain the project and material information,

1. Deselect all Districts but San Antonio from the "RESPONSIBLE DISTRICT" filter (Figure 4.14).
2. Deselect all Items and select only 341-DG Item from the "ITEM" filter. This will narrow down the projects with Item 341 for the San Antonio District (Figure 4.15).
3. Click on the "SHOW PROJECT PERFORMANCE" button to navigate to the "D2_Project performance and material information" dashboard (Figure 4.16).

#### 4.2.3.2 Understanding the dashboard

From the table of the "D5_State: dist item perf dynm" dashboard in Figure 4.14, it is apparent that there are 4 projects that use Item 341, among which two projects have a service life of 4 years. If one selects the circular marker, as shown in Figure 4.14, the dashboard highlights the projects related to the Item performance for that year.

Navigating to the "D2_Project performance" dashboard in Figure 4.16, and carefully observing the performance of the highlighted project, one can notice that the project with CSJ 0017-10-275 showed a significant drop of the skid score in 2023. The highlighted material information in the "MATERIAL INFORMATION" table reveals that this was a small project of 94 tons that was constructed in 2020. The surface layer used WMA and PG 64-22 binder in the mixture with a recycle binder percentage of 1.0.

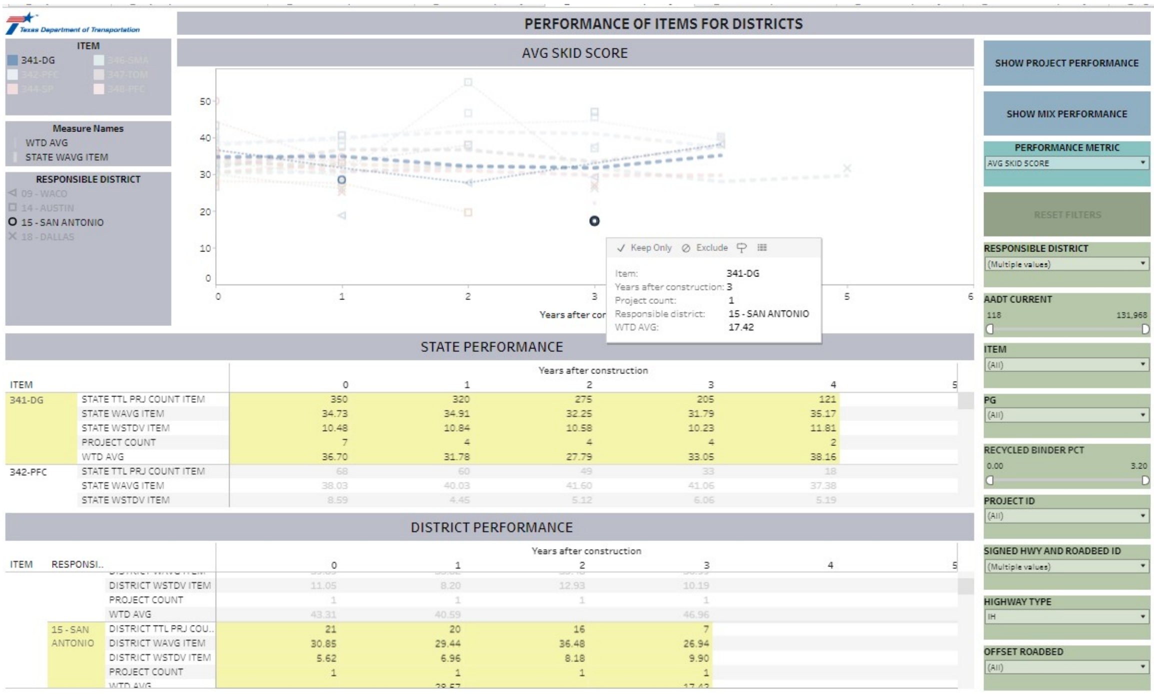


**Figure 4.14. Highlighting the Item of interest.**

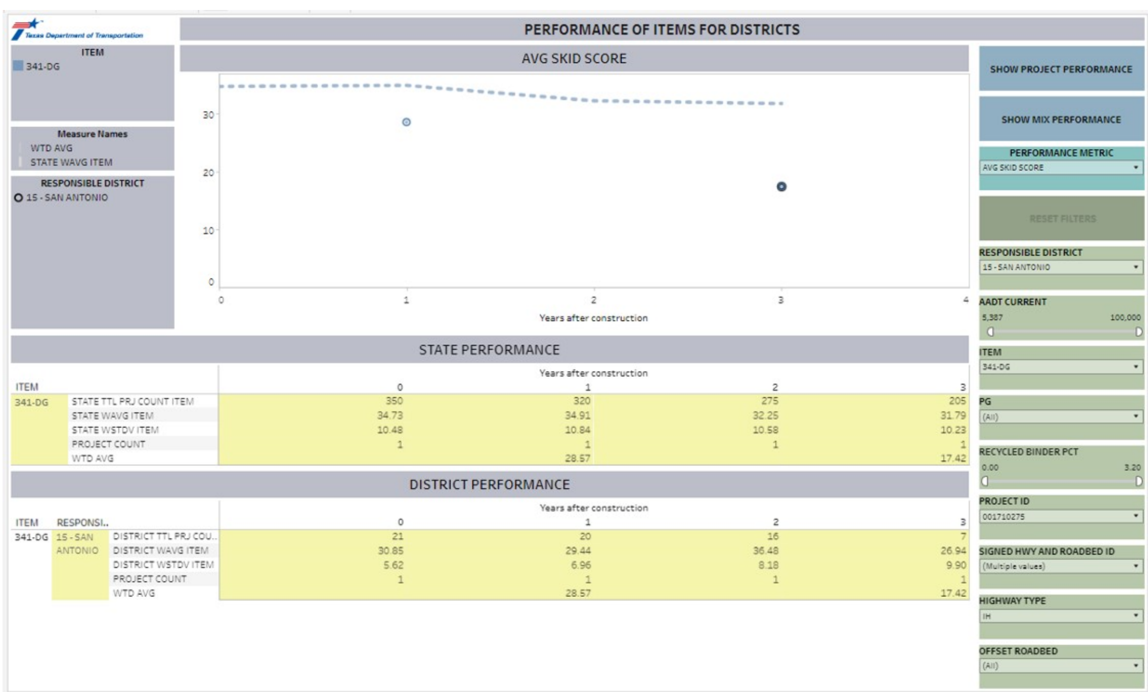


**Figure 4.15. Isolating the Item of interest.**

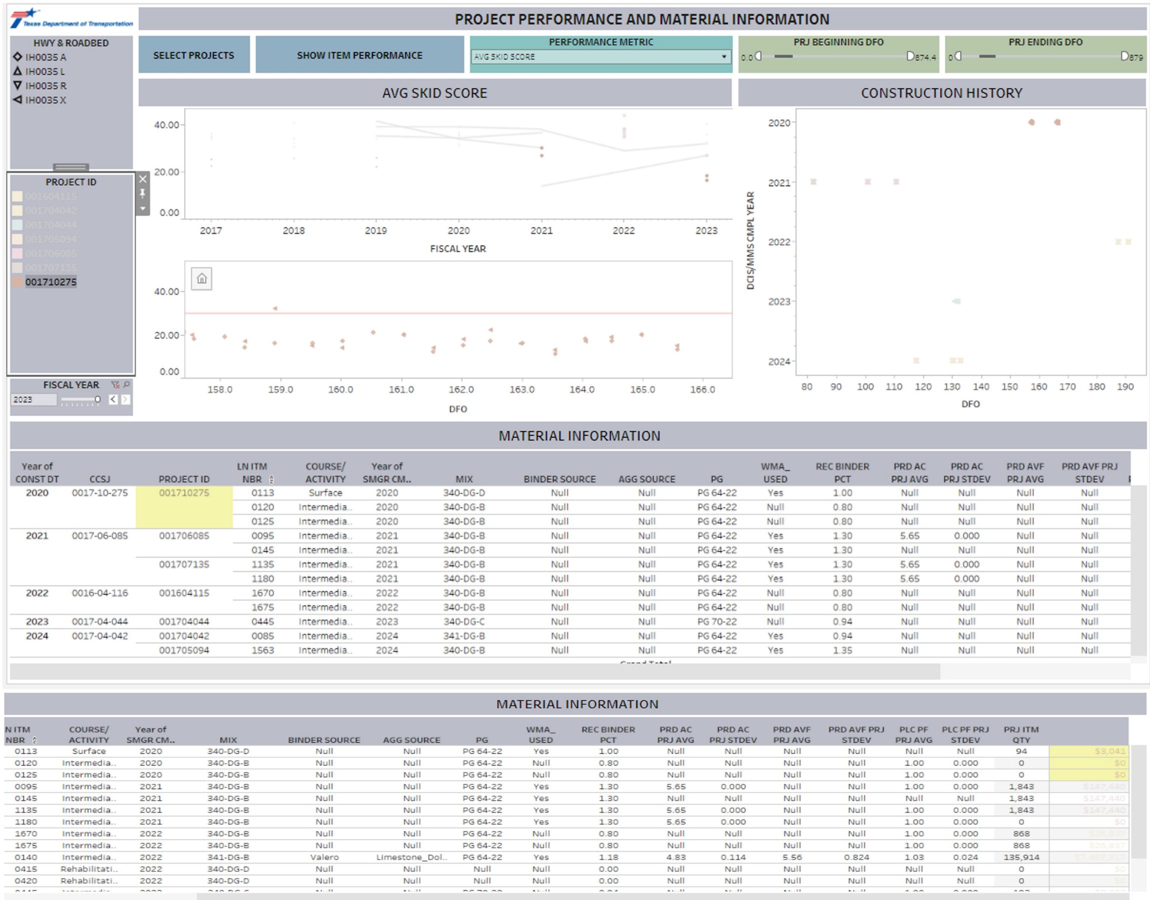


**Figure 4.16. Tracking projects from the Item/Mix performance.**

## 4.3 MANAGING THE DATA SOURCES, FLOWS, AND DASHBOARD

The dashboards are developed with data sources that are connected to SMGR Oracle database via a live connection, and the data sources are updated on a regular basis. The following section is intended for users with administrative privileges with access to the data sources and permission to edit the dashboards. This section demonstrates how a new data source can be added to the existing data source. In addition, it shows how one can create a new dashboard consisting of the newly added data source. Finally, some general tips are provided to avoid unwanted modification to the dashboard views.

### 4.3.1 Adding new data sources and flows

The following steps demonstrate how the existing data source can be expanded to include more data. In this example, the surface aggregate classification (SAC) from the mixture design form the SiteManager database is added. Before adding a new field to the data source or altering the data source that the dashboard is built upon, it is a good practice to make a copy of the existing data source and make changes to the copied data source, so that there isn't any unwanted change that may affect the dashboards.

