TRC2101: Update of the ARDOT Workforce Forecasting System

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Content Outline

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

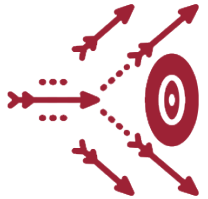
Objectives

Develop an annual forecasting model

Integrate forecasting model in an automated forecasting software tool

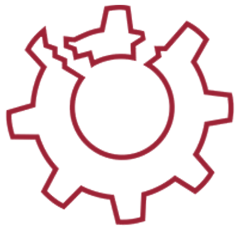
Existing Forecasting System

Outdated system first introduced in 1970s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Formulas need constant update and are out of date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

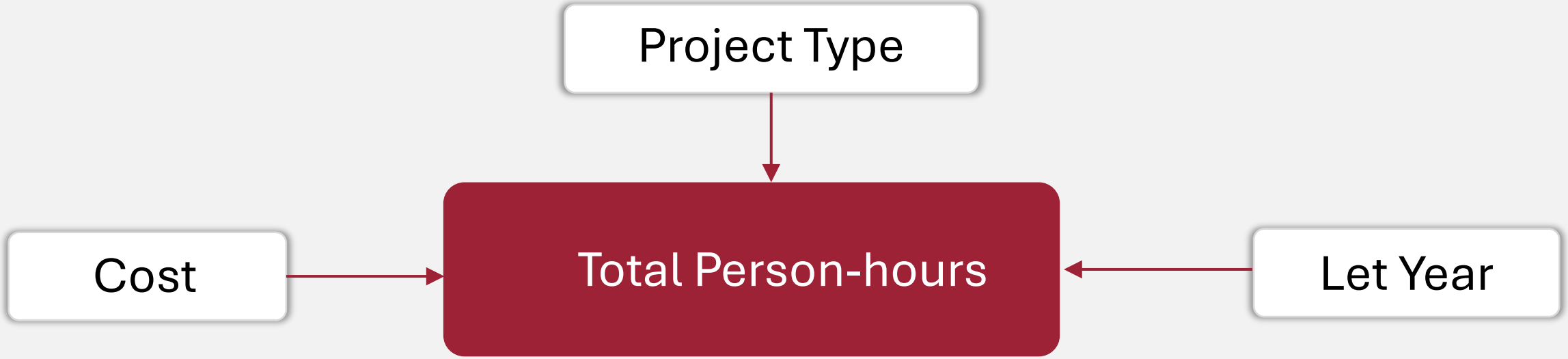
- Machine learning Models
- Simple and multiple linear regression models
- Econometrics timeseries and neural network based such as recurrent neural networks
- System Dynamic approach using stock and flow modeling

Data

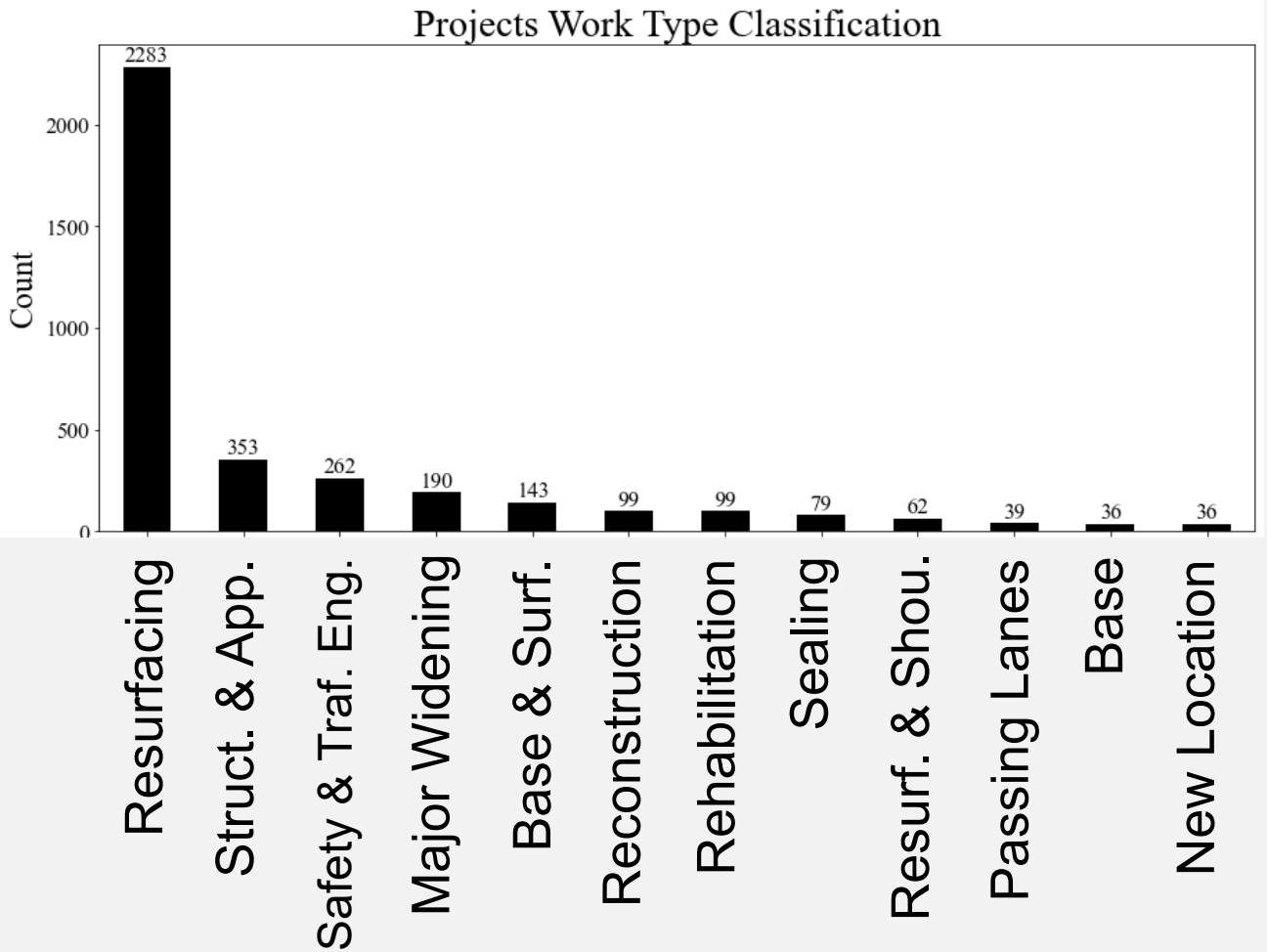
- Data received was for the period of **2012 – 2021**
- Over a million record for employee hours and more than **3000** project information
- Employee data includes key details such as hours, project ids, job title descriptions
- Project data includes important variables: project type, ids, cost, status,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

