



# TRC2101: Update of the ARDOT Workforce Forecasting System

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# Background



Fewer staff are assigned  
to manage increasing  
highway mileage



Need for proper future  
planning to save cost from  
emergency hiring



Talents are being  
attracted into other  
industries



Quality is preserved with  
adequate workforce overseeing  
projects across RE offices

# Objectives



Develop an annual forecasting model

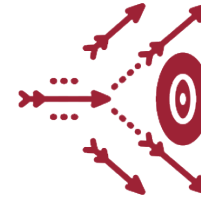


Integrate forecasting model in an automated forecasting software tool

# Existing Forecasting System



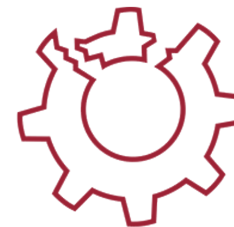
Outdated system first introduced in 1970s



Forecasts are inaccurate and unreliable



Formulas need constant update and are out of date



Not well integrated with today's tool, technology, and workflow

# State-of-the-practice



- ★ E-WoW System for forecasting using data from multiple State Transportation Agencies (STAs) and simple cost ratio based on quartiles
- ★ TxDOT forecasts based on simple linear regression
- ★ SCDOT adopts simple linear regression using cost and person-hours by project categories

# State-of-the-Art Techniques



- ★ Machine learning Models
- ★ Simple and multiple linear regression models
- ★ Econometrics timeseries and neural network based such as recurrent neural networks
- ★ System Dynamic approach using stock and flow modeling

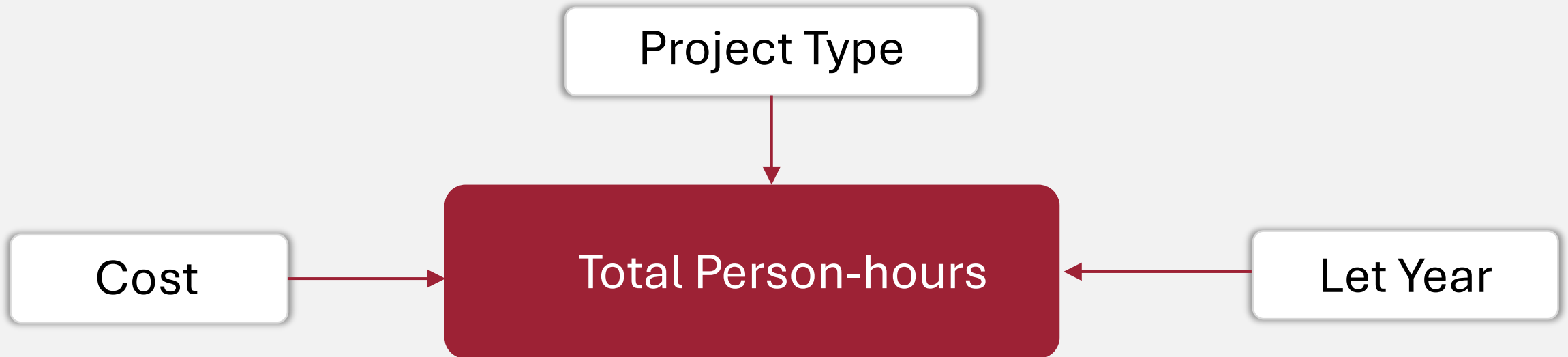
# Data



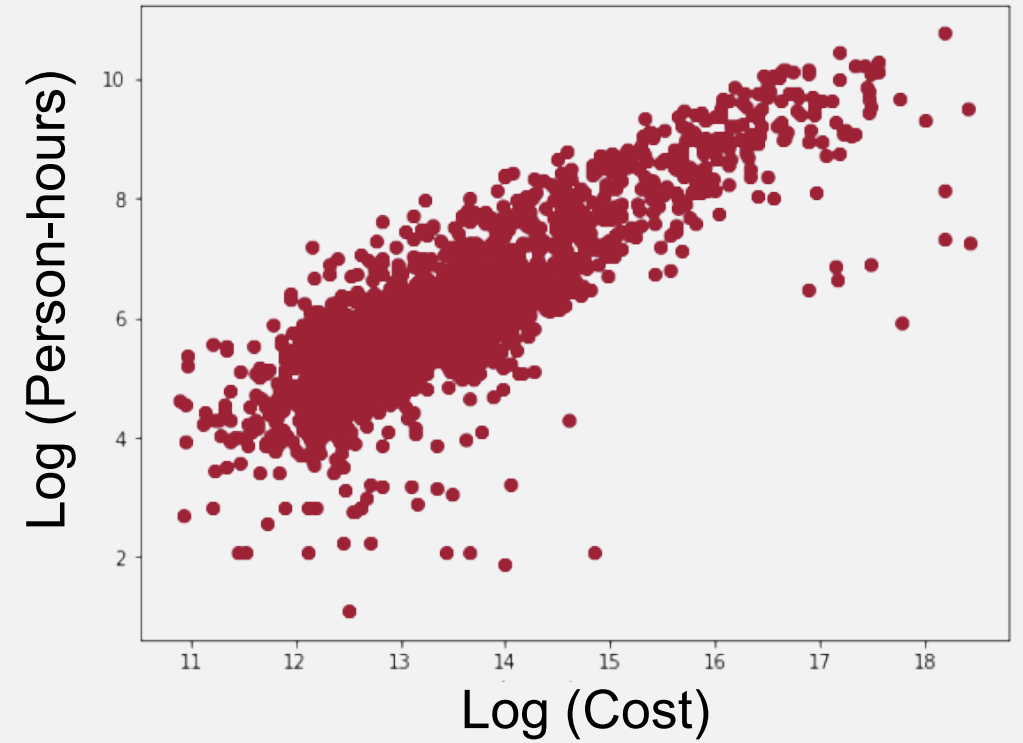
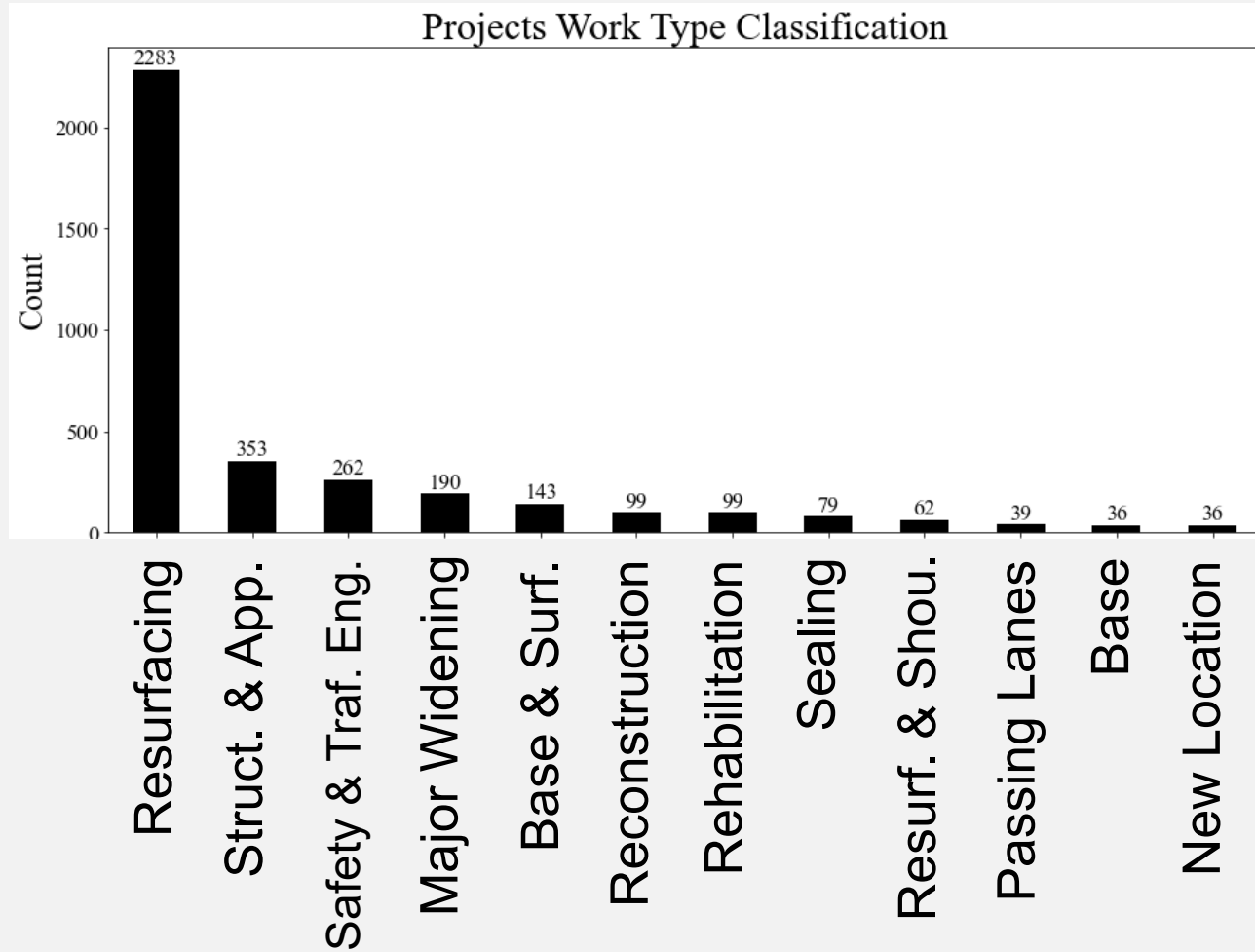
- ★ Data received was for the period of **2012 – 2021**
- ★ Over a million record for employee hours and more than **3000** project information
- ★ Employee data includes key details such as hours, project ids, job title descriptions
- ★ Project data includes important variables: project type, ids, cost, status, begin and end dates

