Iowa Pavement Analysis Techniques (IPAT) Tool

User Guide
June 2021

IOWA STATE UNIVERSITY
Institute for Transportation

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16. Abstract

Recent federal legislation requires state highway agencies (SHAs) and local road agencies to utilize performance-based approaches in their pavement management decision-making processes. The use of a remaining service life (RSL) model would be one such performance-based approach that could facilitate the pavement management decision-making process.

This study developed a Microsoft Excel macro and Visual Basic for Applications (VBA)-based Iowa Pavement Analysis Techniques (IPAT) automation tool that Iowa county engineers can use to estimate the project- and network-level pavement performance and RSL. To address this aim, statistics and artificial neural network (ANN)-based pavement performance and RSL models were developed using pavement structural features, traffic, construction history, and pavement performance records obtained from the Iowa Department of Transportation (DOT) Pavement Management Information System (PMIS) and the Iowa county agencies' database. The accuracy of the models was evaluated using the real database representing Iowa county pavement systems.

The IPAT tool provides a series of options for four pavement types representing Iowa county pavement systems—jointed plain concrete pavement (JPCP), asphalt concrete (AC) pavement, AC over JPCP, and portland cement concrete (PCC) overlay—to estimate RSL through different approaches based on various conditions and distress data availability from an individual county.

The IPAT tool is expected to be used as part of performance-based pavement management strategies and to significantly help decision-makers facilitating maintenance and rehabilitation decisions for better prioritization and allocation of resources.

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IOWA PAVEMENT ANALYSIS TECHNIQUES (IPAT) TOOL

User Guide
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USING THE IPAT TOOL

The Iowa Pavement Analysis Techniques (IPAT) tool is a Microsoft Excel, macro, and Visual Basic for Applications (VBA)-based automation tool that is comprised of a navigation panel (main tool) and sub-tools. Depending on the version of the operating system, various security warning messages may appear, or the tool may appear in a different font when the tool is first run. The system requirements to run this tool are Excel 2016 and VBA.

Document Scope

This user guide describes a systematic procedure on how to use the IPAT tool that helps local agencies and engineers in their decision-making process by estimating various pavement performance and pavement remaining service life (RSL) under different pavement management levels of service.

Interface of Main Tool

Select Predictive Model Types

The main tool provides users with selections for predictive model types, pavement type, and pavement performance indicators. The main page of the main tool gives users two options to select predictive model types, statistics-based model and artificial intelligence (AI)-based models, as shown in Figure 1.

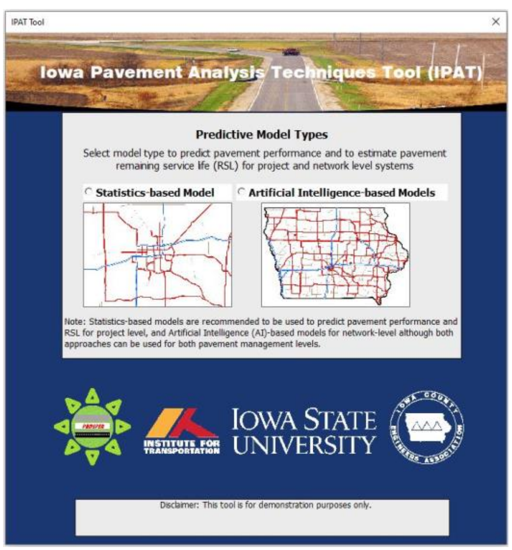


Figure 1. Predictive model type selection (main) page of IPAT main tool

Note that the authors recommend the statistics-based model to predict pavement performance and RSL at the project level and AI-based models at the network level, although both approaches can be used for both pavement management levels.

Select Pavement Type

Figure 2 shows the interface of the selection page for pavement type for both statistics- and AI-based approaches.

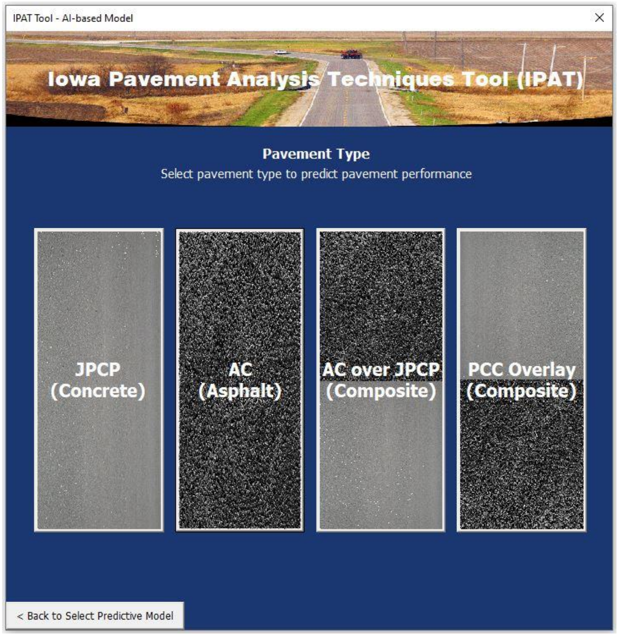
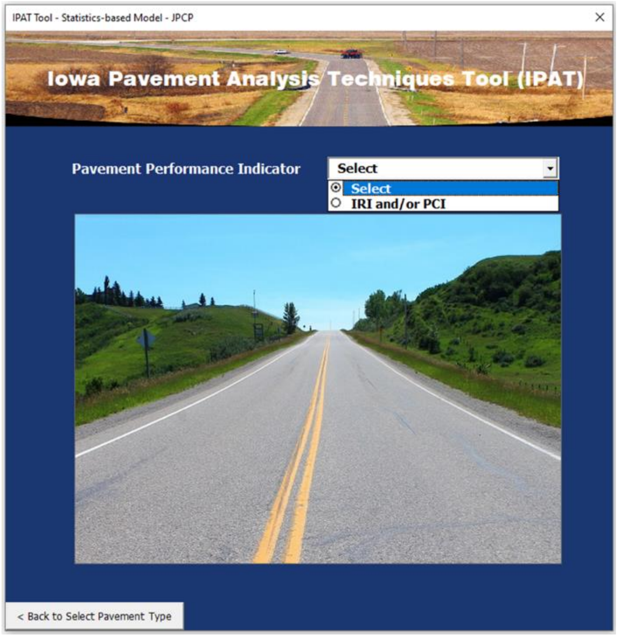


Figure 2. Pavement type selection page of IPAT main tool

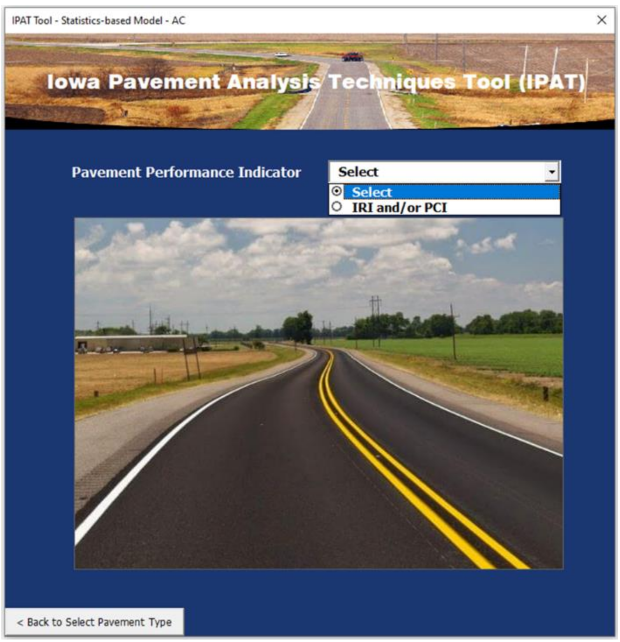
The pavement types include jointed plain concrete pavement (JPCP), asphalt concrete (AC), AC over JPCP, and portland cement concrete (PCC) overlay.

Select Pavement Performance Indicator

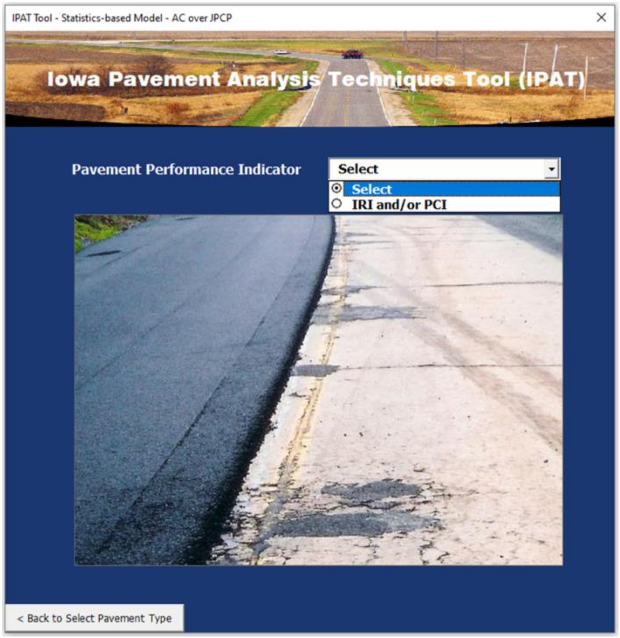
Figure 3 shows sample pages of the statistics-based models for selecting pavement performance indicator for (a) JPCP, (b) AC, (c) AC over JPCP, and (d) PCC overlay.