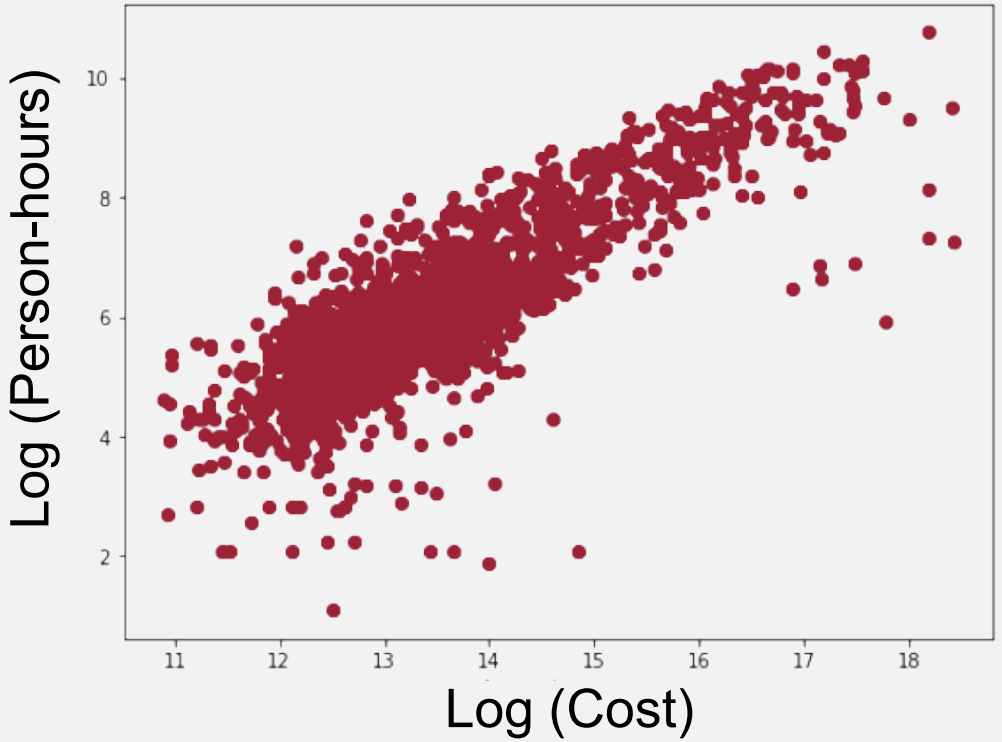
Data

Predictor Data for Workforce Estimation



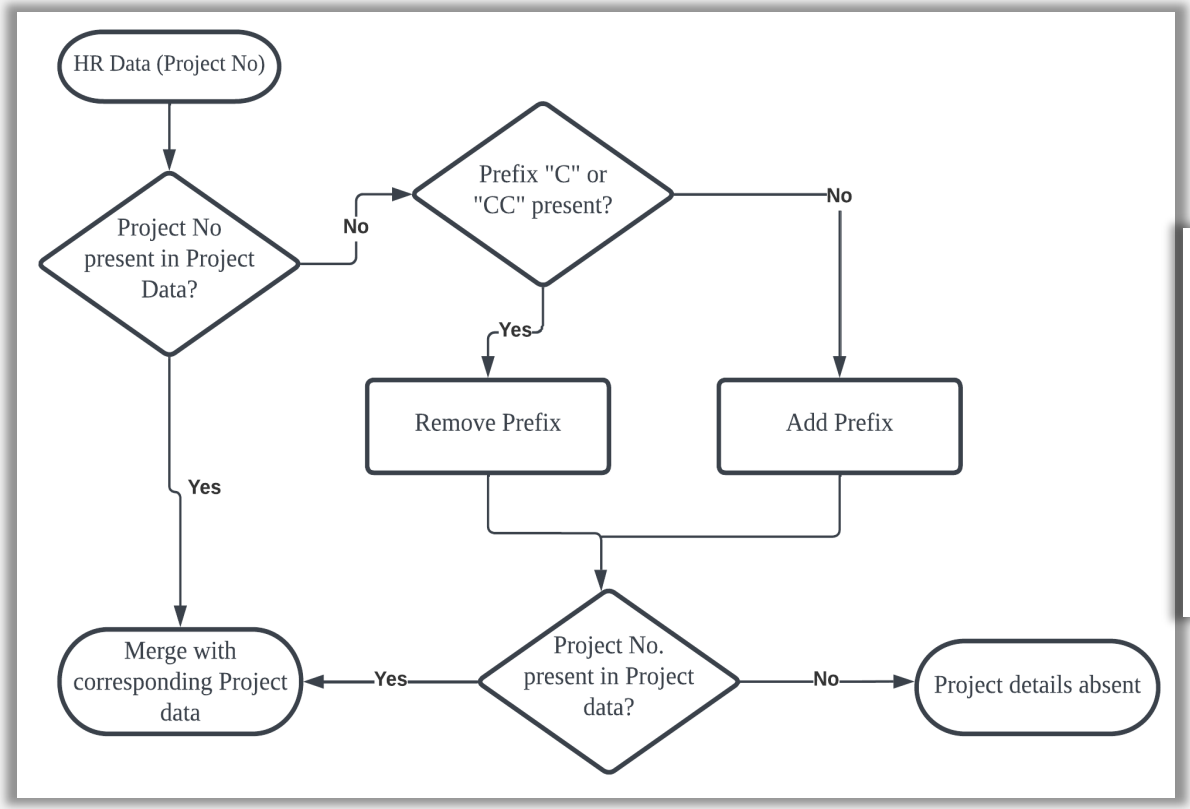
Data


Projects Work Type Classification
Count
0
500
1000
1500
2000
2283
353
262
190
143
99
99
79
62
39
36
36
Resurfacing
Struct. & App.
Safety & Traf. Eng.
Major Widening
Base & Surf.
Reconstruction
Rehabilitation
Sealing
Resurf. & Shou.
Passing Lanes
Base
New Location

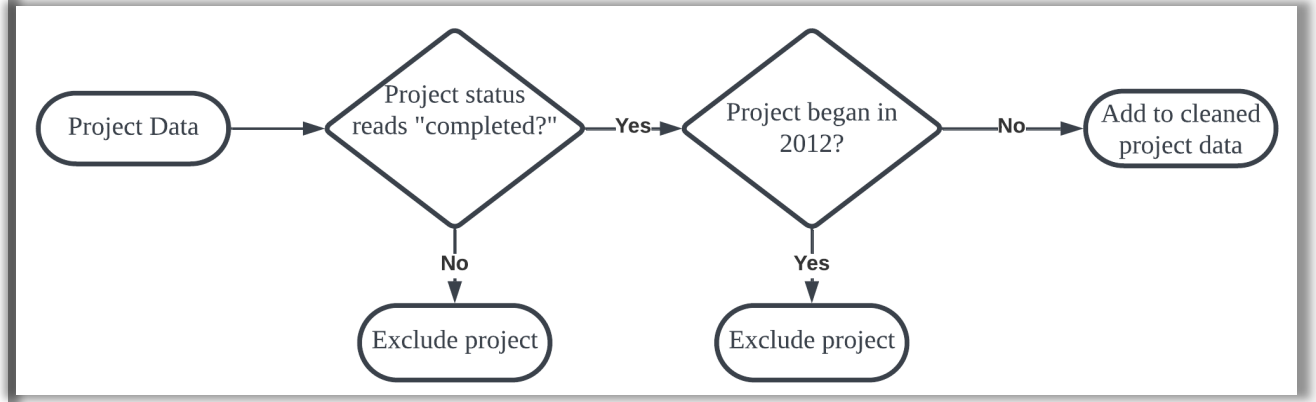

Log (Person-hours)
2
4
6
8
10
11
12
13
14
15
16
17
18
Log (Cost)