# Data

## Predictor Data for Workforce Estimation

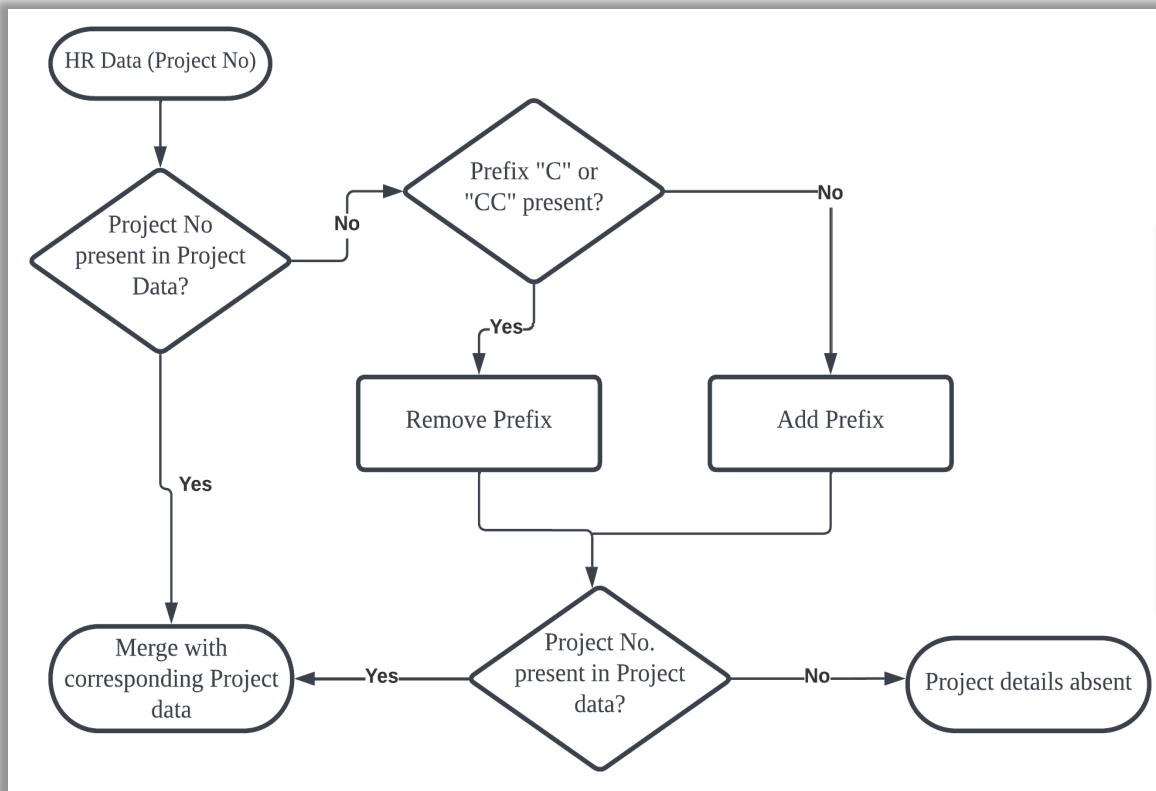


# Data

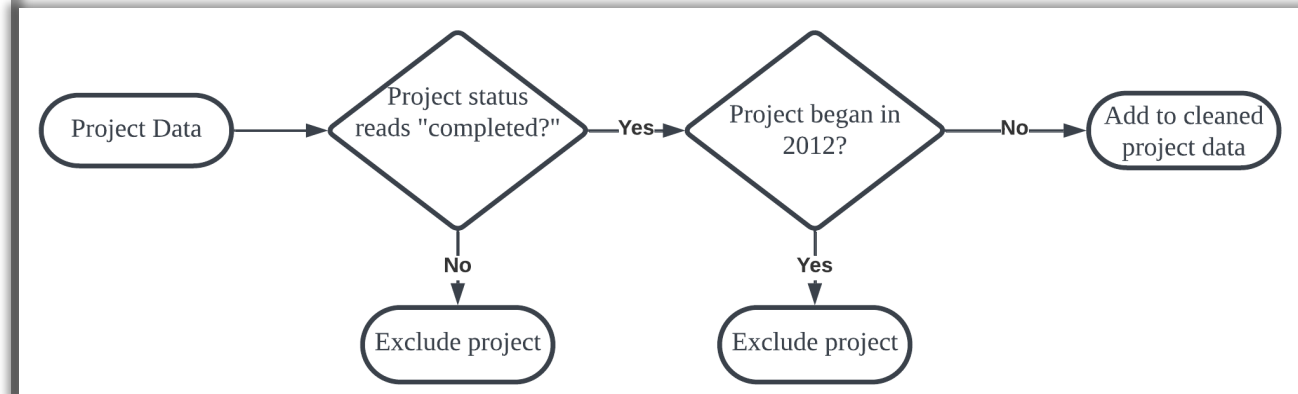


# Preprocessing

- Simplified charts showing the data cleaning process



Merging and cleaning data



Project data cleaning

# Forecasting

- ★ Multiple linear regression models employed for total person-hours forecast
- ★ Need for grouping of multiple project types that have insufficient number of projects