IPAT Tool - Statistics-based Model - JPCP
Iowa Pavement Analysis Techniques Tool (IPAT)
Pavement Performance Indicator
Select
Select
IRI and/or PCI
< Back to Select Pavement Type

(a) JPCP


IPAT Tool - Statistics-based Model - AC
Iowa Pavement Analysis Techniques Tool (IPAT)
Pavement Performance Indicator
Select
Select
IRI and/or PCI
< Back to Select Pavement Type

(b) AC

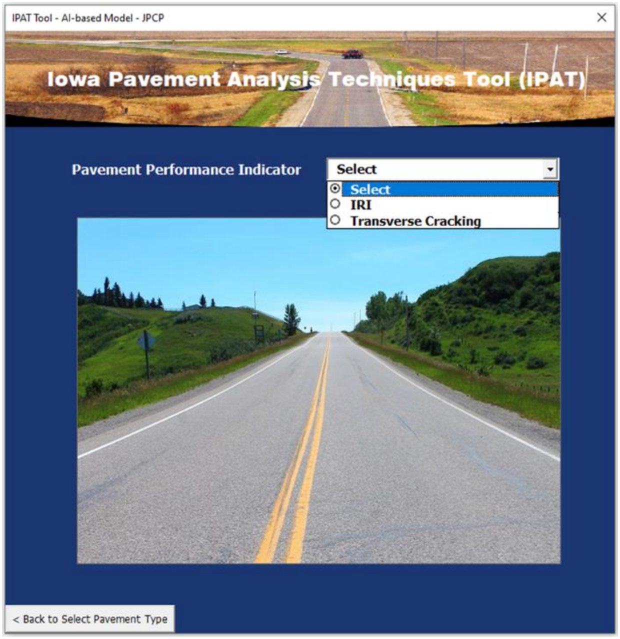


(c) AC over JPCP

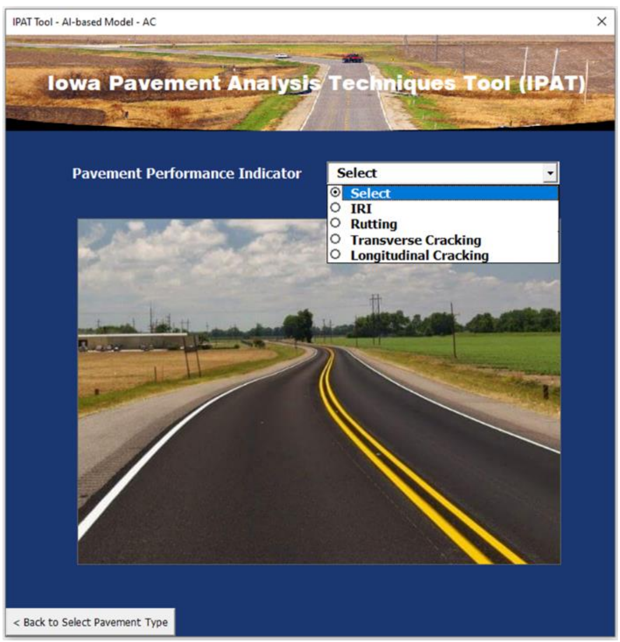
(d) PCC overlay

Figure 3. Pavement performance indicator selection page for statistics-based models for various pavement types

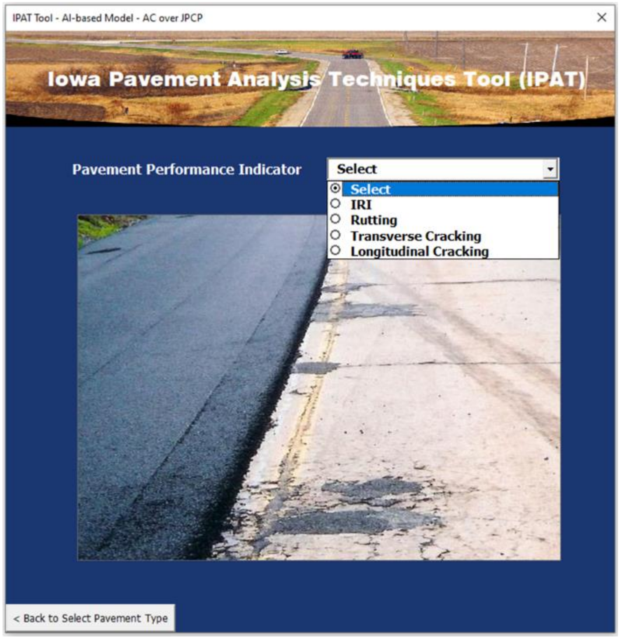
The performance indicators for the statistics-based models are the international roughness index (IRI) and pavement condition index (PCI). Figure 4 shows sample pages of the AI-based models for selecting pavement performance indicator for (a) JPCP, (b) AC, (c) AC over JPCP, and (d) PCC overlay.


IPAT Tool - AI-based Model - JPCP
Iowa Pavement Analysis Techniques Tool (IPAT)
Pavement Performance Indicator
Select
Select
IRI
Transverse Cracking
< Back to Select Pavement Type

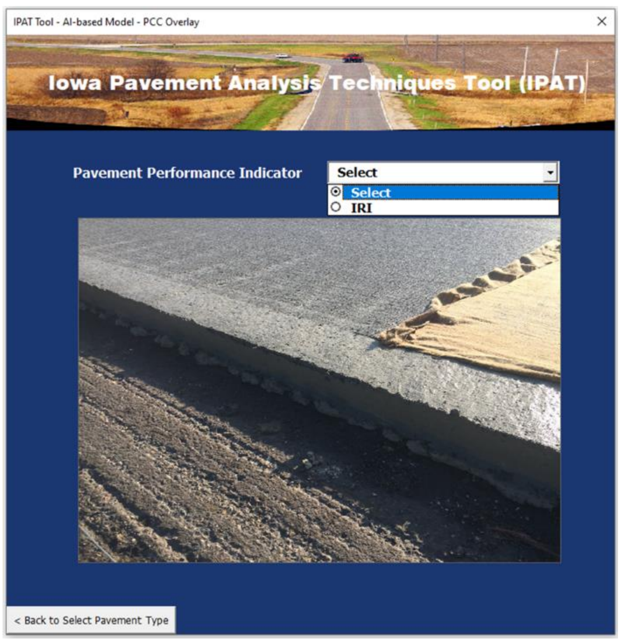
(a) JPCP


IPAT Tool - AI-based Model - AC
Iowa Pavement Analysis Techniques Tool (IPAT)
Pavement Performance Indicator
Select
Select
IRI
Rutting
Transverse Cracking
Longitudinal Cracking
< Back to Select Pavement Type

(b) AC



(c) AC over JPCP



(d) PCC overlay

Figure 4. Pavement performance indicator selection page for AI-based models for various pavement types

The performance indicators for AI-based models vary for each pavement type. For JPCP, they are IRI and transverse cracking; for AC and AC over JPCP, they are IRI, rutting, transverse and longitudinal cracking; for PCC overlay, it is IRI. Selecting any pavement performance indicator at each pavement type navigates the user to different questions to check the availability of the required data to launch the sub-tools.

Figure 5 and Figure 6 show sample interfaces for the checking process of the required data to predict IRI before launching the sub-tool for the AC pavement type using statistics- and AI-based models, respectively.