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

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

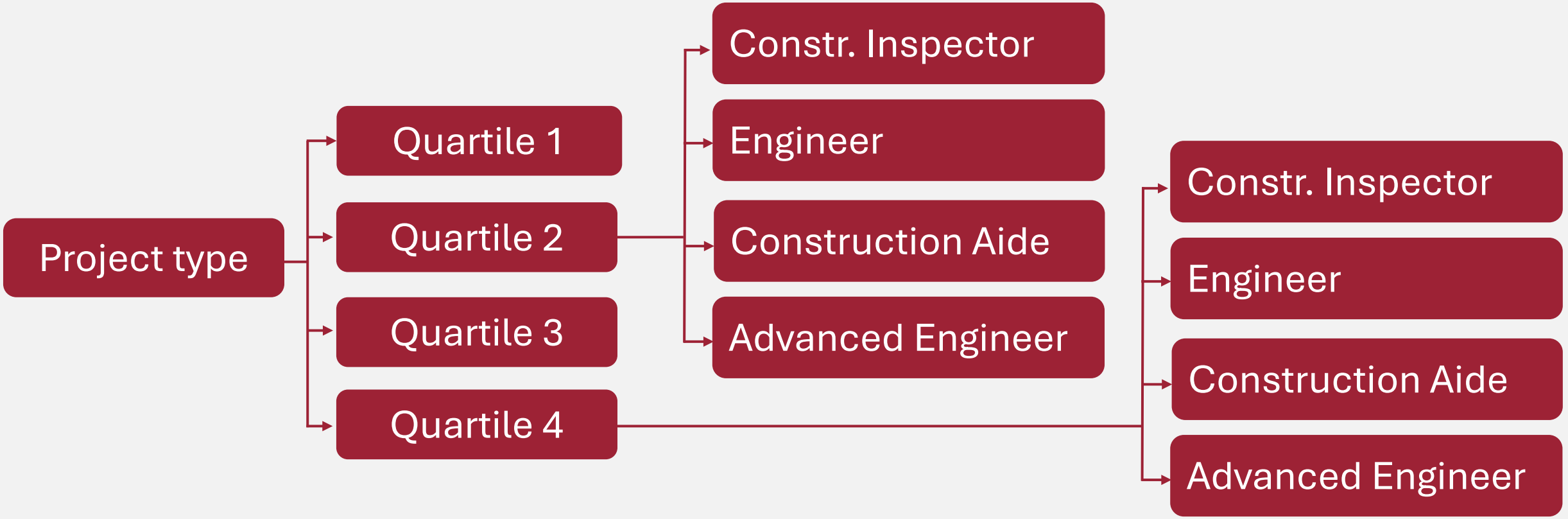
Project type/grouping	β_0	β_1	β_2	R^2
All dataset	-6.956	0.974	0.029	**0.808**
Resurfacing	-5.933	0.875	0.052	**0.735**
Structure & Approaches	-3.397	0.767	0.054	**0.788**
Safety & Traffic Eng.	-2.647	0.668	0.081	**0.722**
Major Widening	-0.398	0.590	0.024	**0.526**
Reconstruction	-1.811	0.675	-0.070	**0.828**
Group 1	-6.213	0.941	0.030	**0.918**
Group 2	-5.560	0.867	0.104	**0.740**
Group 3	-5.955	0.935	0.020	**0.820**

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 μ number of stages as below:

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

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

$W_{S0} = 0$

μ = Number of stages
X = Xth stage of μ
W_t = number of hours in t^{th} month
n = number of months (for current project)

A.P.C. Chan et al. (2005)

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

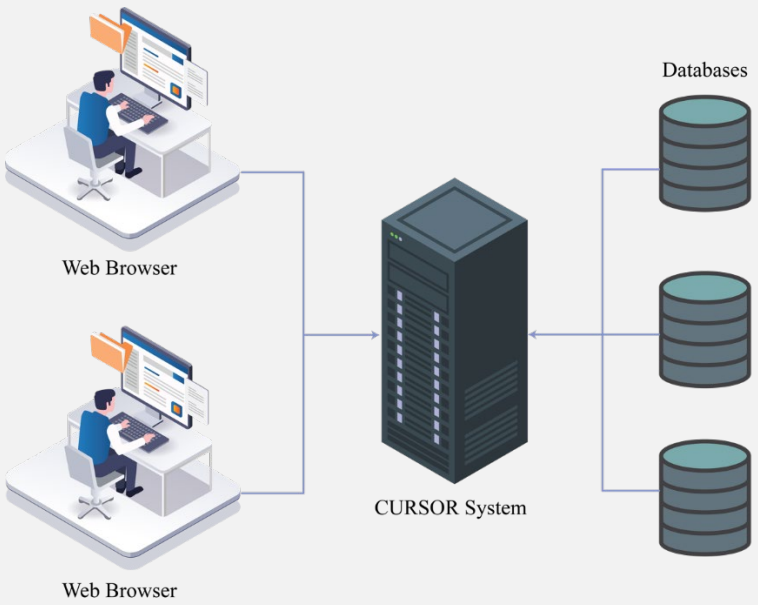
Forecasting tool was built into a webapp

The webapp could be accessed from any modern web browser

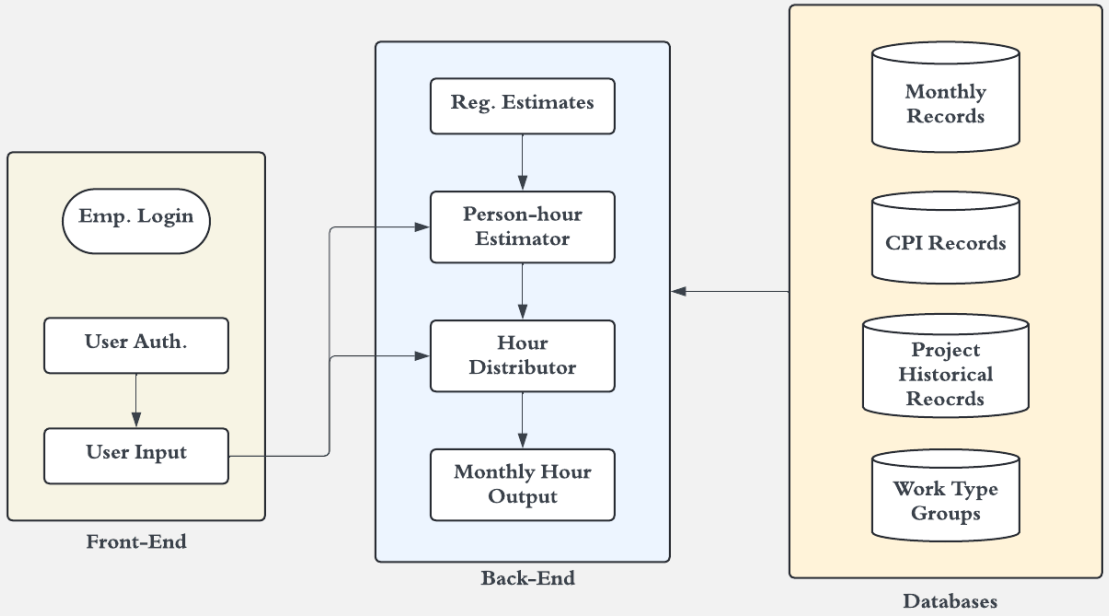
security authentication requirement for end users