Group 01 (39)	Group 02 (36)	Group 03 (53)
Base Stabilization (12)	Buildings (6)	Emergency (3)
Base & Drainage (2)	Minor Widening (3)	Interchange (9)
Grading, Drainage & Base (1)	Surfacing (7)	Passing Lanes (12)
Grading & Structures (2)	Roadside Appurtenances (6)	RR Crossing (2)
Base (7)	Sealing (5)	Rehabilitation (11)
Base & Surfacing (15)	Miscellaneous (9)	New Location (11)
		Bridge Rehabilitation (5)

# Forecasting Model

$$\text{Log}(\text{person\_hour}) = \beta_0 + \beta_1 \times \log(\text{adjusted cost}) + \beta_2 \times (\text{year\_difference})$$

Project type/grouping	$\beta_0$	$\beta_1$	$\beta_2$	R <sup>2</sup>
All dataset	-6.956	0.974	0.029	<b>0.808</b>
Resurfacing	-5.933	0.875	0.052	<b>0.735</b>
Structure & Approaches	-3.397	0.767	0.054	<b>0.788</b>
Safety & Traffic Eng.	-2.647	0.668	0.081	<b>0.722</b>
Major Widening	-0.398	0.590	0.024	<b>0.526</b>
Reconstruction	-1.811	0.675	-0.070	<b>0.828</b>
Group 1	-6.213	0.941	0.030	<b>0.918</b>
Group 2	-5.560	0.867	0.104	<b>0.740</b>
Group 3	-5.955	0.935	0.020	<b>0.820</b>

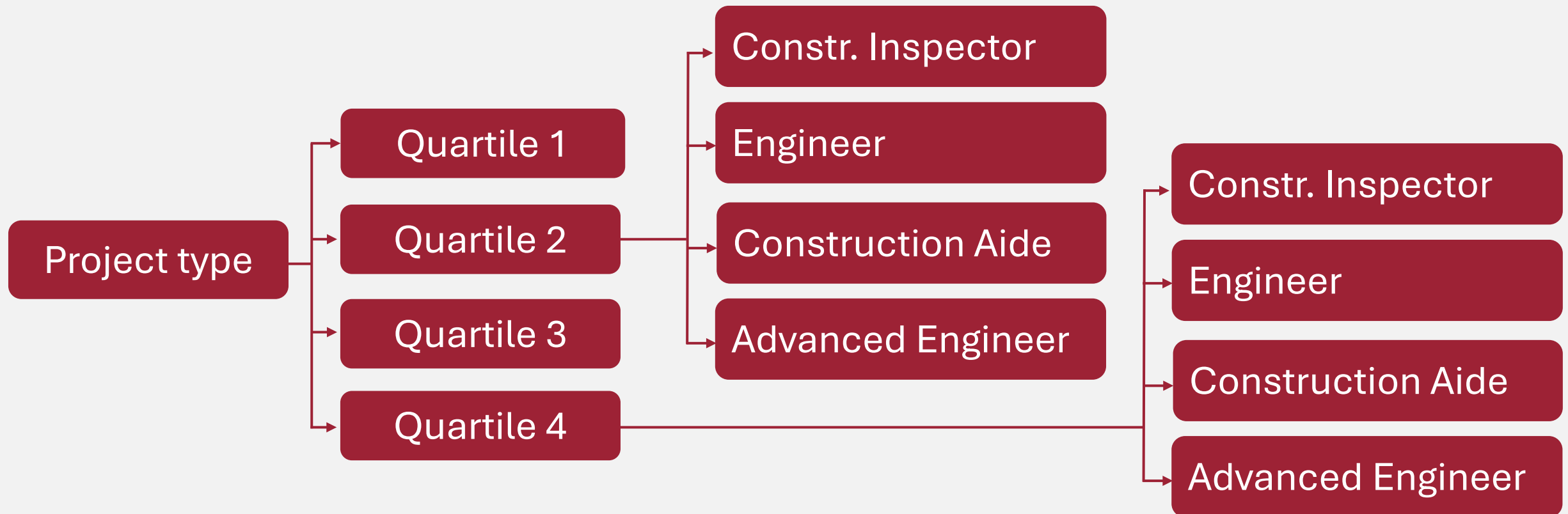
# Distribution Models



- ★ Uses historical distribution as reflected by past projects
- ★ Cost quartiles employed for job title distributions
- ★ Timeline distribution employed historical trend and person-hour distributions
- ★ Varying duration of similar project types warranted the need to normalize distribution over varying lengths

# Job Title Distribution

- ★ Similar project types across various cost quartiles have similar distribution of inspector types for their projects



# Time Distribution Model

- ★ Project durations vary across the project types and need to be normalized for a consistent period.
- ★ Based on the assumption that all projects go through similar stages of work, they are normalized in to  $\mu$  number of stages as below:

$$W_{SX} = \sum_{Y=1}^t W_Y + \left[ \left( \frac{n}{\mu} * X \right) - t \right] \times W_{t+1} - \sum_{z=0}^{X-1} W_{Sz}$$

$$\left( \frac{n}{\mu} \times X \right) - 1 < t \leq \frac{n}{\mu} \times X \quad t \in \{Z^+ \cup 0\}$$

$\mu$  = Number of stages

X = Xth stage of  $\mu$

$W_t$  = number of hours in  $t^{\text{th}}$  month

n = number of months (for current project)

$$W_{S0} = 0$$

# Software Tool



- ★ Forecasting tool was built into a webapp
- ★ The webapp could be accessed from any modern web browser
- ★ Tool installed in ARDOT's server with security authentication requirement for end users
- ★ Webapp designed for automated model estimation and forecast

# Software Tool



Forecasting tool was  
built into a webapp



The webapp could be  
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modern web browser