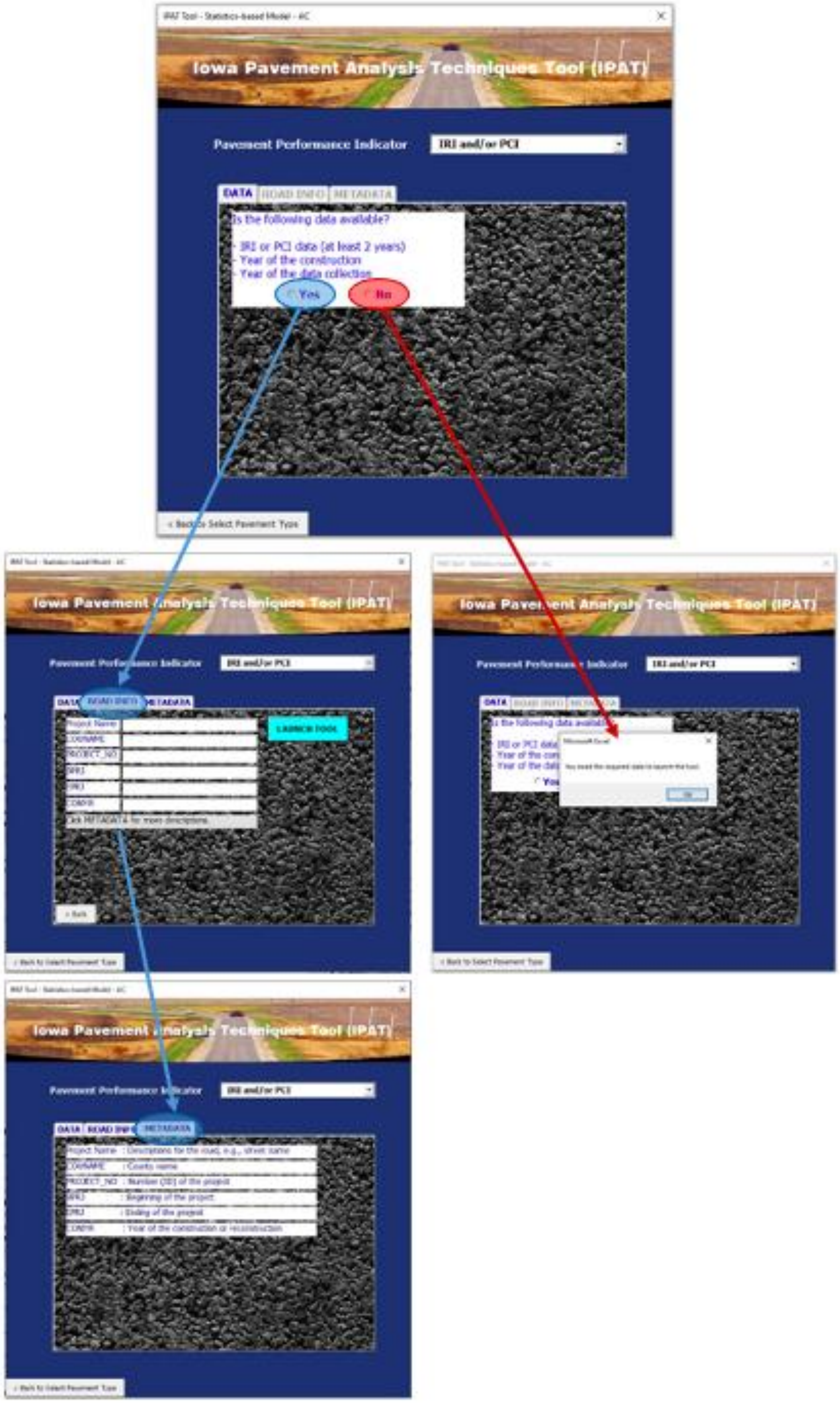


Figure 5. Required data check to launch sub-tool for IRI for statistics-based model for AC pavement type

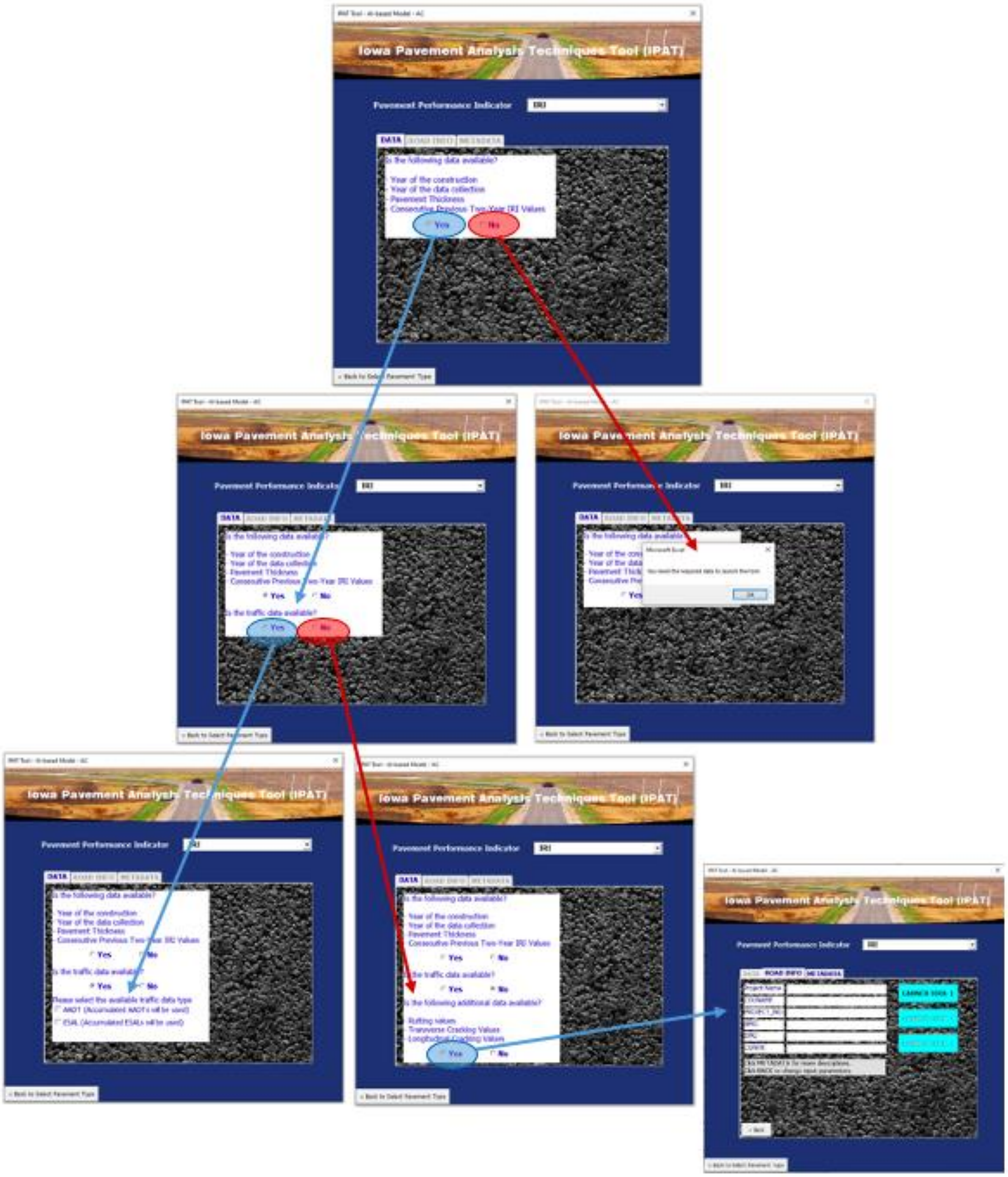


Figure 6. Required data check to launch sub-tool for IRI for AI-based model for AC pavement type

A detailed process for each pavement performance indicator and pavement type is indicated as a flowchart in Figure 7 through Figure 15.