Automated Integration with planning database

Software Architecture

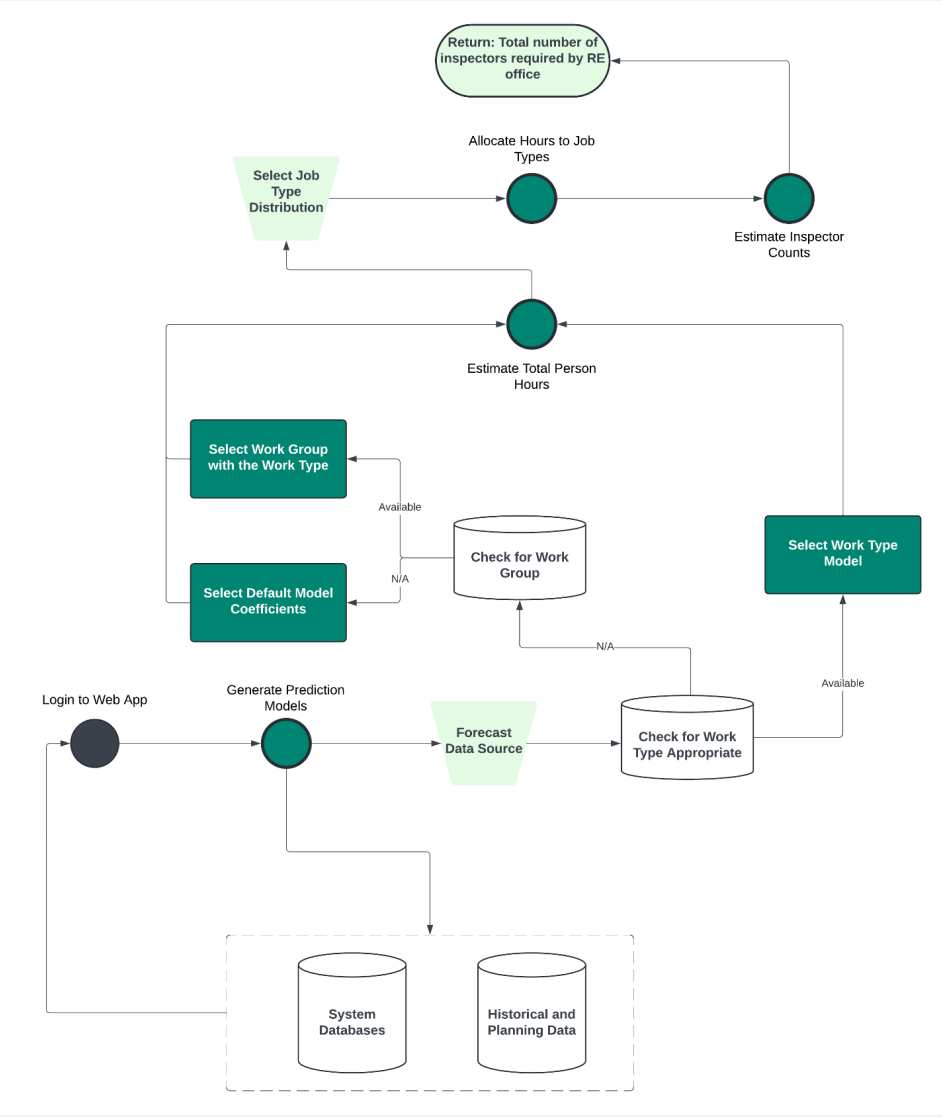


Context diagram

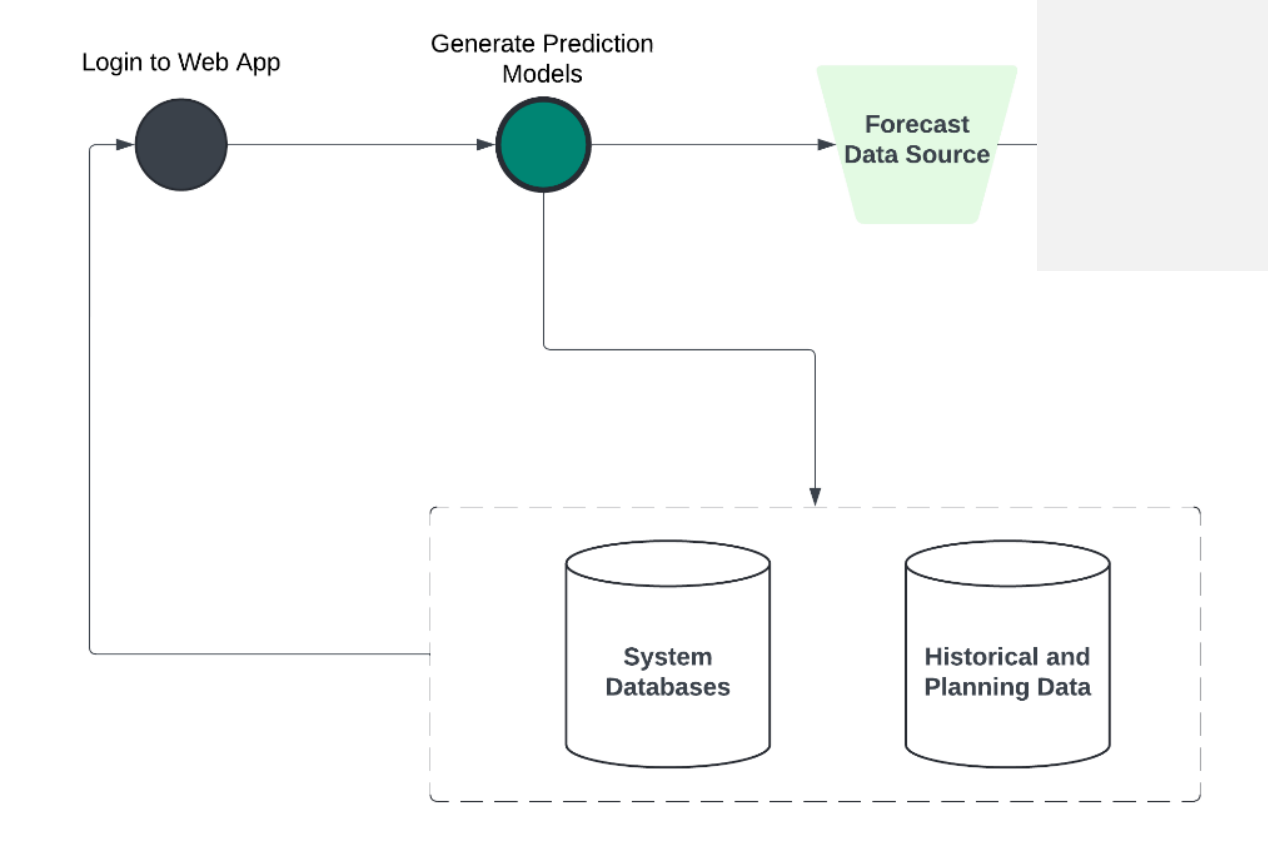


Data flow within system