The following steps show the creation of a flow that queries SAC information from the mixture design form using a live connection to the SMGR Oracle database

1. Connect to the SMGR Oracle database using the server information shown in Figure 4.17.
2. Create a "Custom SQL" to query the surface aggregate classfication information from all seven bins from the "TX_TST_RSLT_VAL" table from the SMGR schema as shown in Figure 4.18.
3. Repeat the same process for all bins with SAC information and join these input sources together using the keys, "smpl_id", "smpl_tst_nbr" and "tst_meth". Refer to the individual "Join" and "Clear" steps to follow the details of the joining clauses and data cleaning steps used in the flow. The flow is saved as "SMGR_mixdes_sac" (Figure 4.19).
4. The SAC information from all seven bins need to be combined together to show the classification for the combined gradation. Typically surface aggregates are classified as A, B, or a blend of A and B classifications. Create a new column that represent the classification of the combined gradation. Create a "Calculated Field" and name it as "SAC" with the calculation shown in Figure 4.20 in a "Clear" step. The formula in Figure 4.20 accounts for the inconsistencies in the data input for SAC. As shown in figure 4.21, the input field for SAC ranges from numeric to various texts without any consistent format making the data processing rather complicated.
5. Add an output step and name the output data source as "Agg_sac".
6. Publish and run the flow. Once the output data source is generated, join the newly published data source with the combined data source of the "SMGR_mixdes" flow (Figure 4.22).
7. Make sure to add the new field to any "Aggregate" step that follows a "Join" step as an aggregated fields. Also check any downstream flows that have "Aggregate"

steps. The “Aggregate” steps only show the fields that are added to the “Grouped” and “Aggregated” fields. If the new added fields are not added as aggregated fields, they will not be carried over to the final output.

8. Since the newly generated data source is based on a live connection, add the flow to “Scheduled Tasks” for the final flow so that the data source is updated on a regular basis. In this case, add the flow at step 1 for the the final flow named “SMGR_PA_DCIS_MMS_SHP” (Figure 4.23).