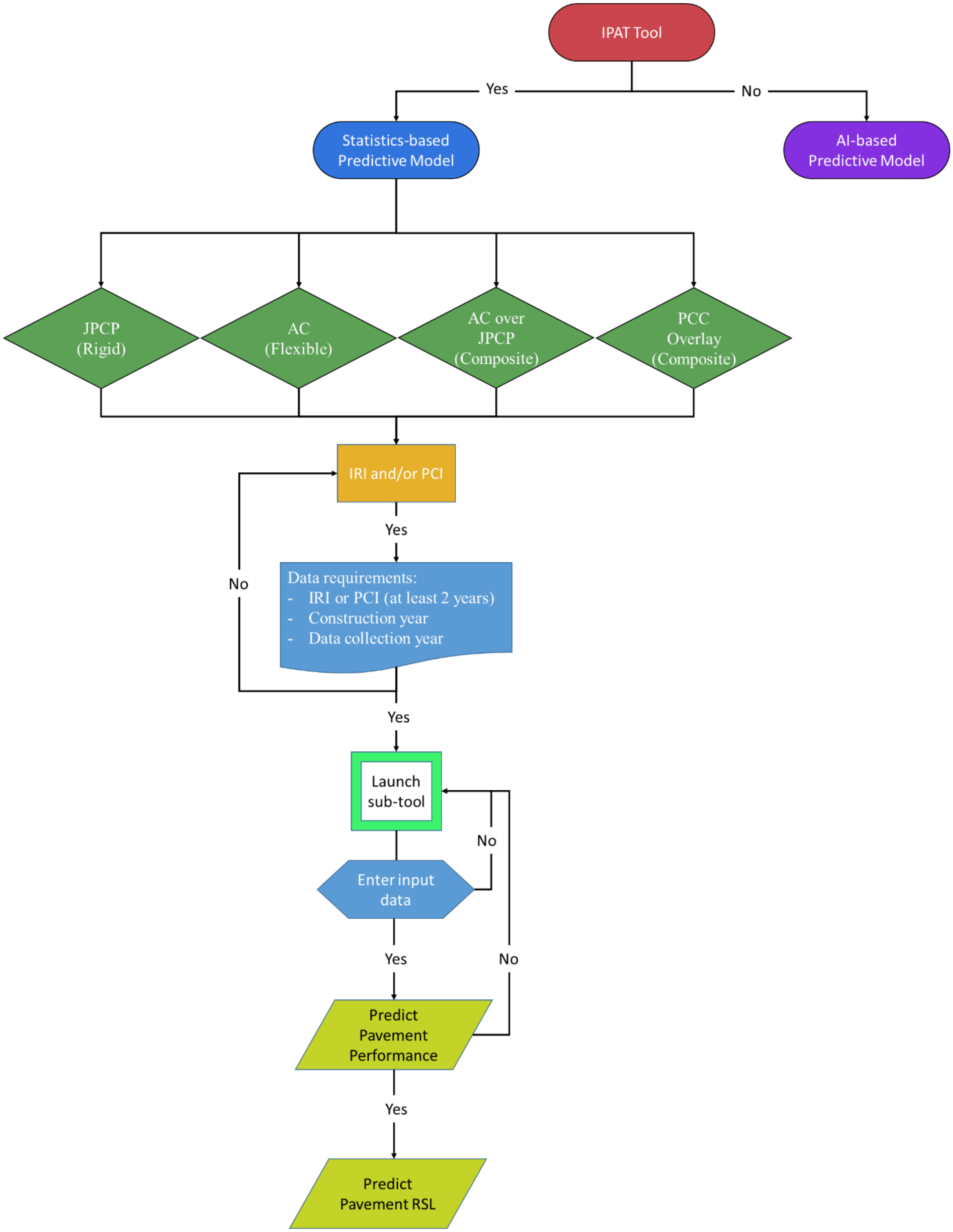


Figure 7. Flowchart of IPAT tool using statistics-based models for all pavement types