Software Architecture

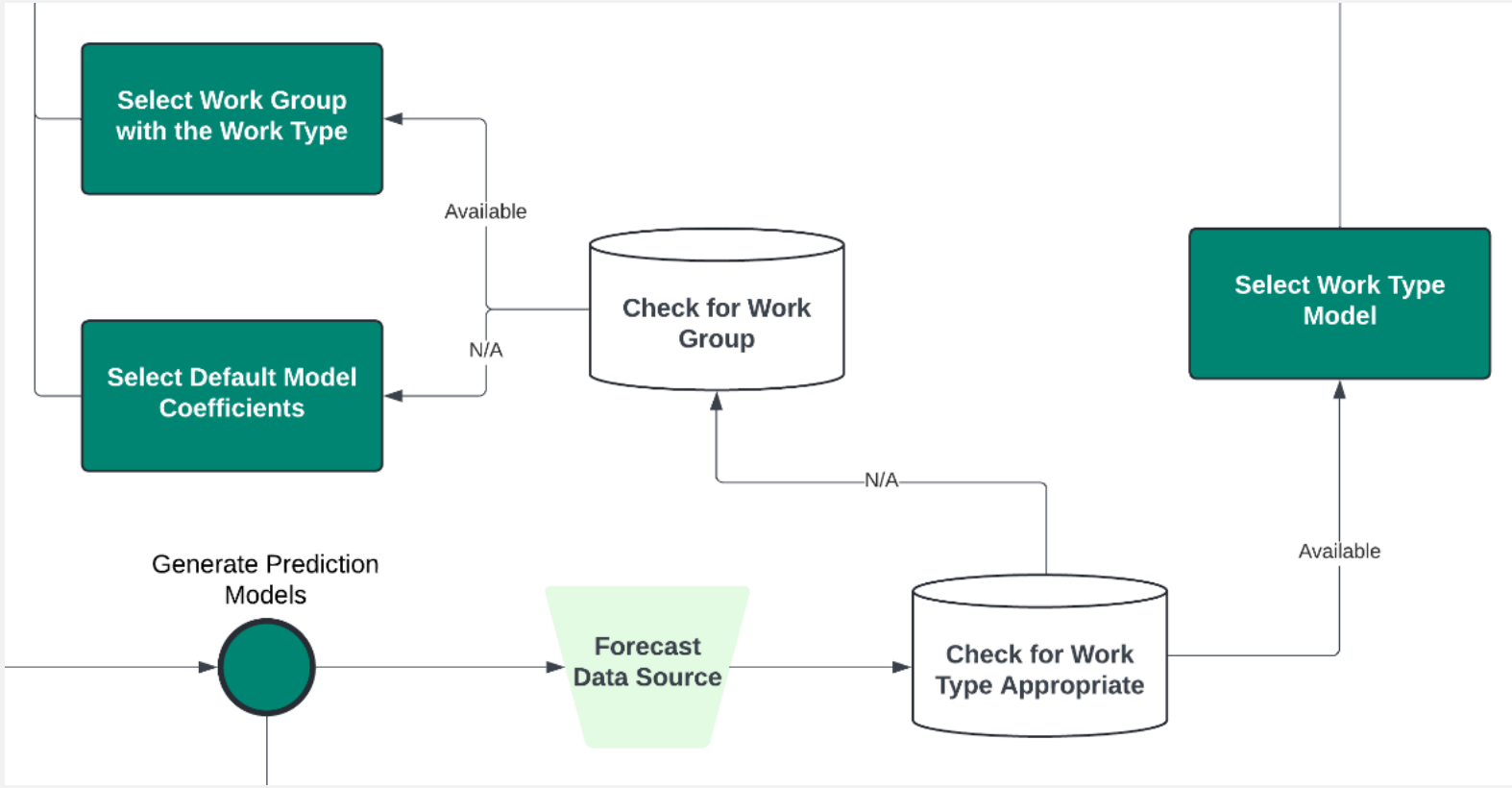


Software Architecture



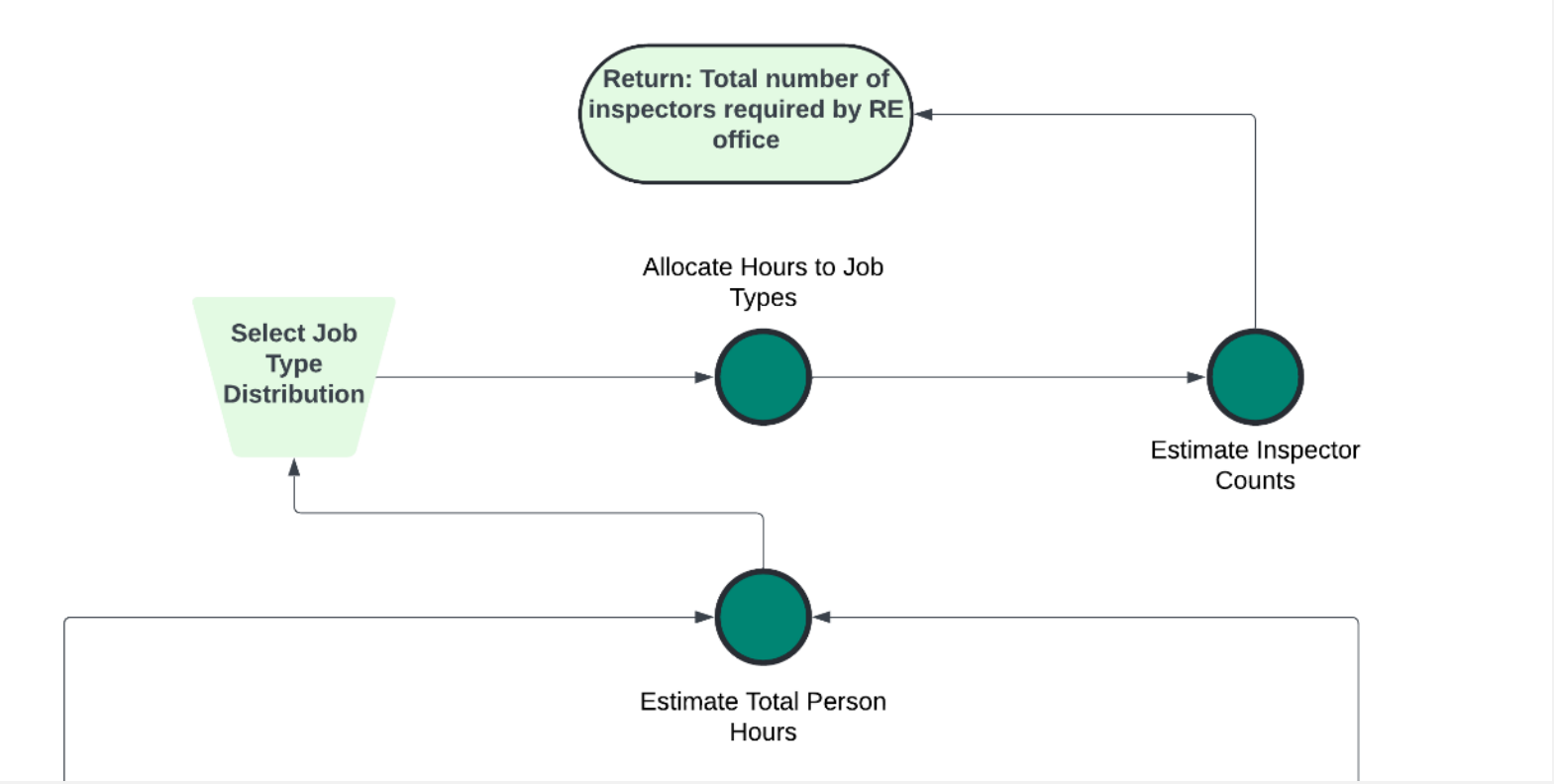
Tool initialization and database connections