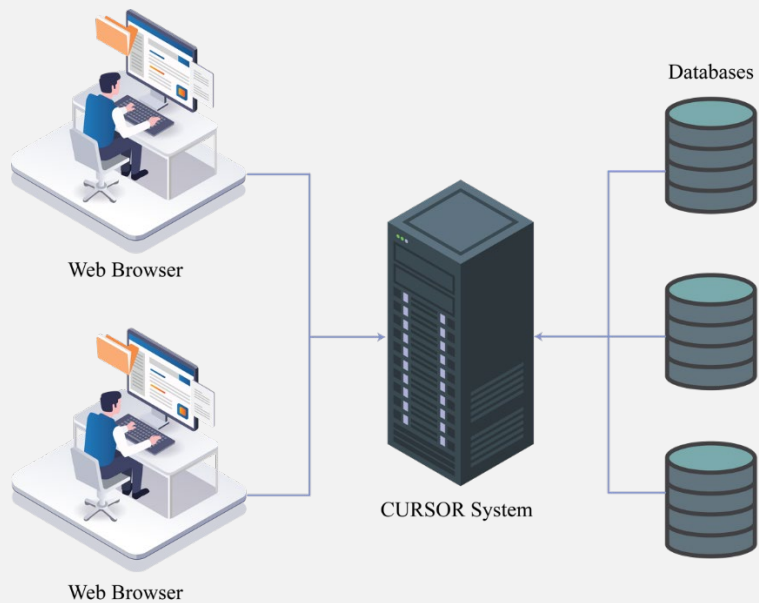


security authentication  
requirement for end  
users

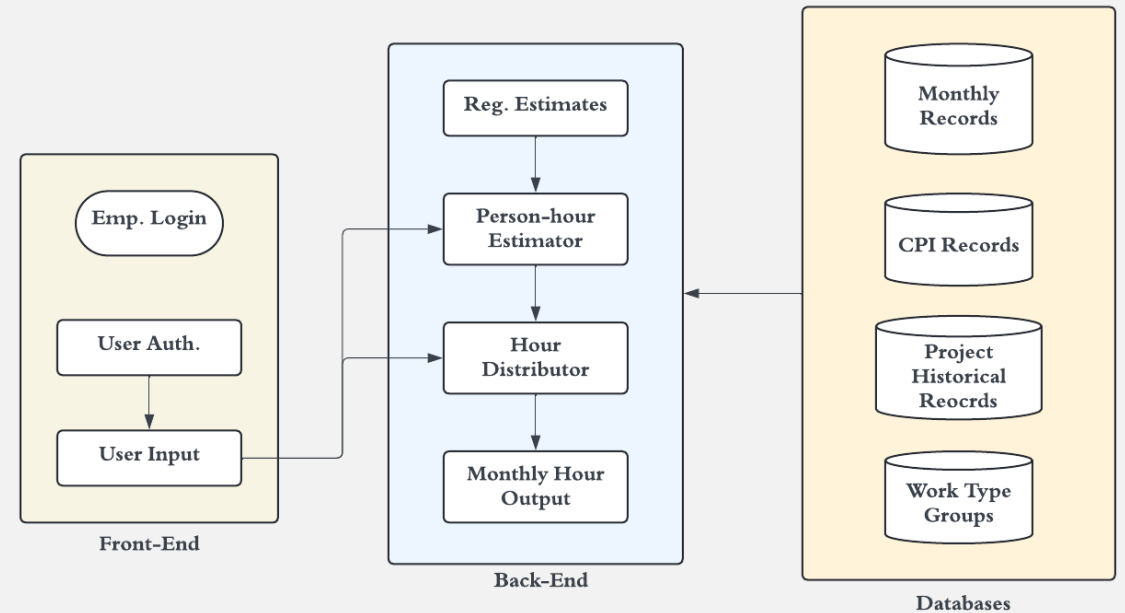


Automated Integration  