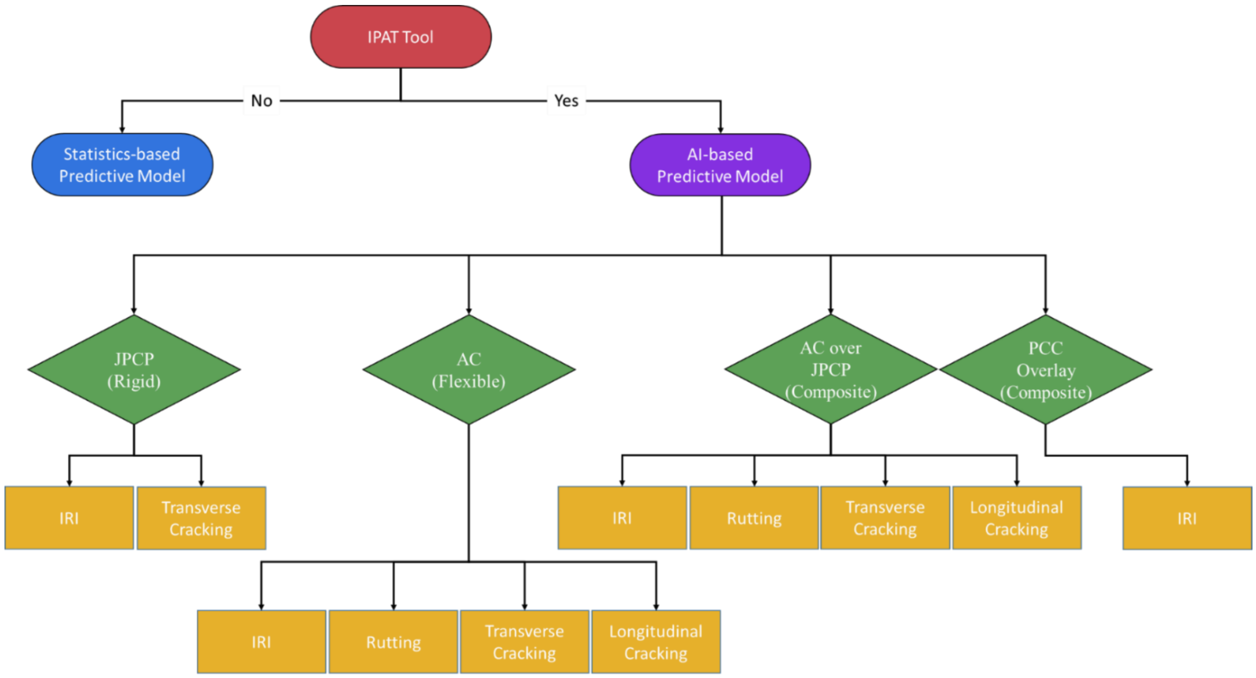


Figure 8. Flowchart of IPAT tool using AI-based models for all pavement types

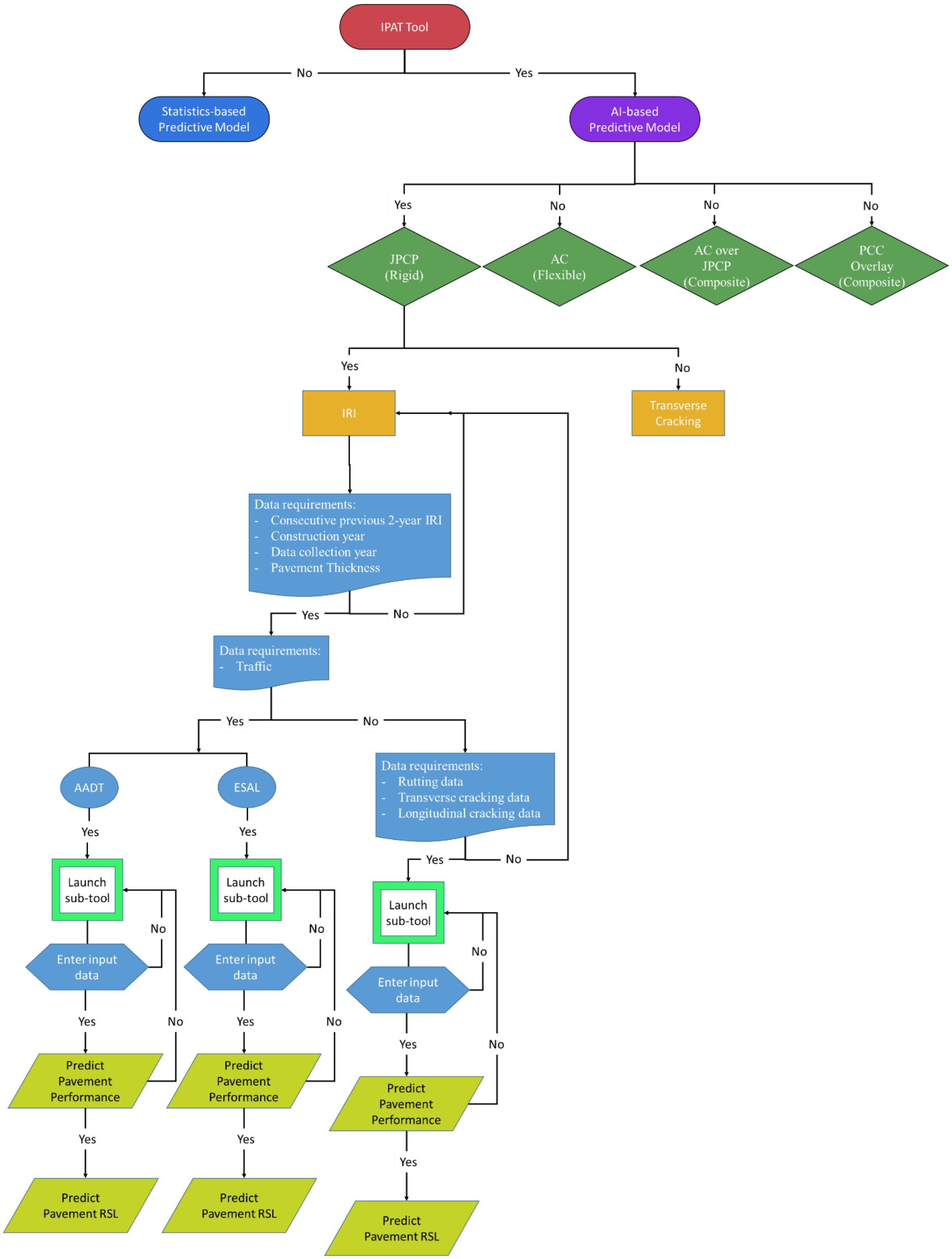


Figure 9. Flowchart of IPAT tool using AI-based IRI model for JPCP

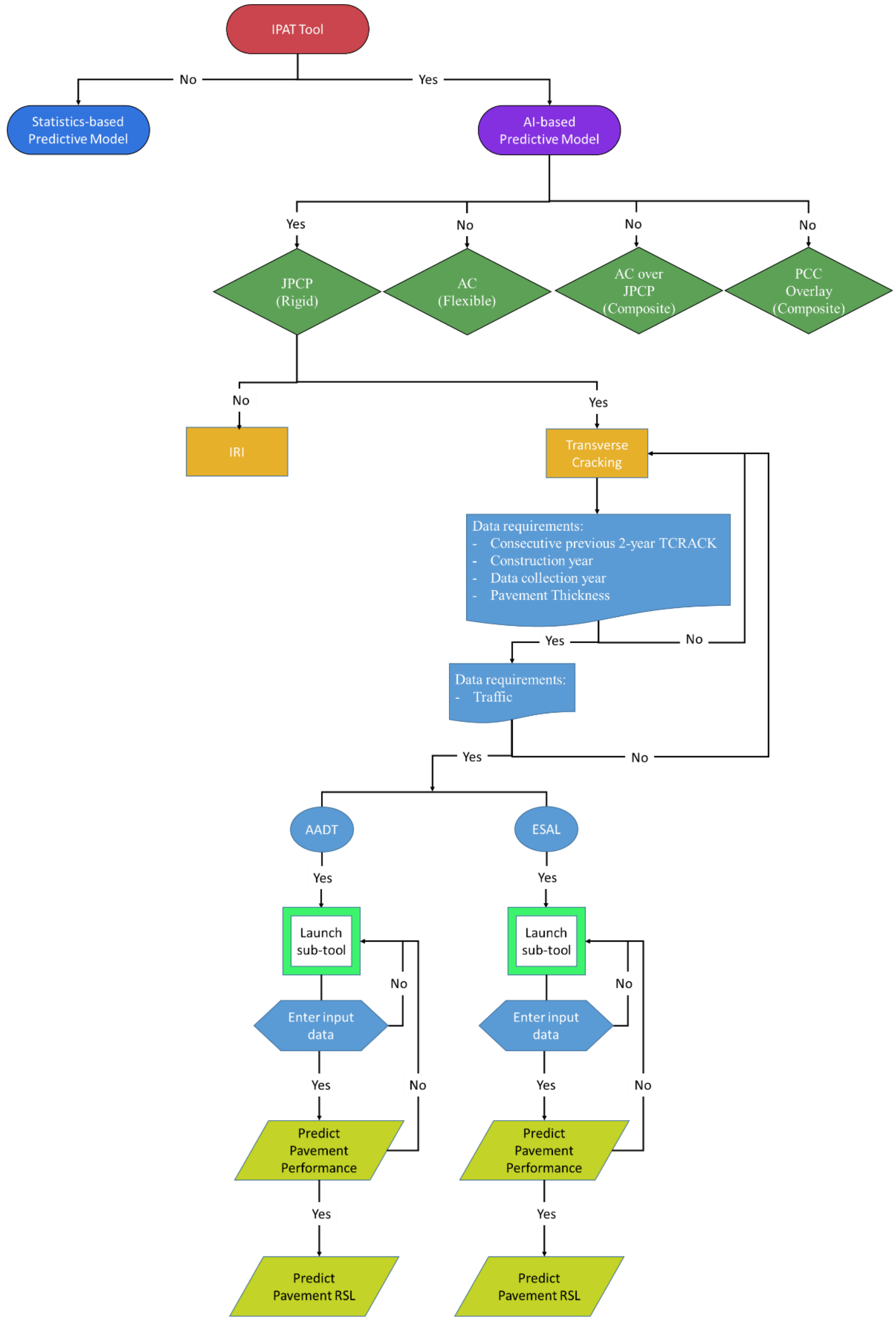


Figure 10. Flowchart of IPAT tool using AI-based TCRACK model for JPCP

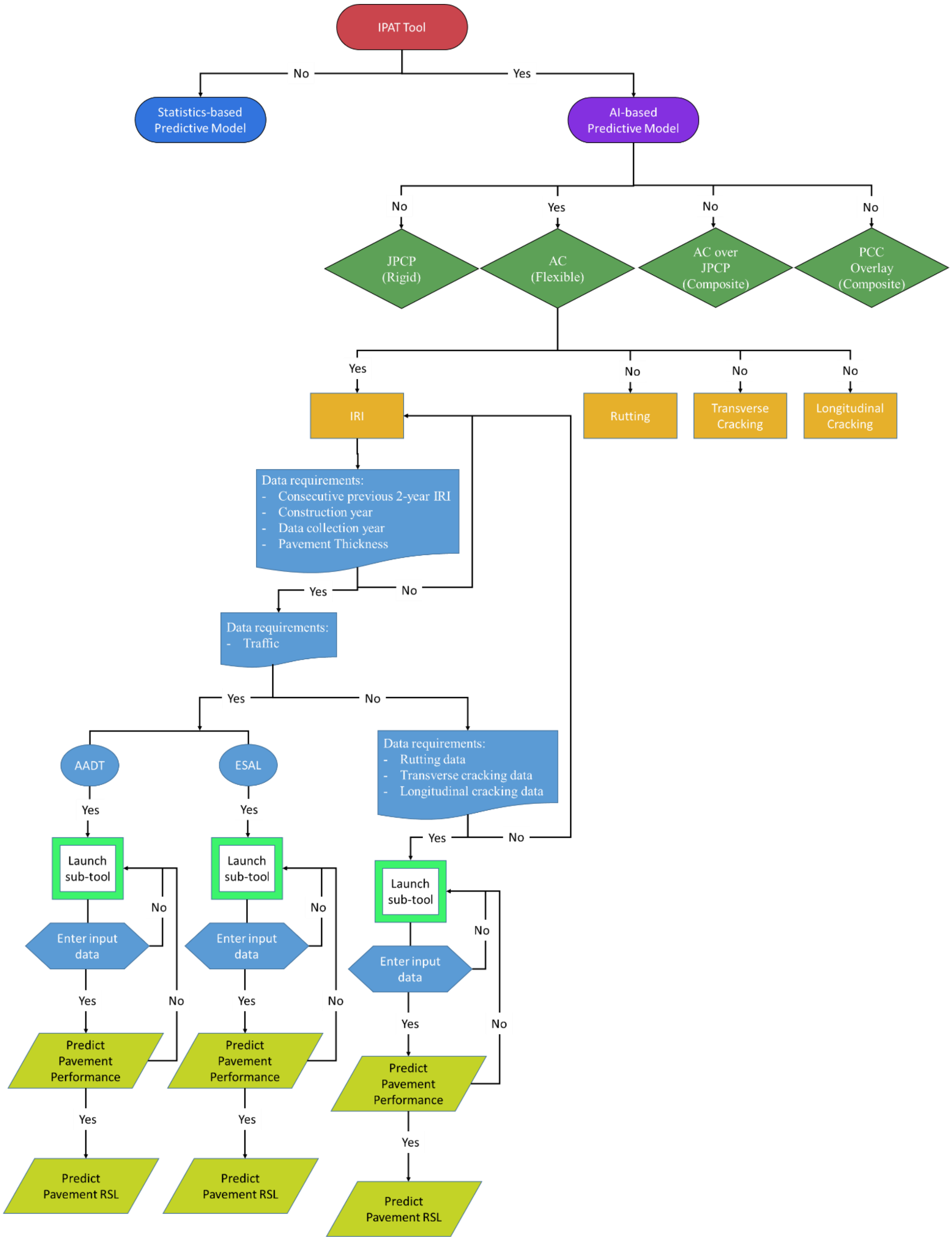


Figure 11. Flowchart of IPAT tool using AI-based IRI model for AC

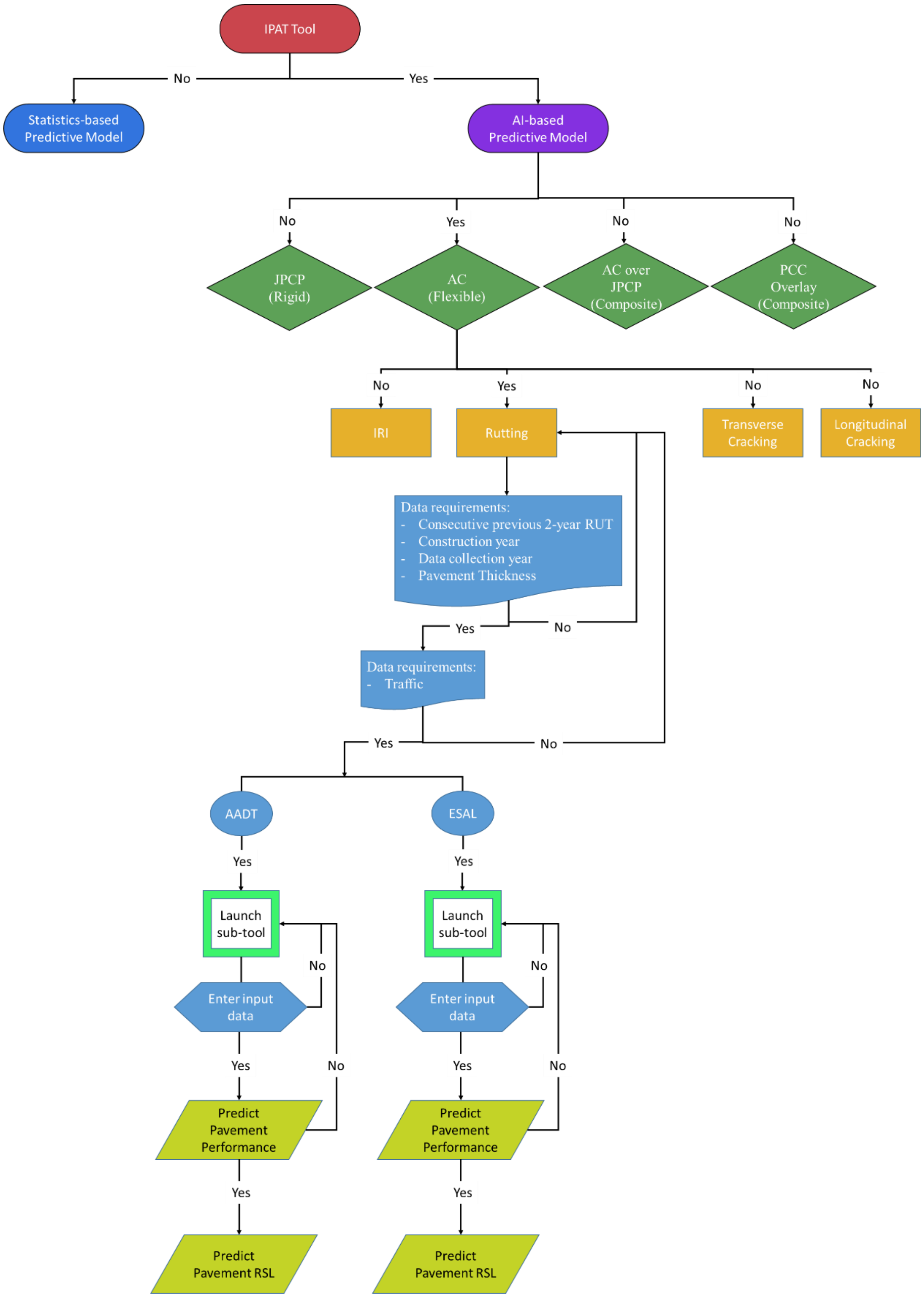


Figure 12. Flowchart of IPAT tool using AI-based RUT model for AC

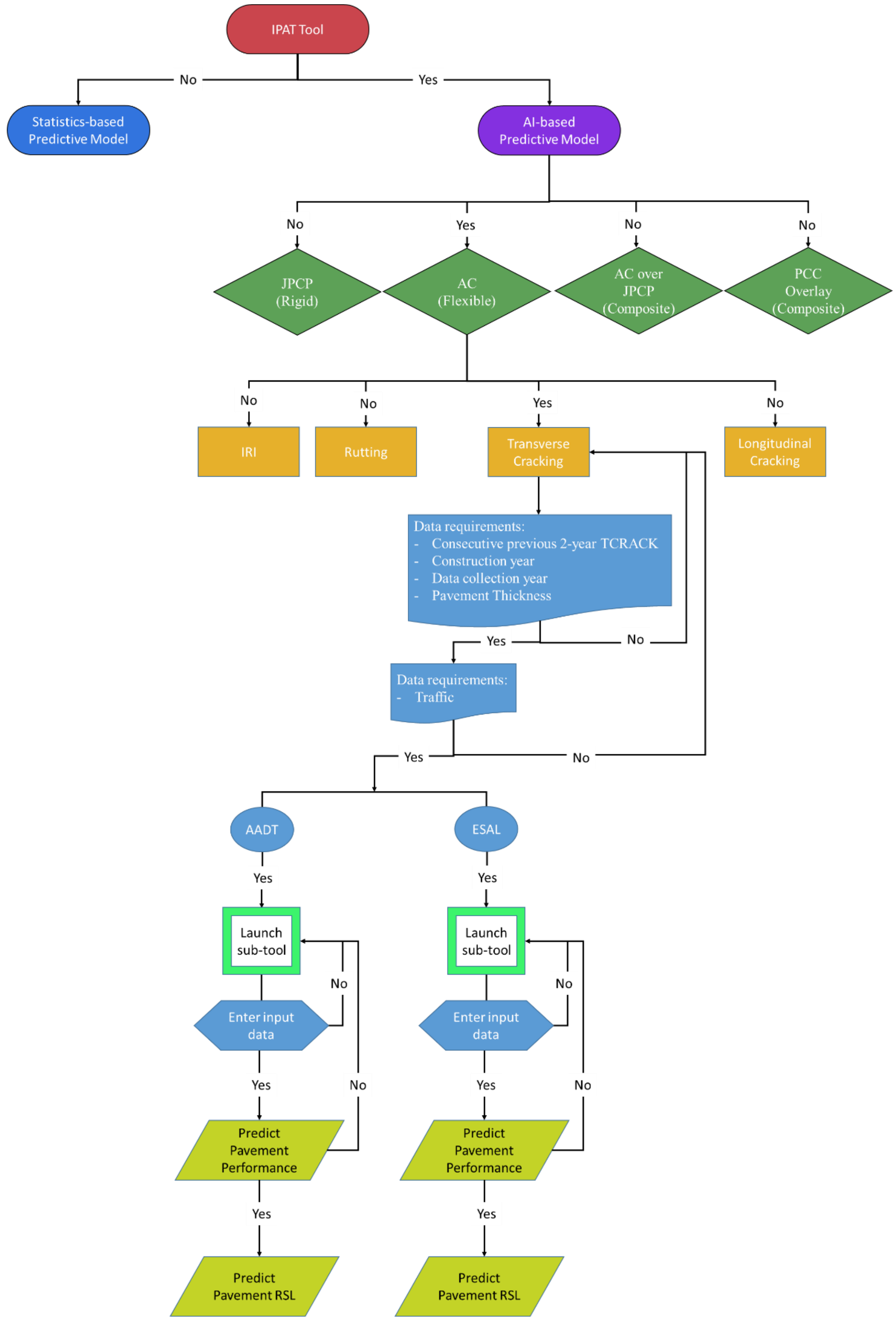