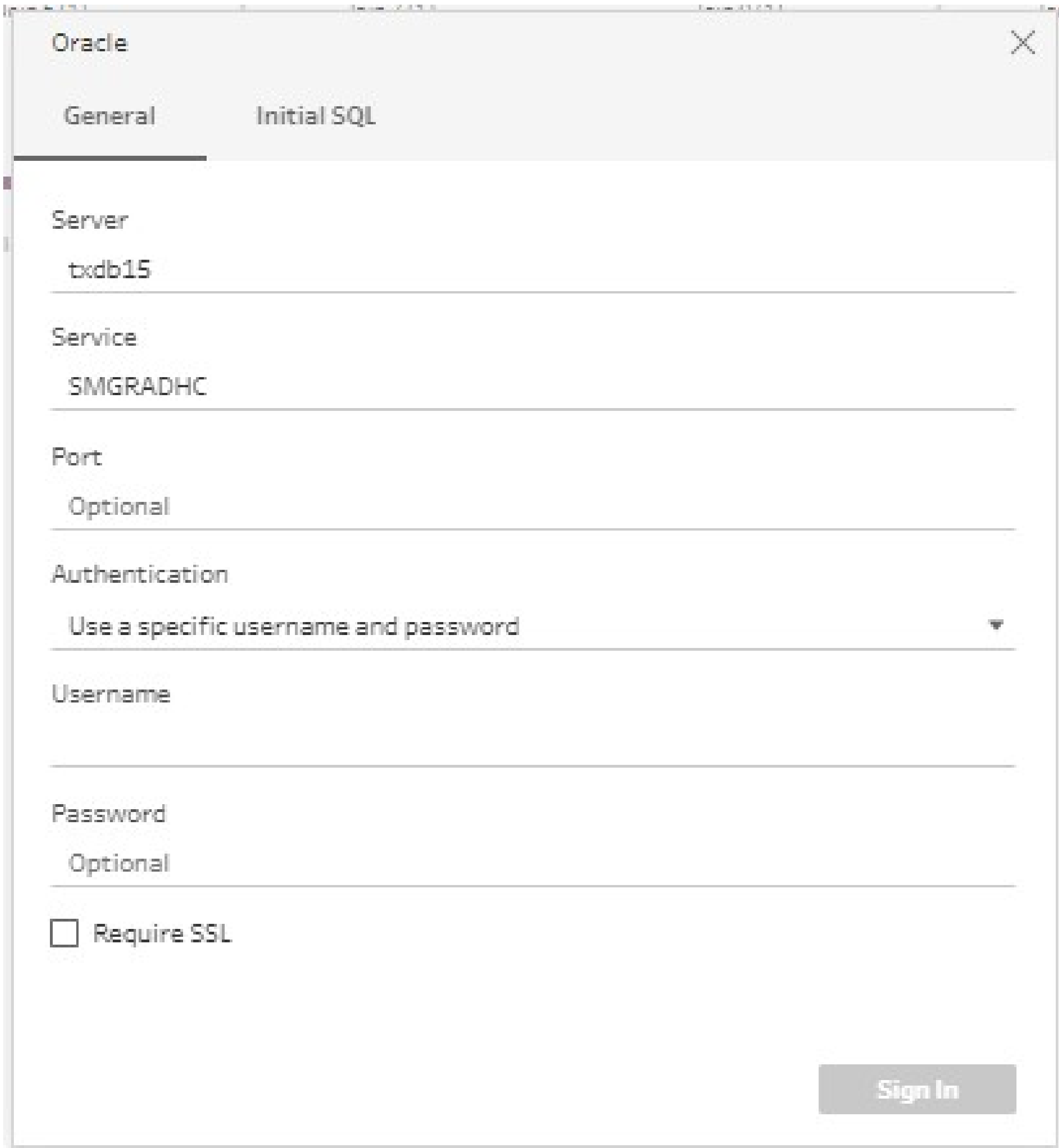


**Figure 4.17. Connection detail for SMGR Oracle database.**

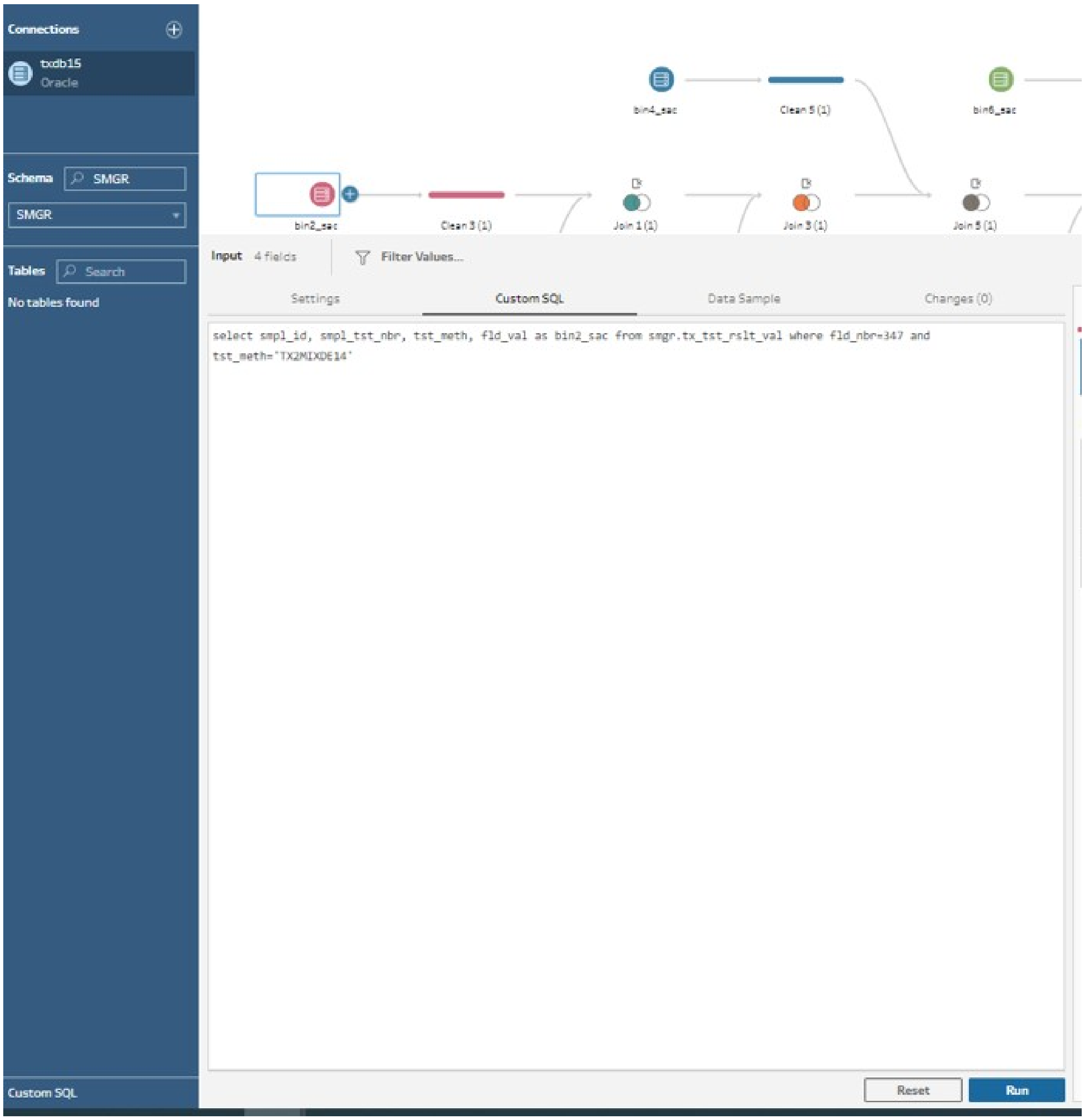


**Figure 4.18. Custom SQL query showing the query for surface aggregate classification (SAC).**

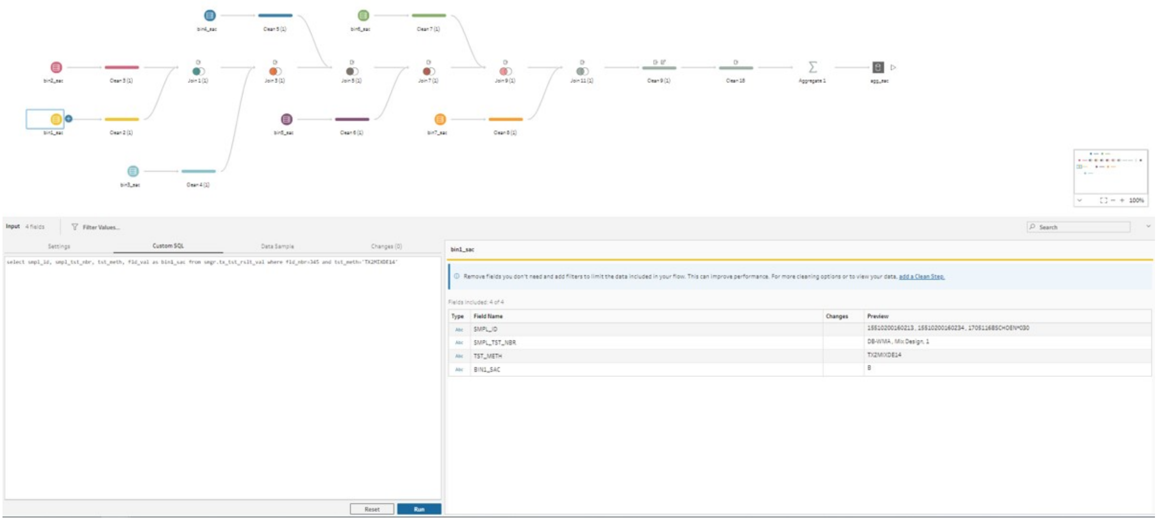


**Figure 4.19. A new flow incorporating surface aggregate classification (SAC) from the mixture design form.**

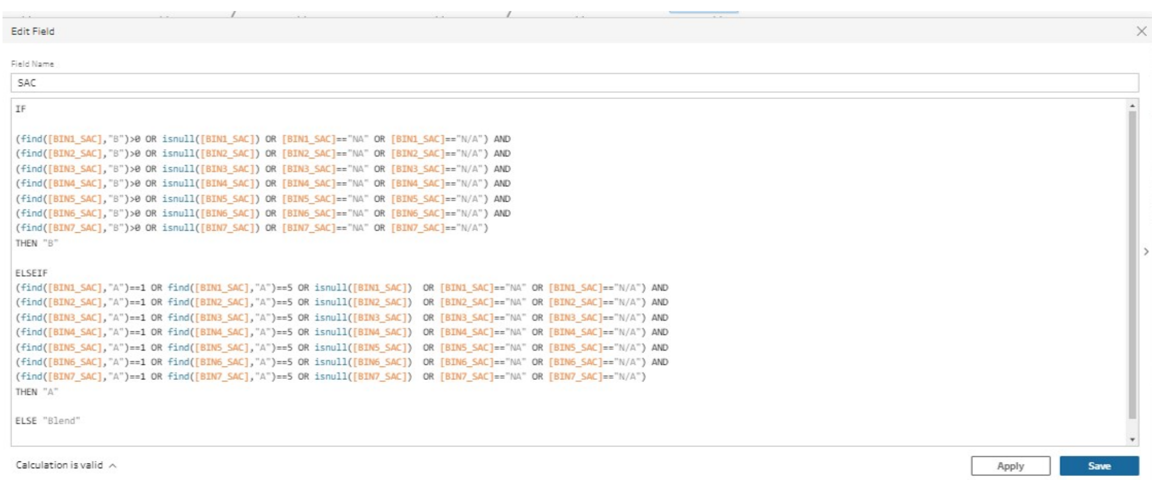


**Figure 4.20. Calculation showing surface aggregate classification (SAC) for combined gradation.**

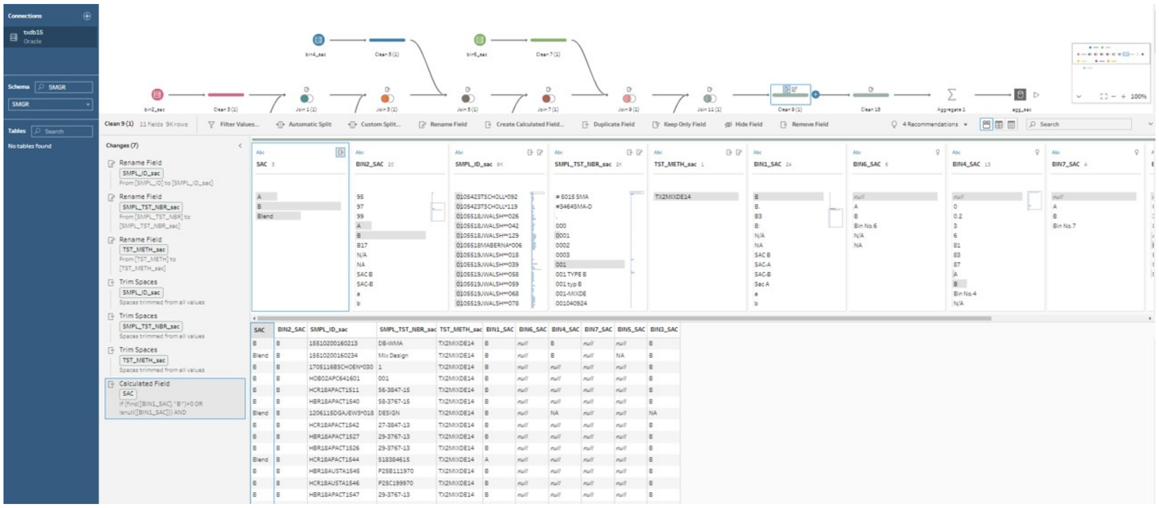

**Figure 4.21. Inconsistencies in surface aggregate classification (SAC) input format in the SiteManager database.**

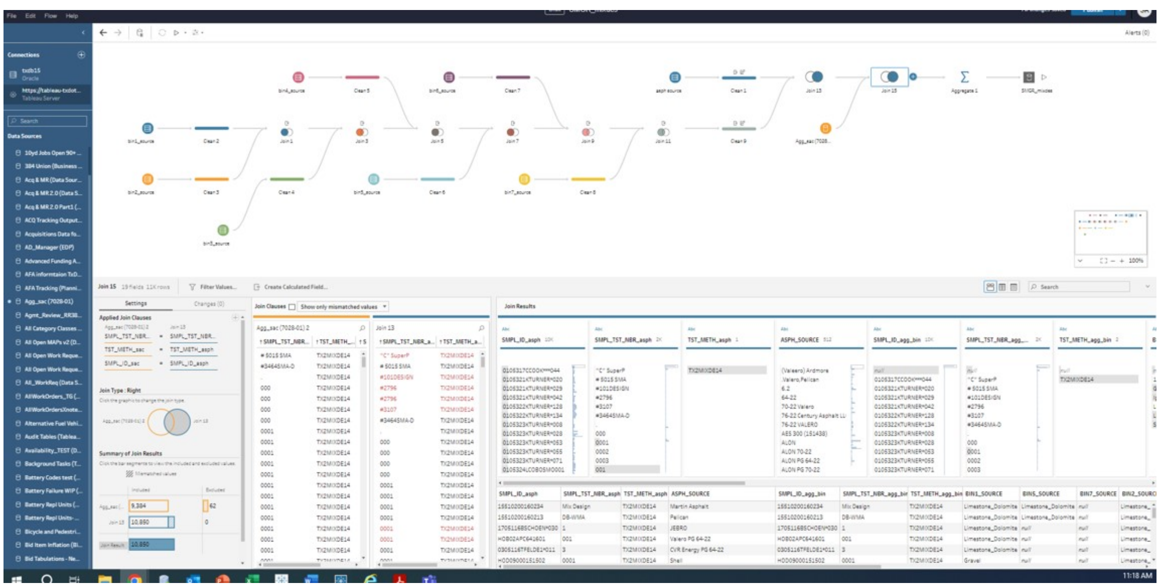

**Figure 4.22. Joining the "Agg_sac" data source to the "SMGR_mixdes" flow.**

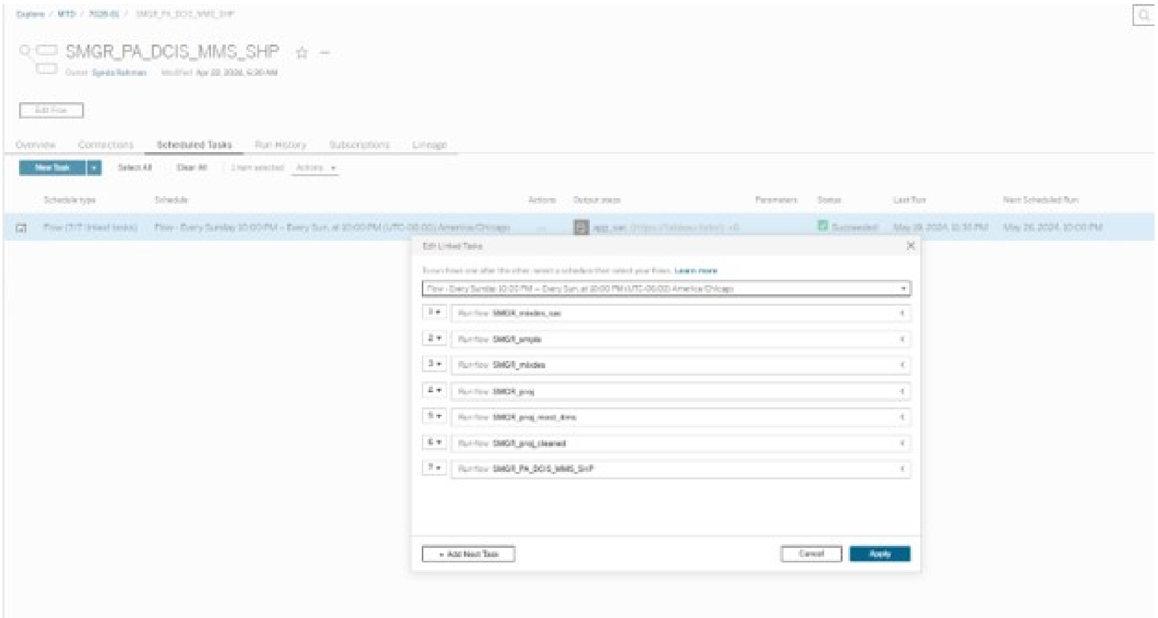