with planning database

# Software Architecture

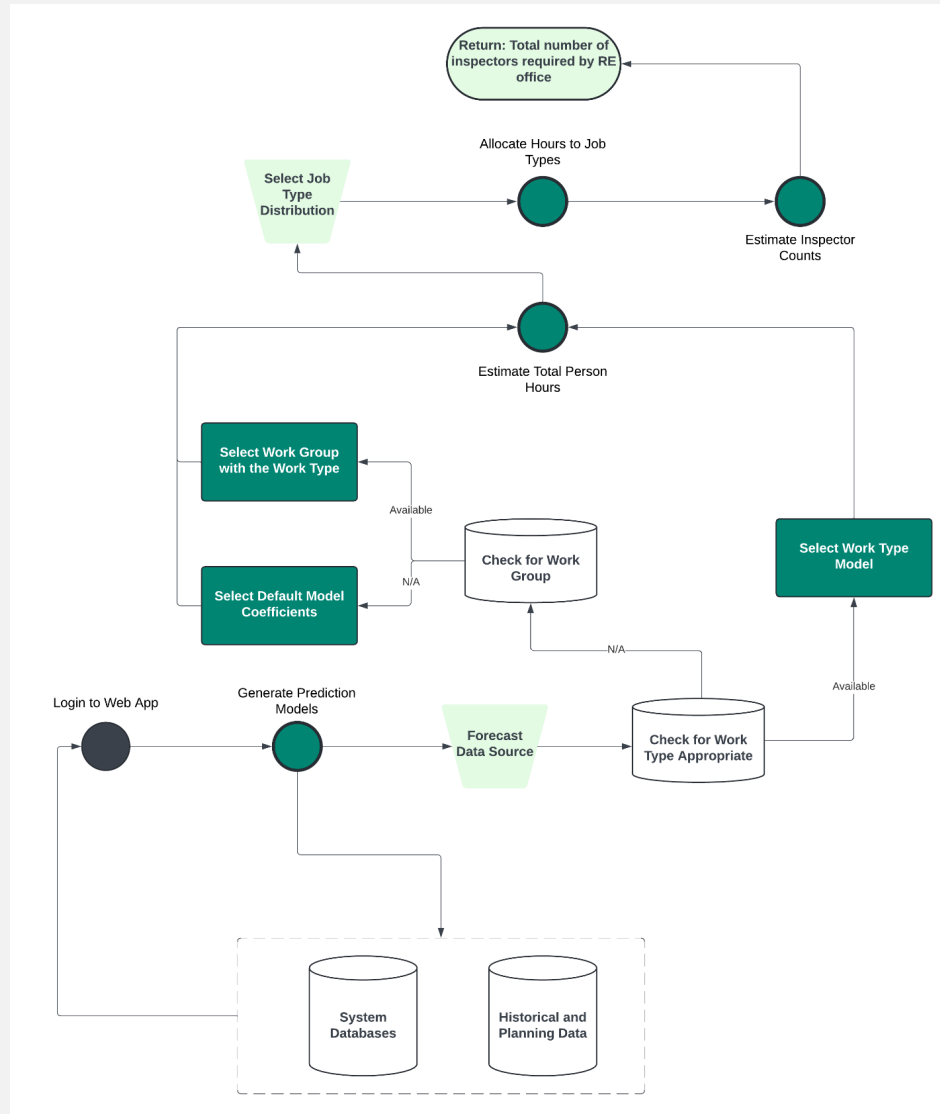


Context diagram

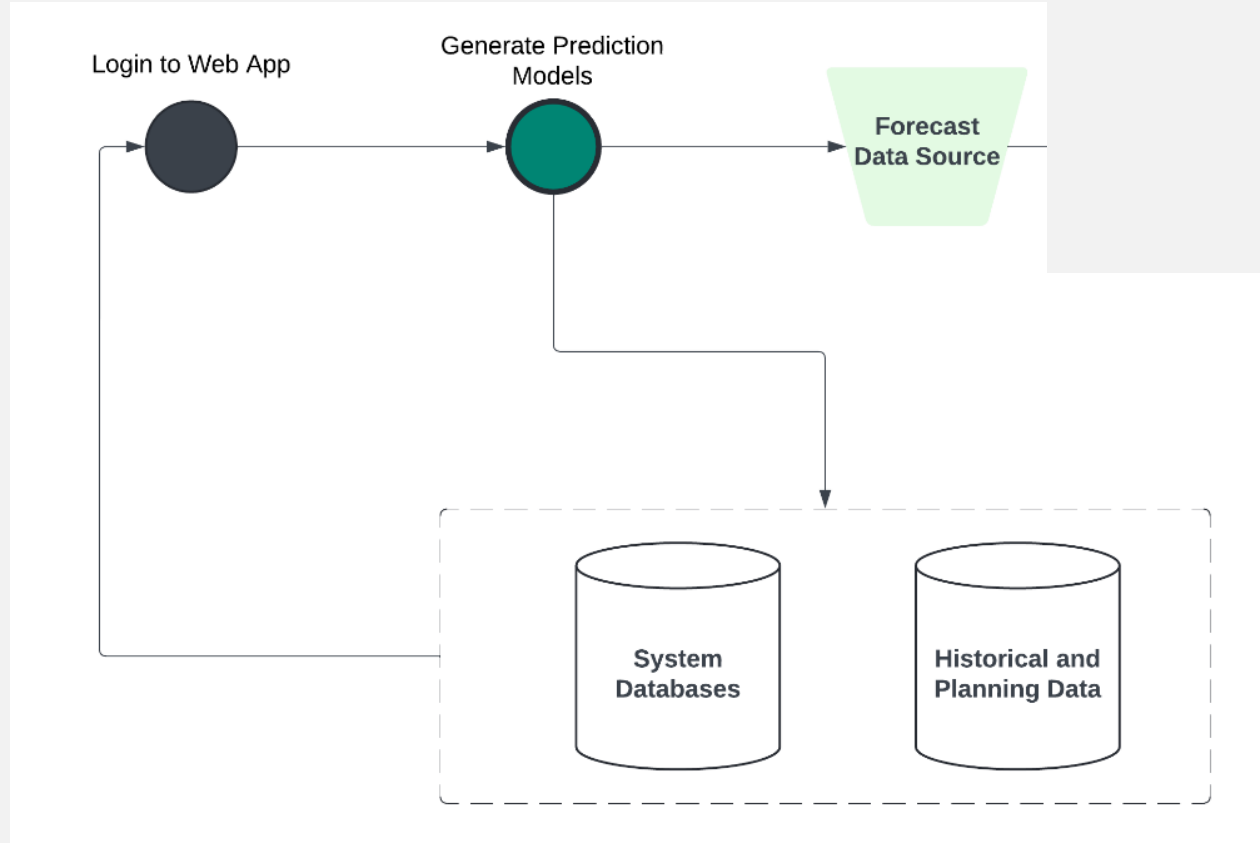


Data flow within system