Figure 13. Flowchart of IPAT tool using AI-based TCRACK model for AC

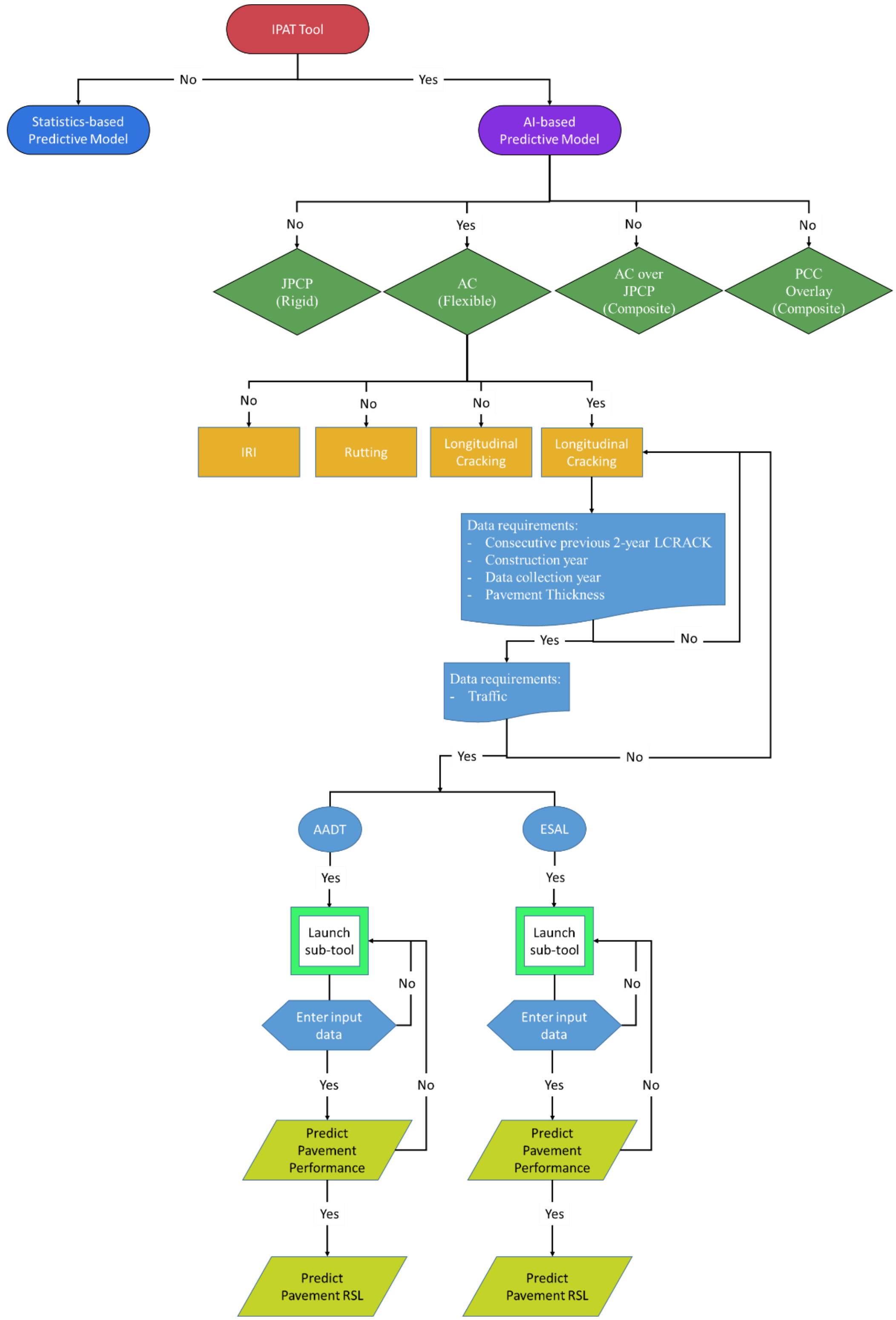


Figure 14. Flowchart of IPAT tool using AI-based LCRACK model for AC

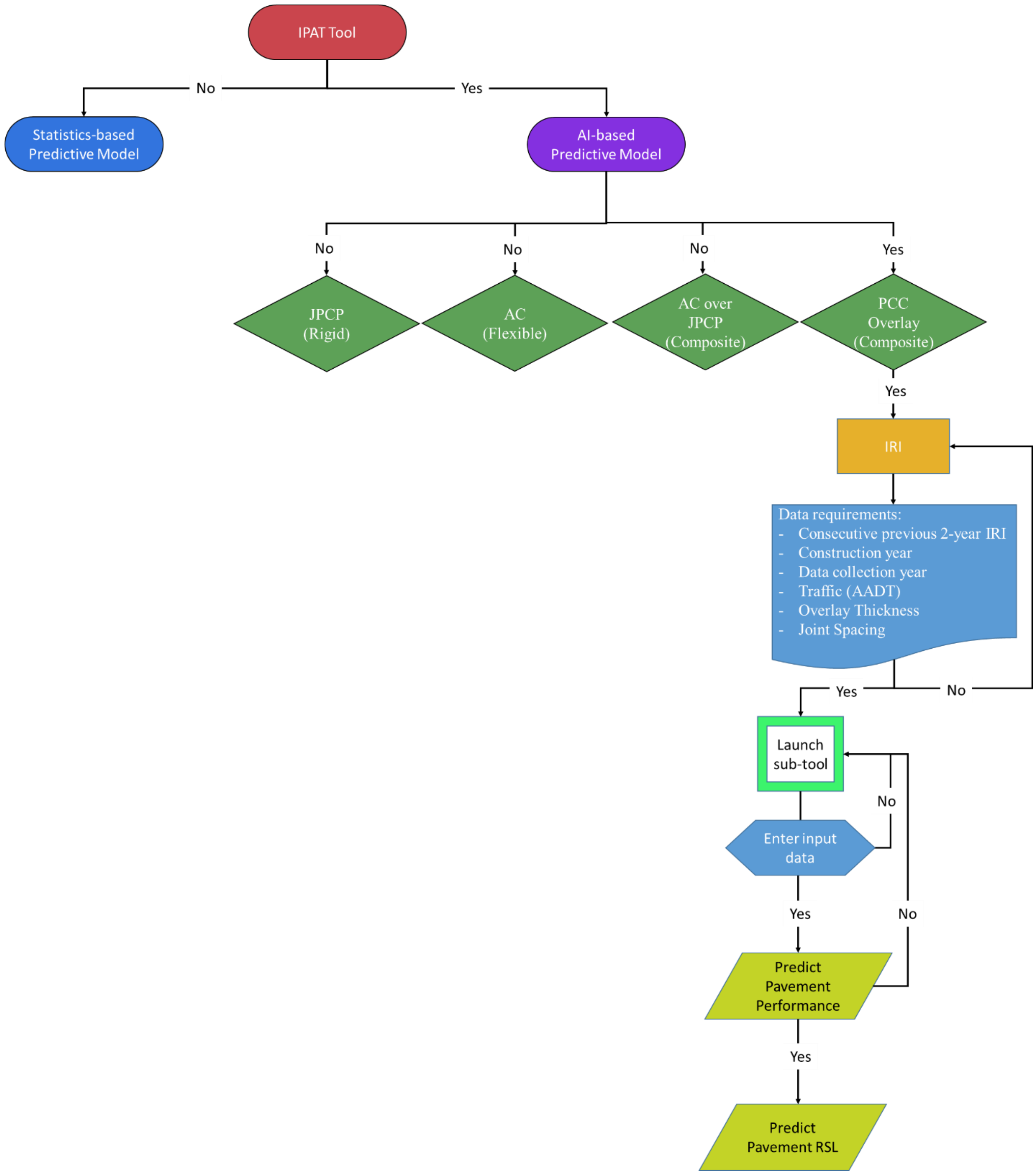


Figure 15. Flowchart of IPAT tool using AI-based IRI model for PCC overlay

Interface of Sub-Tools

Enter Inputs

The IPAT sub-tools for each pavement performance indicator and pavement type are launched by clicking the launch tool in the IPAT main tool. The sub-tool interfaces, which were developed based on the Excel format that includes macros, have the option of statistics- and AI-based