**Figure 4.23. Adding the new flow, "SMGR_mixdes_sac", to the Scheduled Tasks of "SMGR_PA_DCIS_MMS_SHP" flow.**

### 4.3.2 Adding new dashboards

In order to create a new dashboard with the newly added data, one needs to create a worksheet first. One can simply take an existing worksheet that matches with the desired output, make a duplicate, rename the worksheet, and make the necessary changes for the desired analysis. One can follow the following steps for creating a new analysis dashboard for SAC.

1. Right-click on the sheet name of the "State-dist item perf dynm", select "Duplicate" and create a copy of the sheet.
2. Rename the copied sheet as "State-sac item perf dynm".
3. Select the "AGG(WTD AVG)" Marks card, and drag the "SAC" measure from the left "Data" pane to the "Shape" marks. This will replace the previous shape marks to "SAC".
4. Drag the "SAC" measure from the left "Data" pane to the "Line" marks in the "Measure Values" Marks card.
5. Remove the "STATE WAVG ITEM" from the Measure Values card. This will rename the "Measure Values" Marks card to "AGG(WTD AVG)" and "AGG(WTD AVG)" Marks card to "AGG(WTD AVG) (2)" .

6. Right click on the sheet name and uncheck "Publish".
7. To create a tabulated form of the plotted results, right-click on the sheet name, select "Duplicate as Cross-tab". This will create a sheet with a table with a summary of the plotted values.
8. Now to create a dashboard, simply create a duplicate of any existing dashboard to keep the formatting. For instance, create a duplicate of the dashboard "D5_State: dist item perf dynm" and rename it as "D10_State: Item sac perf".
9. Select the existing plot you want to replace with the new plot. Select the "State-sac item perf dynm" sheet from the "Sheets" pane and click on "Swap Sheets" button to swap the sheets. Repeat the same process to swap the tables.
10. Make necessary additional changes corresponding to the new plots and tables.

The final worksheets should appear similar to Figures 4.24 and 4.25, and the final dashboard should appear similar to Figure 4.26.