# Software Architecture

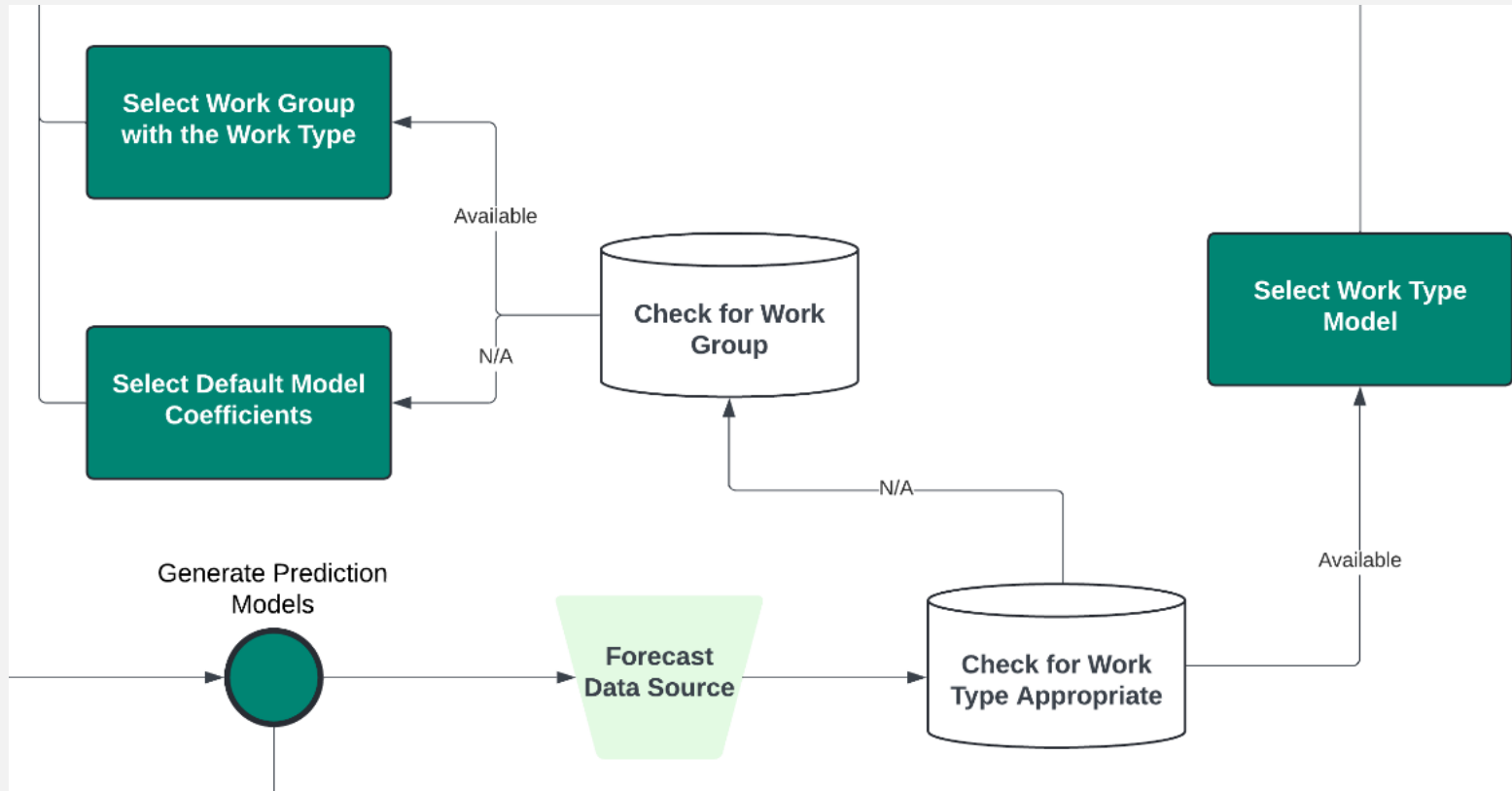


# Software Architecture



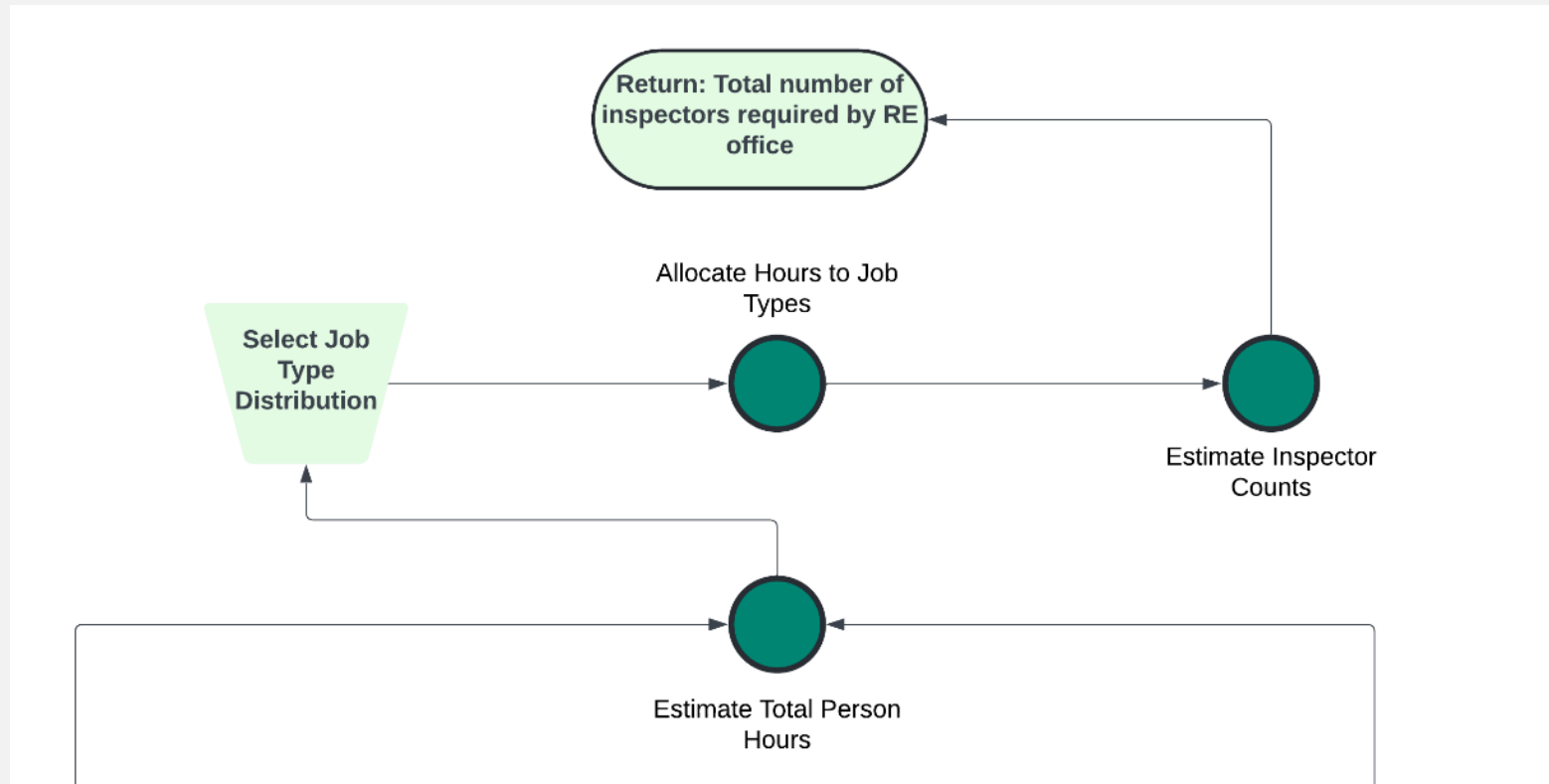
Tool initialization and database connections