models, developed by using the Iowa Department of Transportation's (DOT's) Pavement Management Information System (PMIS) database (e.g., PMIS model) and improved by using data from a database from counties (e.g., county model), and are shown in Figure 16–Figure 37.

Figure 16. Sub-tool to predict IRI using statistics-based model

Figure 17. Sub-tool to predict IRI using AI-based IRI approach 1 county model for JPCPs (launch tool 1 in main tool)

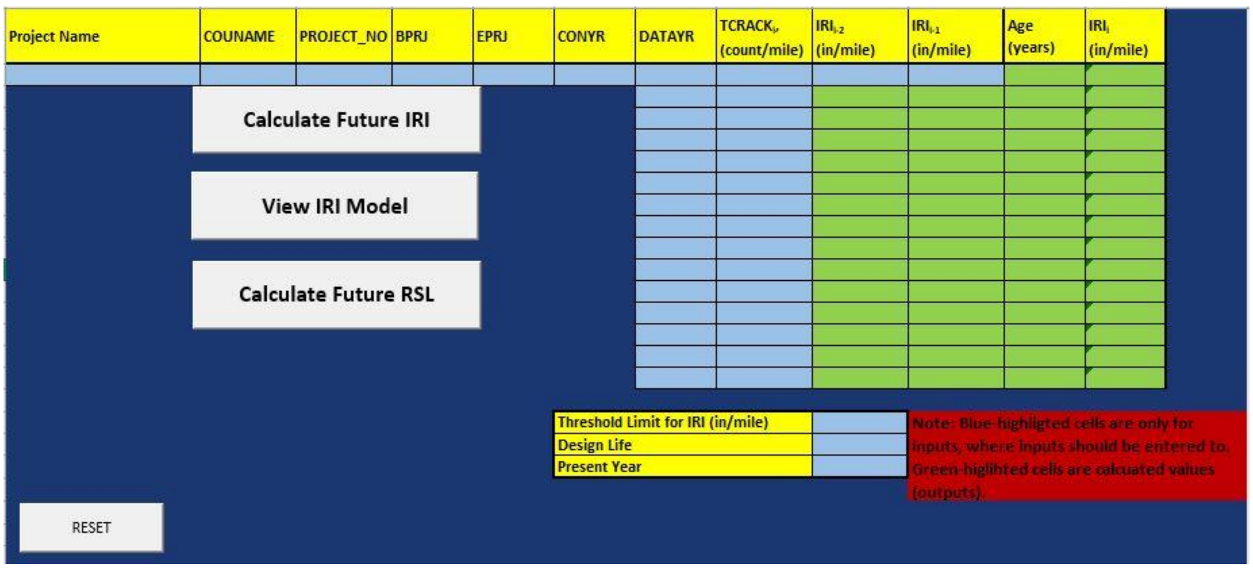


Figure 18. Sub-tool to predict IRI using AI-based IRI approach 2 county model for JPCPs (launch tool 2 in main tool)