Software Architecture



Selecting appropriate model for estimate

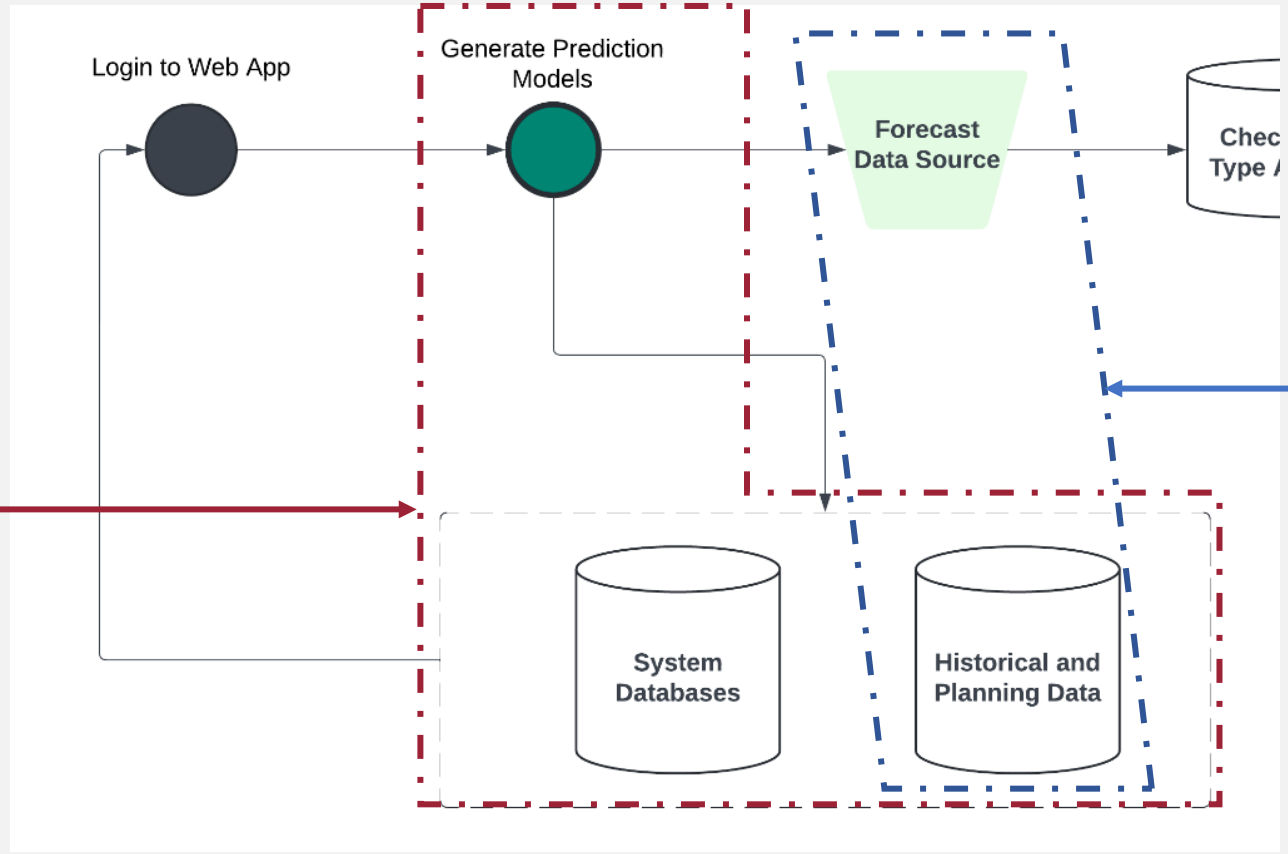
Software Architecture



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

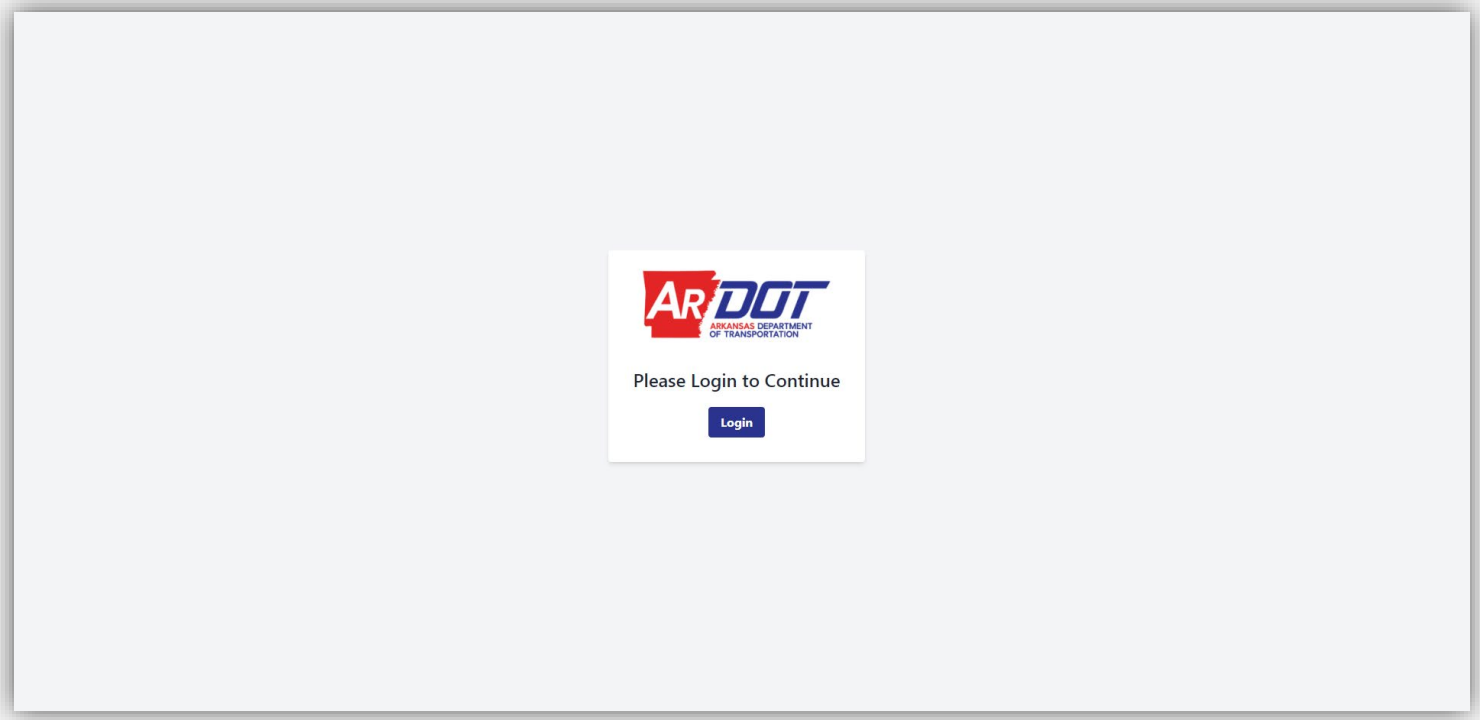


Automated Model Coeff. Updates

Project details streamed from ARDOTs' Database