# Software Architecture



Selecting appropriate model for estimate

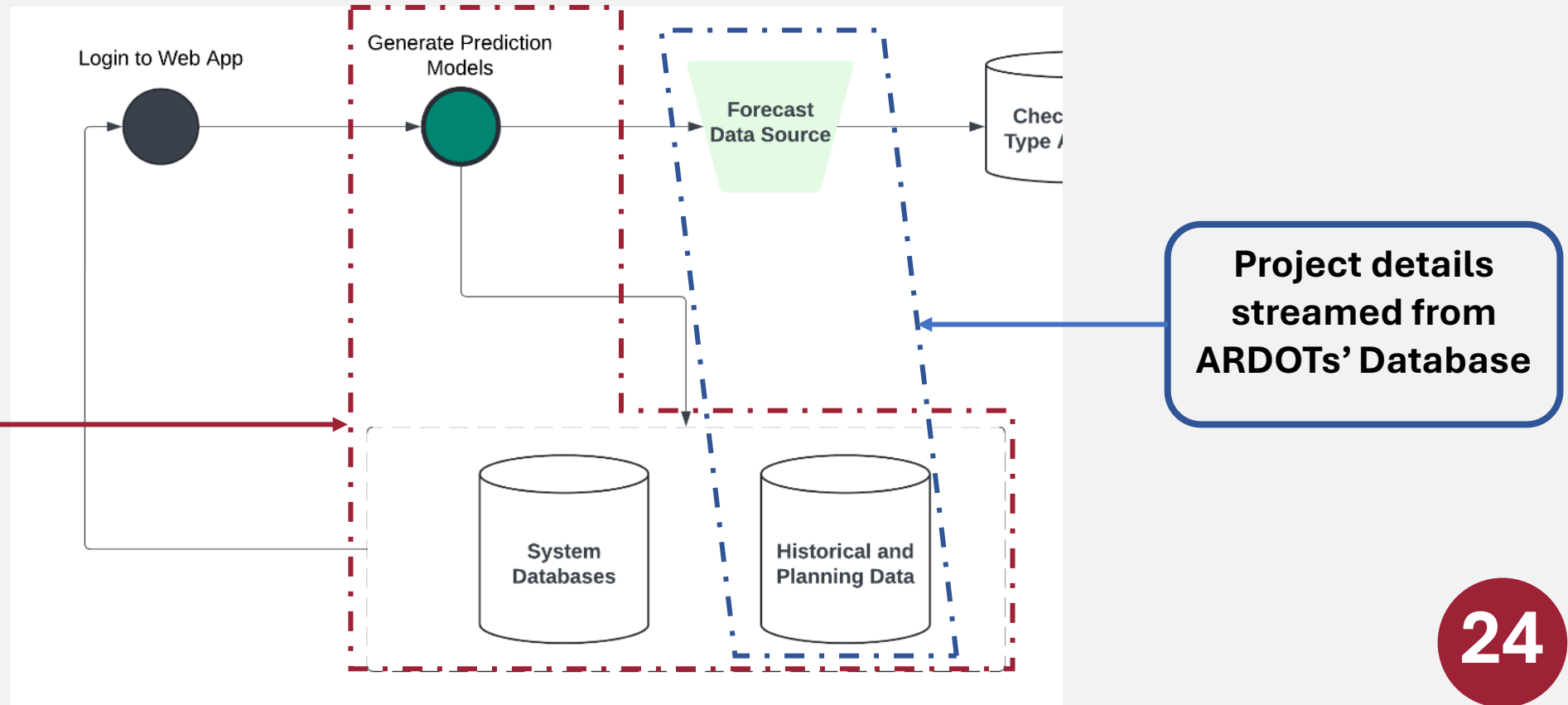
# Software Architecture



Distribution models for job type and final workforce estimate by RE Office

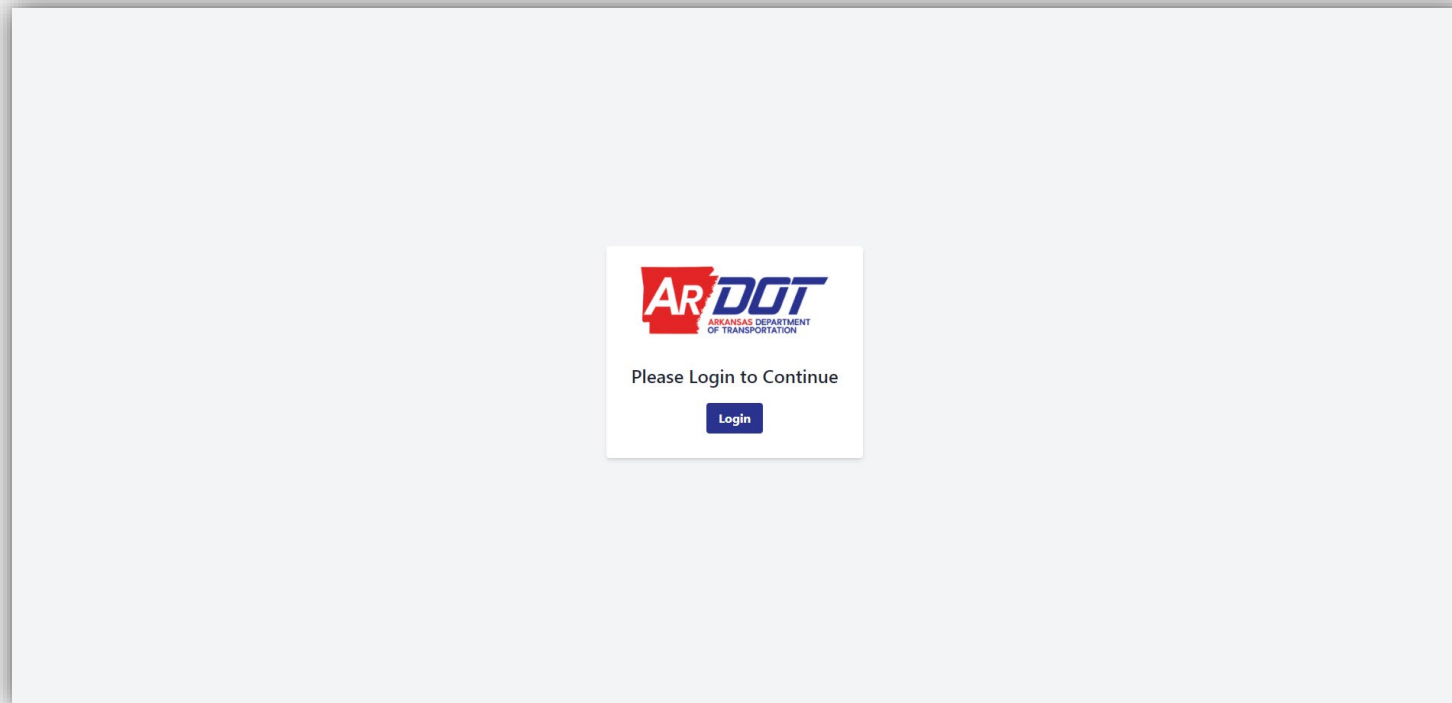
# Automation

- ★ Seamless integration into ARDOT's existing databases
- ★ Automatic update of model coefficients using most recent data



# User Interface


- ★ Visualization of the user interface
- ★ Microsoft user authentication



Login interface

# User Interface





ARDOT Workforce Forecasting

Logout

Current Projects

Results 5

Select Resident Engineer Office: 11

Job Distribution
Current Staff
Existing Crew

Historical Mean
8
6

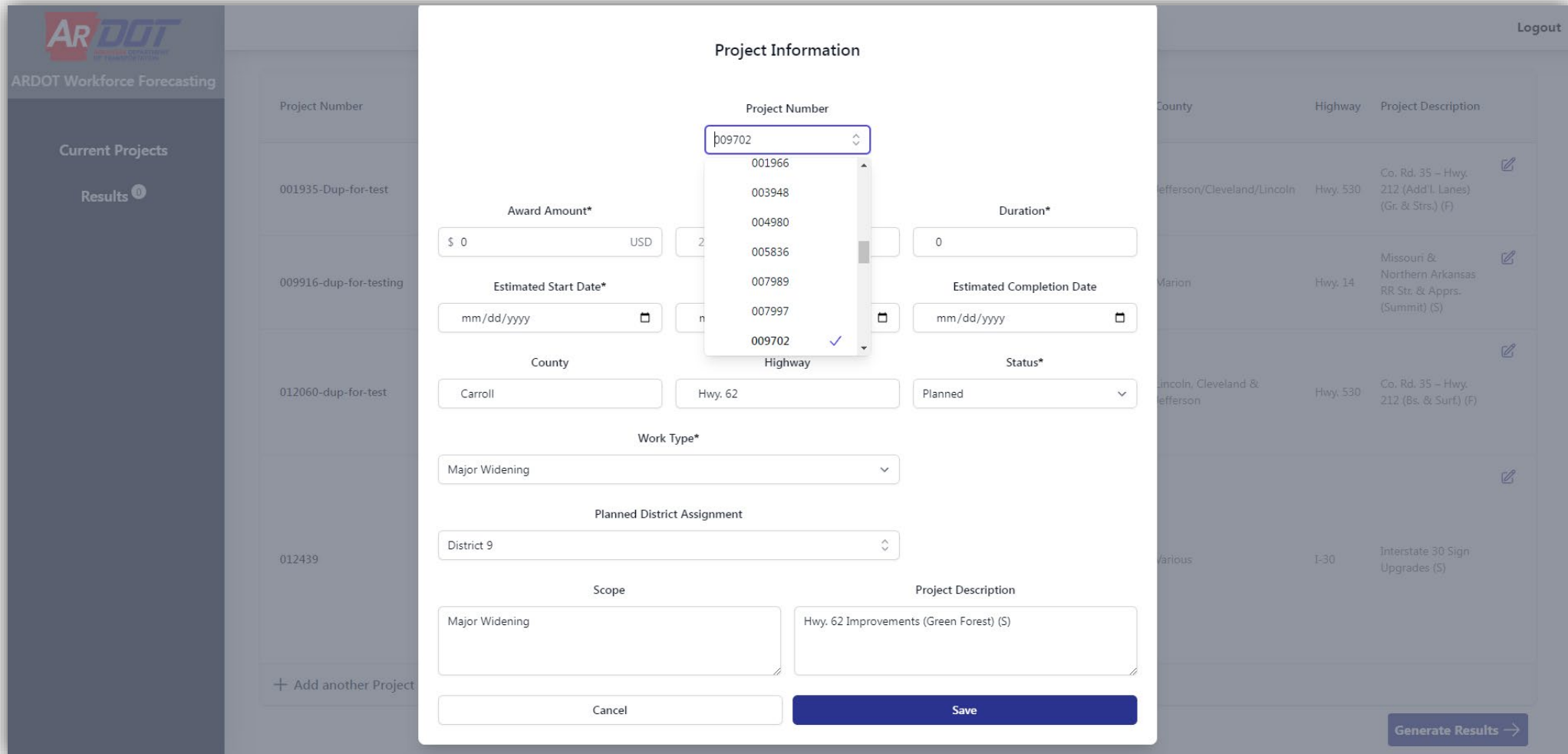
Projects

A list of all current & planned projects with the Predicted RE Office set to: **11**.