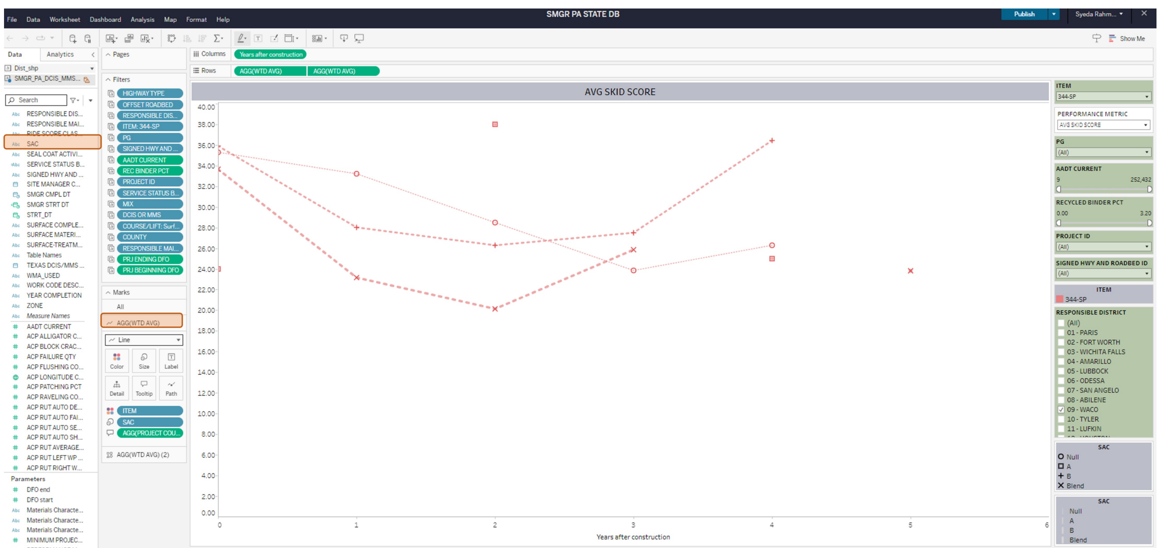


**Figure 4.24. Creating a new worksheet with surface aggregate classification information.**

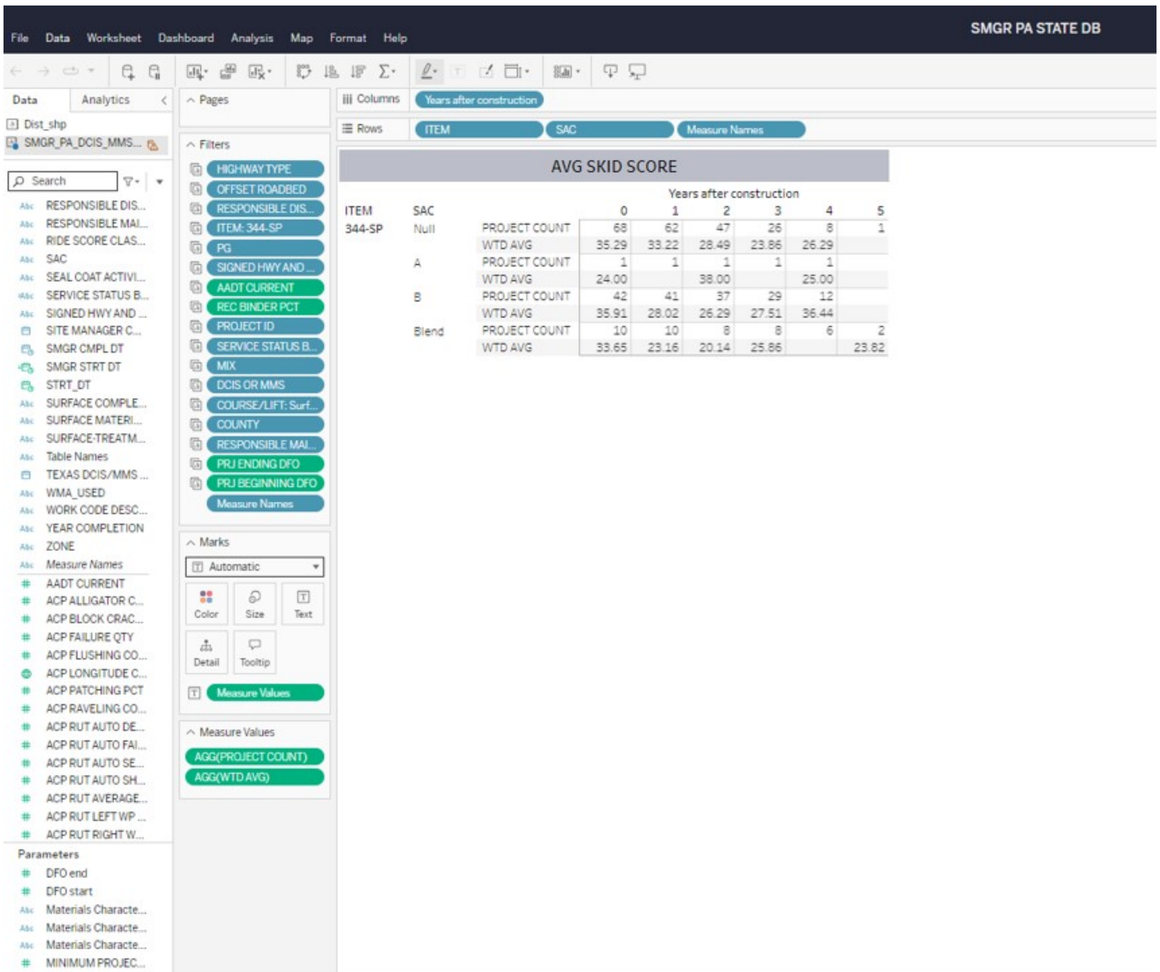


**Figure 4.25. Creating a table with surface aggregate classification.**

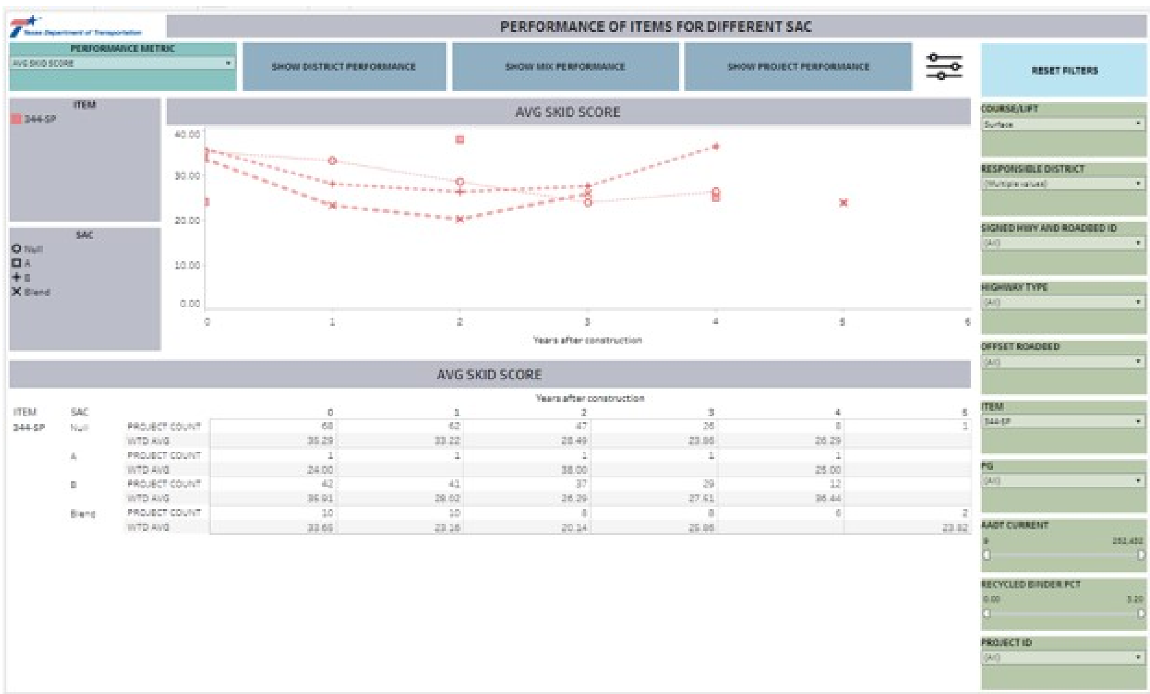


**Figure 4.26. Development of a new dashboard with surface aggregate classification.**

### 4.3.3 Some general tips

Here are some general guidelines that one should keep in mind while managing the dashboards:

1. If any filter is added to the dashboard, make sure to include them in the “RESET FILTERS” action for that dashboard.
2. Each dashboard has its own “RESET FILTERS” button except dashboard D2.
3. Do not reset “COURSE/LIFT” filter for dashboards D4-D8 and D10. The state wide average calculation includes “COURSE/LIFT”. It is a “Fixed Level of Detail” calculation and will appear as $*$ instead of numeric values if more than one “COURSE/LIFT” is selected.
4. When handling filters, exercise caution as this may affect outputs. For instance “Min prj cns dt” filter should never be reset and should not be added to any “RESET FILTERS” action. It’s connected to the “MINIMUM PROJECTS” parameters.
5. To highlight selected items on the “Legend” card, make sure that the “Highlight Selected Items” button is switched on. This button appears as  when you hover the mouse over the top right corner of the “Legend” card.

## 4.4 SUMMARY

This chapter provides guidelines for managing and operating the dashboards. Three case studies are presented to show how one can use the dashboards to analyze project and Item performance, as well as track materials and project information back from the Item performance. Steps for adding a new data source to the existing one and creating new dashboards are also provided. This text guide is accompanied with a video guide that shows the step-by-step processes and includes more details for cases and examples shown here.

# CHAPTER 5. SUMMARY AND CONCLUSIONS

## 5.1 OVERVIEW

The primary objectives of this study were to:

- evaluate the long term performance of specification Items and mixtures,
- account for maintenance activities in determining the age of pavement surfaces and total dollar value spent on a given section,
- bench-mark performances of specification Items and mixtures, and
- ultimately develop an investigative tool to track activities leading to satisfactory and unsatisfactory performance.

To achieve these goals, this study was conducted in three major parts. In the first part, material and project related information from the SMGR database and pavement surface conditions and project locations from the PA database were extracted. This extracted and combined data consists of materials information, construction parameters, and performance measures of hot mix asphalt pavements. Data related to materials include the as-produced hot mix asphalt mixture properties, collected as part of QCQA, such as laboratory molded density, in-place air void, mixture type, binder grade and content, and recycled materials. In addition, project related information such as letting and completion date, as well as bidding information such as quantity and unit price of the specification Items involved in a project were extracted. These data were accessed from the SMGR Oracle database by setting up a direct connection through Tableau Prep Builder.

Included in the integrated data were also historical performance measures, such as condition scores, distress scores, ride scores, international roughness index, and surface distresses and data collection section information such as traffic, load, and vehicle speed for the state maintained highway system. These data were extracted from the PA database as csv files. The data were collected, processed, and combined using a commercially available software, namely Tableau Prep Builder. Furthermore, the DCIS and MMS projects and their locations planned for four-year planning cycles were extracted as xlsx files from the PA database and integrated with the pavement surface condition data and material information on Tableau Prep Builder. Finally, the integrated data were published on the Tableau-TxDOT server, which were then fed to Tableau as the principal data-source for the development of the visualization dashboards.

In the second part of the study, the integrated data from the previous task were further processed and imported to Tableau and several dashboards were developed. The dashboards have the capability to show the analysis for projects and mixture items whereby performances of the projects, mixtures, and constituent materials can be visualized, studied, and compared. The dashboards also offer several filters allowing a user to select projects based on the desired characteristics including district, county, responsible maintenance section, highway type, route, traffic, mixture and material properties. The dashboards analyze pavement surface conditions, e.g. condition score, distress score, IRI, ride score, alligator cracking, rut depth, and skid score.

In the third part of this study, guidelines to manage and operate the dashboards were created. Several case studies are presented to show how one can use the dashboards to analyze project and Item performance, as well as track materials and project information back from the Item performance. Steps to add new data source to the existing one and create new dashboards are also provided. The text guide is accompanied with a video guide that shows the step by step processes and includes more details for the cases and examples documented in this report.

## 5.2 DASHBOARD DESIGN AND FUNCTIONALITY

The dashboards were designed to perform project level, specification Item/mixture level, and material level analysis:

- Project level analysis – to compare and analyze the performance of projects from the same section or different sections with the same traffic and weather condition;
- Mixture level analysis – to analyze and benchmark the performance of different specification Items used under similar traffic and weather condition; and
- Material level analysis – to determine the effect of selected specific materials and their proportions and to improve mixture design.

The three levels of analysis will enable Divisions and Districts of TxDOT to perform state-wide and district-wide comparison of various projects and specification Items for the following purposes:

- Planning – locating roadway sections on a map and summarizing pavement condition, construction history, and material properties for projects constructed on that section. This will allow planning for future projects for that roadway sections.
- Project level investigation – analyzing materials and construction practices used in past projects and investigating their effect on the pavement performance.
- Bench-marking – aggregating and comparing the performance of items or mixtures,

which in turn will provide insights for the modification of specifications.

- Estimating – incorporating the cost of the contracted and in-house maintenance activities performed in-between contracted projects and estimating the total dollar value spent on a given section.

## 5.3 KEY ACHIEVEMENTS

Some of the key achievements from this study are summarized below:

- Developed a first-ever unified system that integrates material, construction, maintenance activities, and pavement surface performance measures.
- Identified and located contracted and in-house maintenance activities and incorporated the cost of these activities in determining the total dollar value spent on the section.
- Incorporated maintenance activities in determining the age of the pavement surfaces in service.
- Developed a system that can be applied by Districts or Divisions as an investigative tool for analyzing the historical performance of the past materials used in projects.
- Developed an application that shows the effect of changes in specifications on the long-term performance.

  The use of these dashboards is expected to help improve mixture design, benchmark mixtures with superior performance, and modify specifications toward long lasting pavements.

## 5.4 FUTURE MANAGEMENT AND EXPANSION

This report provides a guideline on how one can manage the existing data-sources as well as add new data-sources to the existing data-sources. An example case study is also provided demonstrating how one can create new dashboards with the additional data-sources.

The flows and the dashboards developed in this study present the foundational framework for integrating and tracking performance of materials and construction practices for various applications, including design-build projects. Similar tools can be developed to evaluate performance of new specification Items that are being introduced in pilot programs. Such a tool may help in identifying primary modes of pavement distress to be considered in the development or modification of new specifications. Furthermore, this tool may be expanded by adding laboratory test results data, which in turn may be used to relate test results to the field performance and evaluate the appropriateness of laboratory tests.