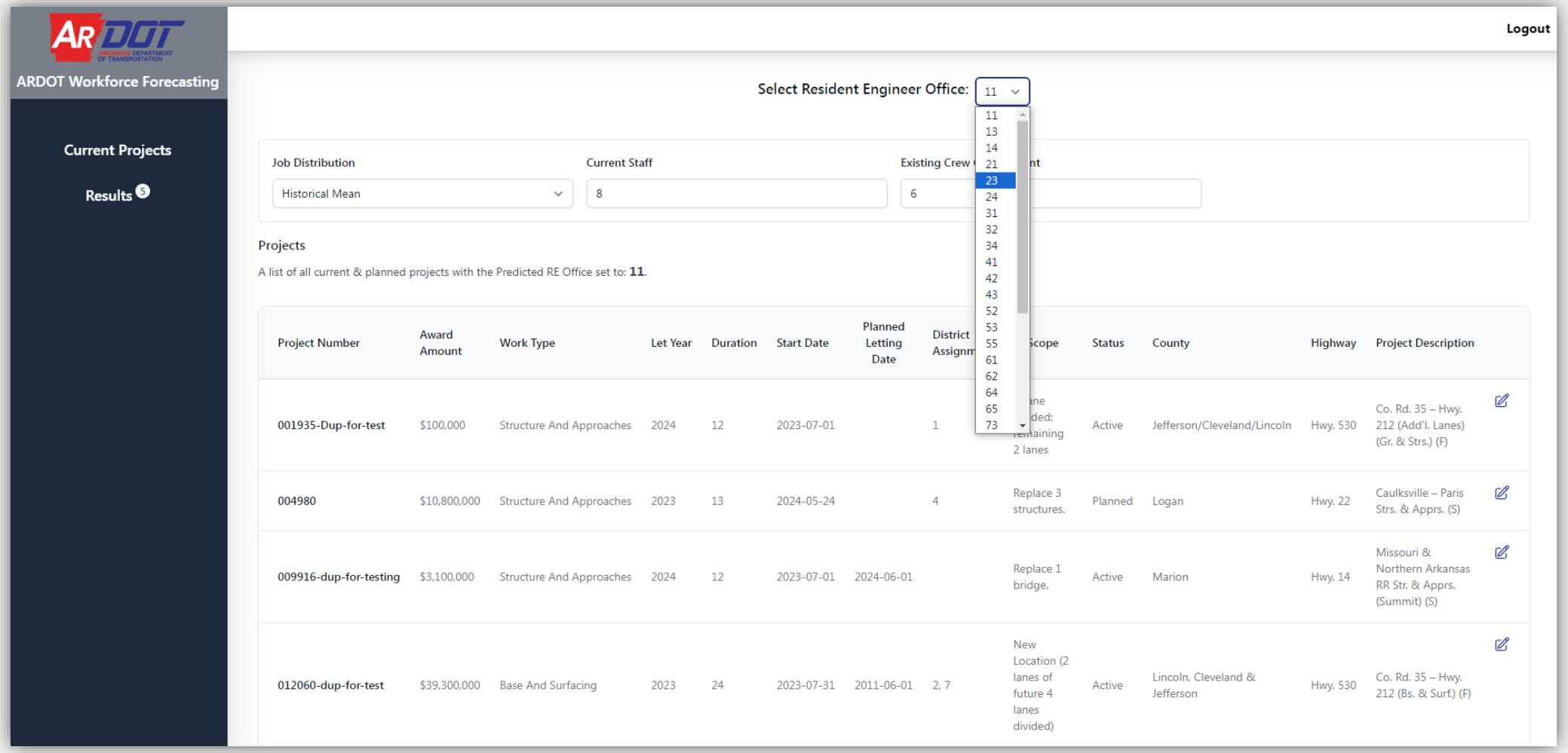
User Interface

- Visualization of the user interface
- Microsoft user authentication



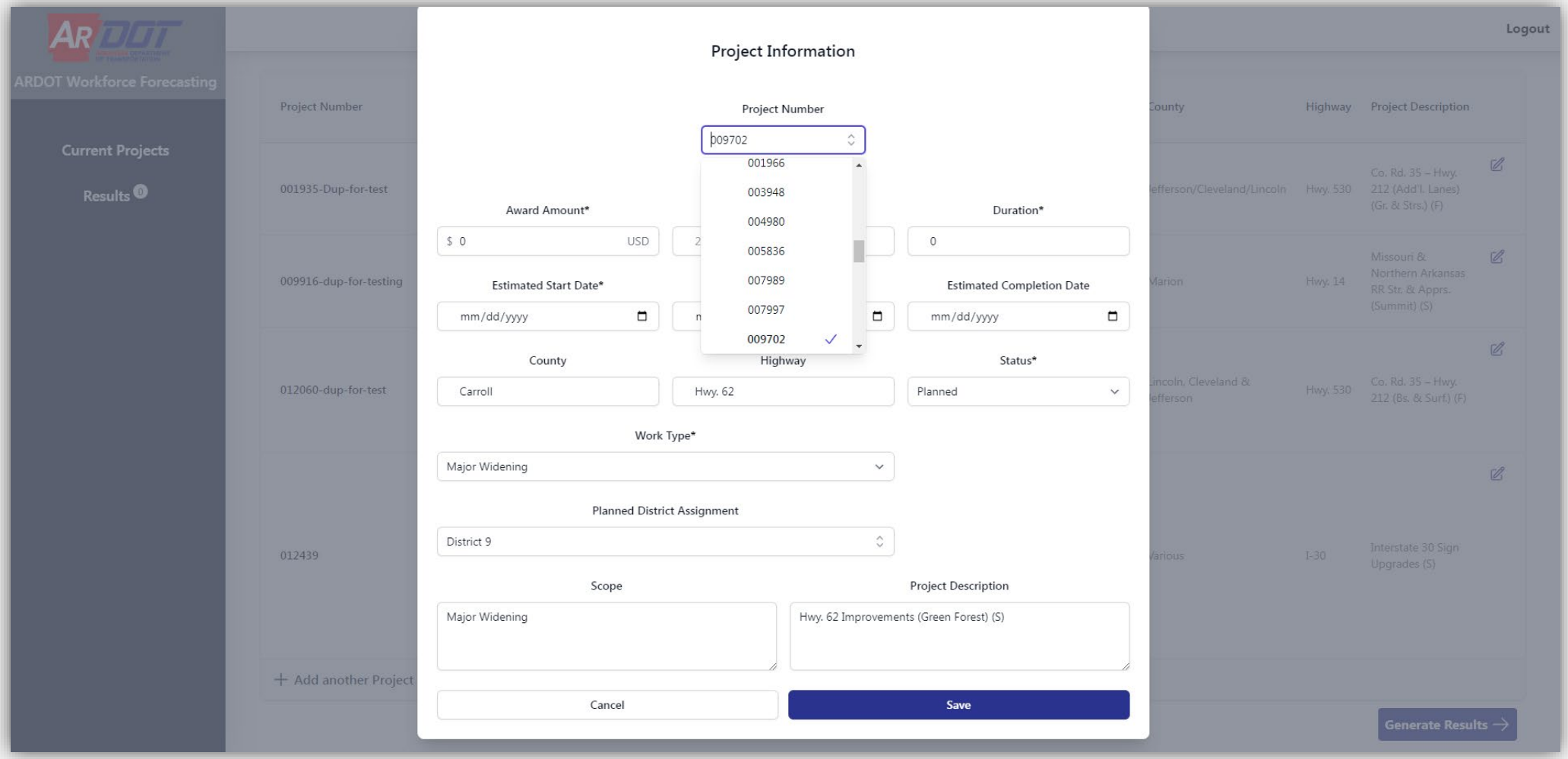
Login interface

User Interface



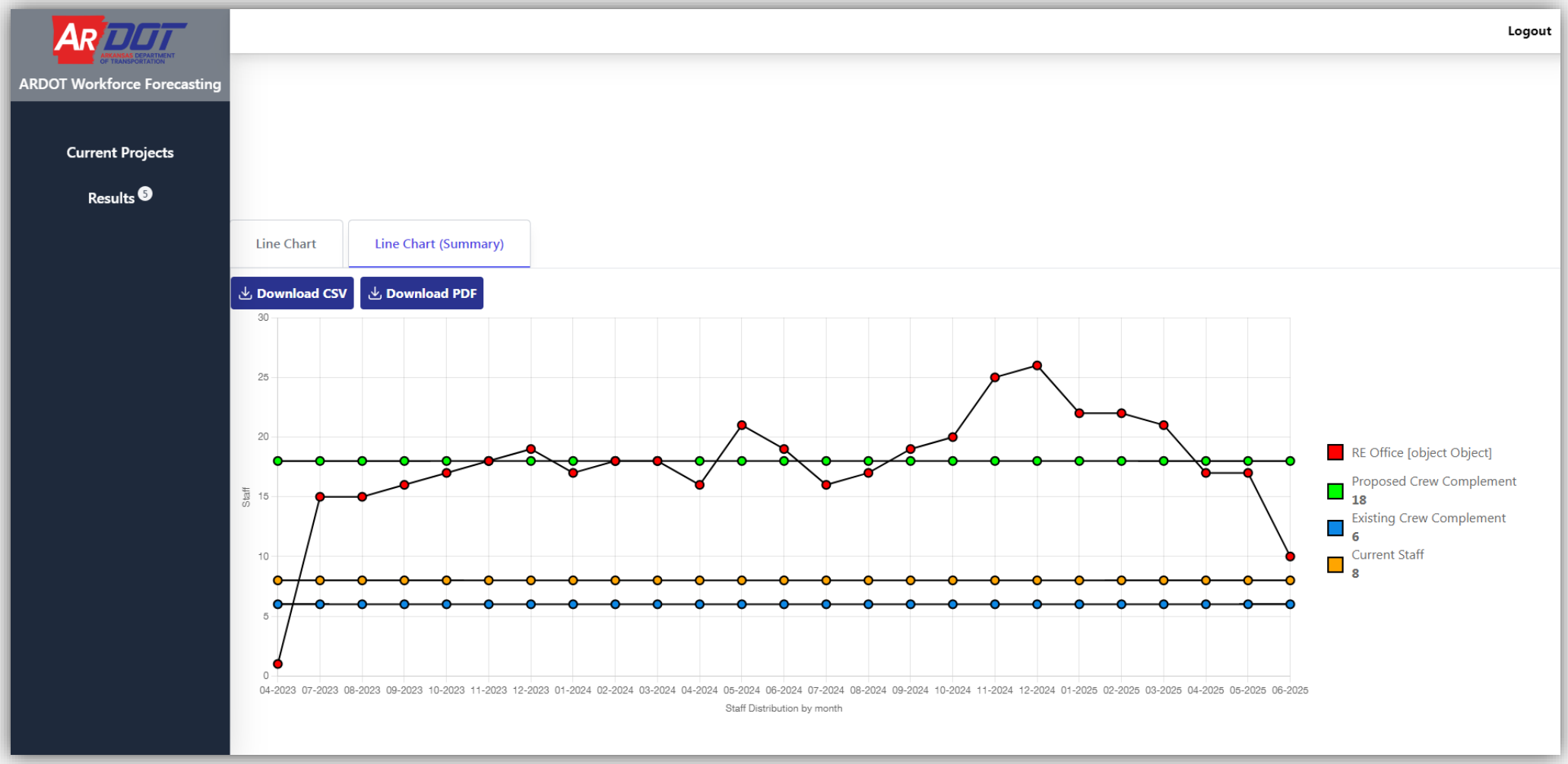
Project Listings for RE offices

User Interface



Adding new project for RE office from database

User Interface



Visualizing results for RE office

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- ArDOT project manager: Mr. Mark Simecek

Thank You

Q & A

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