Project Number	Award Amount	Work Type	Let Year	Duration	Start Date	Planned Letting Date	District Assignm	Scope	Status	County	Highway	Project Description
001935-Dup-for-test	\$100,000	Structure And Approaches	2024	12	2023-07-01		1	Line ded; remaining 2 lanes	Active	Jefferson/Cleveland/Lincoln	Hwy. 530	Co. Rd. 35 – Hwy. 212 (Add'l. Lanes) (Gr. & Strs.) (F)
004980	\$10,800,000	Structure And Approaches	2023	13	2024-05-24		4	Replace 3 structures.	Planned	Logan	Hwy. 22	Caulksville – Paris Strs. & Apprs. (S)
009916-dup-for-testing	\$3,100,000	Structure And Approaches	2024	12	2023-07-01	2024-06-01		Replace 1 bridge.	Active	Marion	Hwy. 14	Missouri & Northern Arkansas RR Str. & Apprs. (Summit) (S)
012060-dup-for-test	\$39,300,000	Base And Surfacing	2023	24	2023-07-31	2011-06-01	2, 7	New Location (2 lanes of future 4 lanes divided)	Active	Lincoln, Cleveland & Jefferson	Hwy. 530	Co. Rd. 35 – Hwy. 212 (Bs. & Surf) (F)

Project Listings for RE offices

# User Interface



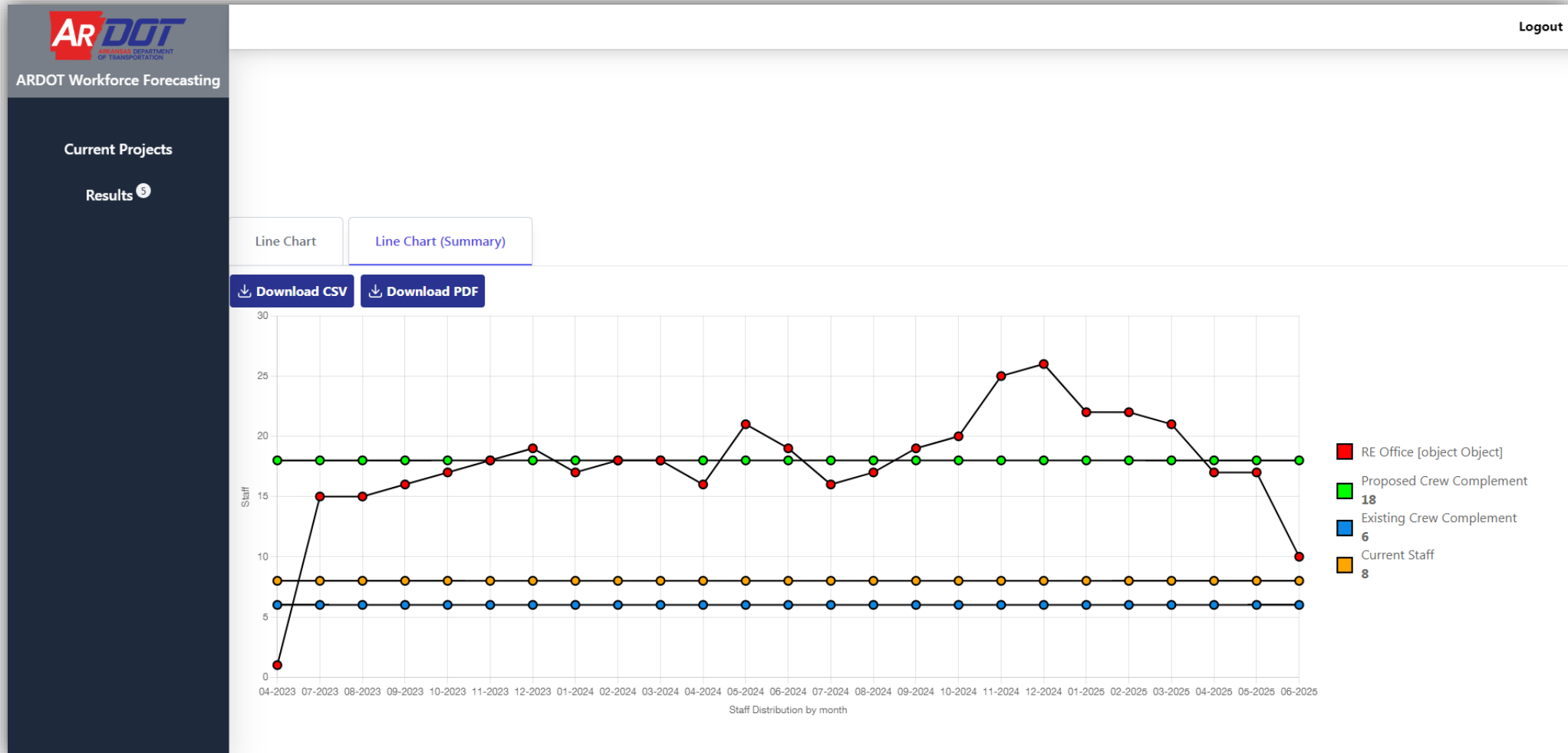
The screenshot displays the ARDOT Workforce Forecasting application. A modal window titled "Project Information" is open, allowing for the creation of a new project. The form includes the following fields:

- Project Number:** A dropdown menu with "009702" selected. The dropdown list shows other project numbers: 001966, 003948, 004980, 005836, 007989, 007997, and 009702 (checked).
- Award Amount\*:** Input field with "\$ 0" and "USD" currency.
- Duration\*:** Input field with "0".
- Estimated Start Date\*:** Input field with "mm/dd/yyyy" format.
- Estimated Completion Date:** Input field with "mm/dd/yyyy" format.
- County:** Input field with "Carroll".
- Highway:** Input field with "Hwy. 62".
- Status\*:** Dropdown menu with "Planned" selected.
- Work Type\*:** Dropdown menu with "Major Widening" selected.
- Planned District Assignment:** Dropdown menu with "District 9" selected.
- Scope:** Input field with "Major Widening".
- Project Description:** Input field with "Hwy. 62 Improvements (Green Forest) (S)".

Buttons for "Cancel" and "Save" are located at the bottom of the modal. The background interface shows a table of existing projects with columns for County, Highway, and Project Description.

Adding new project for RE office from database

# User Interface



Visualizing results for RE office

# Acknowledgements



- ★ CAST partners: Clayton Sexton, Hailey Hames, and Erin Mullin
- ★ ARDOT subcommittee
- ★ ARDOT project manager: Mr. Mark Simecek



Thank You

Q & A



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