# REFERENCES

Rahman, S., Sun, J., Bhasin, A., and Zhang, Z. (2022). Capitalizing on construction records to identify relationships between construction and long-term project performance: Final report. Technical report, Texas Department of Transportation and the Federal Highway Administration.

# APPENDIX A. VALUE OF RESEARCH

## A.5 PROJECT TITLE

Integrated SiteManager and Pavement Analyst Database on an Online Platform

## A.6 PROJECT STATEMENT

In a recent project, 0-7028, data from the SMGR and PA databases were compiled and analyzed to study the effect of material properties on the long-term pavement performance. In this study, several pavement sections were selected for site visits to validate results obtained from the compiled data. The comparison of the filed observations with the compiled data revealed that there was a need to incorporate maintenance activities to accurately capture the performance of materials and construction practices. Furthermore, currently TxDOT does not have a system to evaluate the performance of materials and assess the effect of modified and new specification Items on the long-term pavement performance. This research study was conducted to integrate material, construction, maintenance, and performance information, and to deploy the unified data on a commercial system licensed by TxDOT so that Division and District personnel can access and interact with these data on a regular interval or an as-needed basis. Table A.1 presents a summary of the benefit areas from project 0-7028-01.

**Table A.1. Functional areas for project 0-7028-01**

| Benefit Area | Qual | Econ. | Both | TxDOT | State | Both |
|---|---|---|---|---|---|---|
| Level of Knowledge | X | | | X | | |
| Increased Service Life | | X | | | X | |
| Reduced Construction, Operations, and Maintenance Cost | | X | | | X | |
| Materials and Pavements | X | | | | X | |
| Infrastructure Condition | X | | | | X | |

## QUALITATIVE BENEFITS

### Level of knowledge

The research team developed a unified system that integrates materials, construction, maintenance activities, and pavement surface performance measures and deployed the integrated system on Tableau-TxDOT server which can be directly accessed by TxDOT personnel from different Divisions and Districts. The system provides a comprehensive summary of available material information from the mixture design and QCQA efforts along with the pavement condition summary and location of all projects for the entire state. Furthermore, the developed system estimates the total dollar value spent on pavement sections and the age of pavement surfaces. Divisions and Districts will be able, in near real time, to evaluate the performance of materials, assess the effect of modifying an existing specification Item or introducing a new specification Item on the long-term pavement performance, and ultimately benchmark and improve the material characteristics and QCQA efforts.

### Materials, Pavements, and Infrastructure Condition

The better understanding of the historical performance of the past and existing specification Items and mixtures will help Divisions and Districts make informed decisions towards the modification of existing specifications, which in turn will improve the service life of materials and pavements leading to improved infrastructure condition.

## ECONOMIC BENEFITS

### Increased service life and Reduced costs

This project started on September 1, 2022 and completed on August 31, 2024 with a duration of 2 years. The total budgeted cost for this project was $139,965. TxDOT's biennial 2024-25 budget dedicates approximately $32.7 billion to fund the development, delivery, and maintenance of state highway projects. For the purposes of this analysis, if an extremely conservative estimate is considered, whereby implementation of this tool improves the QCQA efforts improving the service life and reducing the construction and maintenance cost by 0.0001%, and a quarter of the biennial budget is allocated to the development and maintenance of the hot mix asphalt pavements per year, the cost savings are about $817,500. This amount was used as the expected value per year.

The aforementioned parameters were used to obtain the Net Present Value (NPV) for this project as shown in Figures A.1 and A.2.

| | | | | | |
|---|---|---|---|---|---|
| Texas Department of Transportation | Project # | 0-7028-01 | | | |
| | Project Name: | Integrated SiteManager and Pavement Analyst Database on an Online Platform | | | |
| | Agency: | CTR | Project Budget | $ | 139,965 |
| | Project Duration (Yrs) | 2.0 | Exp. Value (per Yr) | $ | 8,175,000 |
| Expected Value Duration (Yrs) | | 10 | Discount Rate | | 0% |
| Economic Value | | | | | |
| Total Savings: | $ 81,610,035 | | Net Present Value (NPV): | $ | 89,785,035 |
| Payback Period (Yrs): | 0.017121 | | Cost Benefit Ratio (CBR, $1 : $___): | $ | 641 |

**Figure A.1. Parameters used for economic analysis for VOR.**

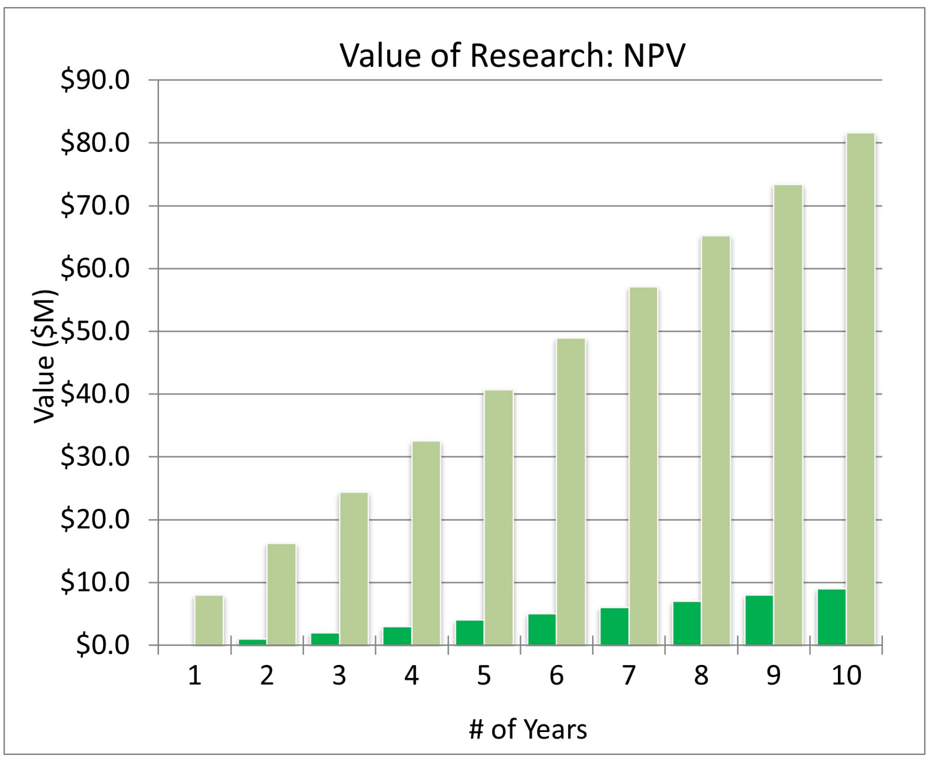


**Figure A.2. Illustration of the NPV over a period of 10 years.**