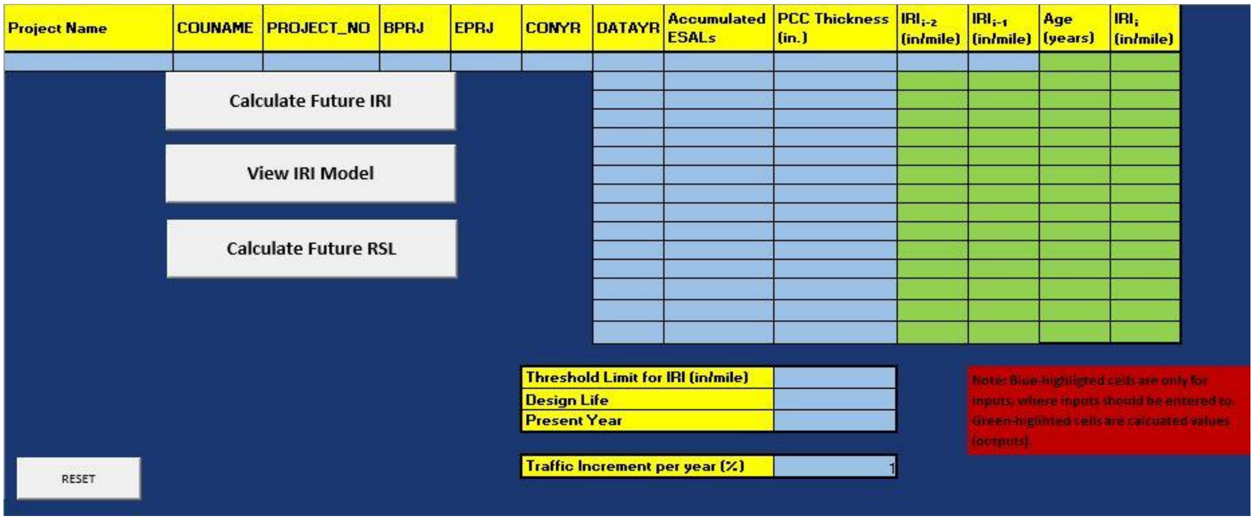


Figure 19. Sub-tool to predict IRI using AI-based IRI approach 1 PMIS model for JPCPs (launch tool 3 in main tool)

Figure 20. Sub-tool to predict IRI using AI-based IRI approach 2 PMIS model for JPCPs (launch tool 4 in main tool)

Figure 21. Sub-tool to predict TCRACK using AI-based county model for JPCPs (launch tool 1 in main tool)

Figure 22. Sub-tool to predict TCRACK using AI-based PMIS model for JPCPs (launch tool 2 in main tool)

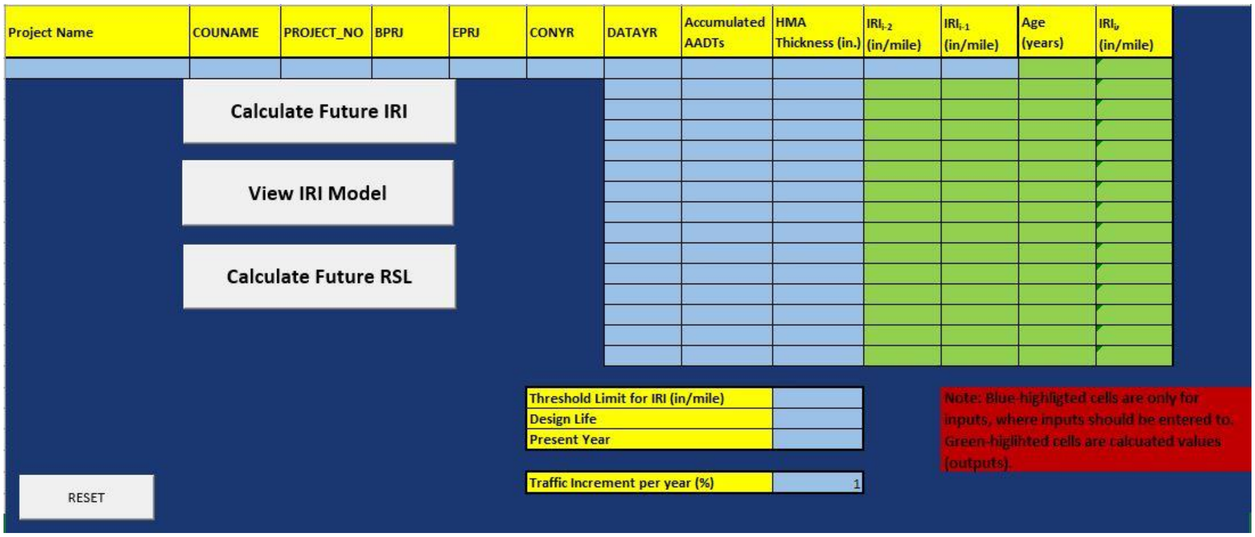


Figure 23. Sub-tool to predict IRI using AI-based IRI approach 1 county model for AC (launch tool 1 in main tool)

Figure 24. Sub-tool to predict IRI using AI-based IRI approach 2 PMIS model for AC (launch tool 2 in main tool)

Figure 25. Sub-tool to predict IRI using AI-based IRI approach 1 PMIS model for AC (launch tool 3 in main tool)

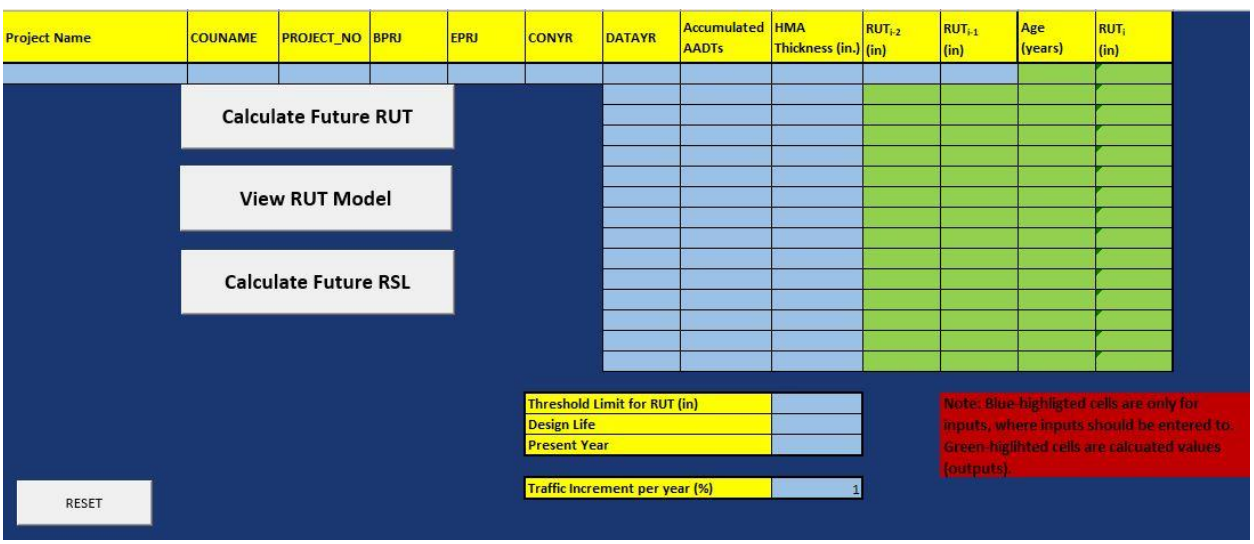


Figure 26. Sub-tool to predict RUT using AI-based county model for AC (launch tool 1 in main tool)

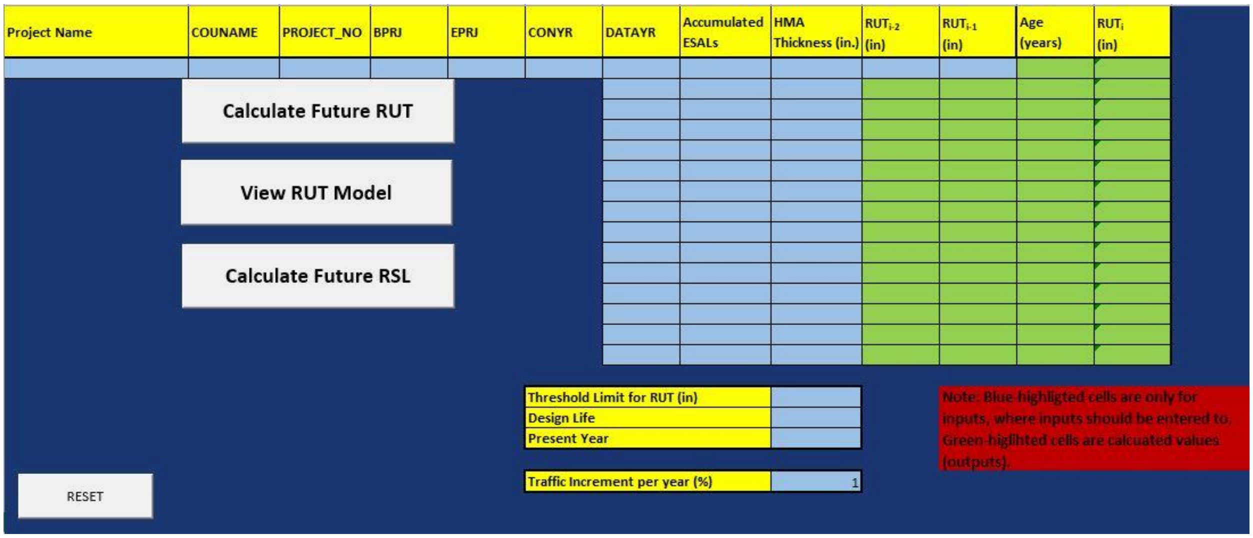


Figure 27. Sub-tool to predict RUT using AI-based PMIS model for AC (launch tool 2 in main tool)

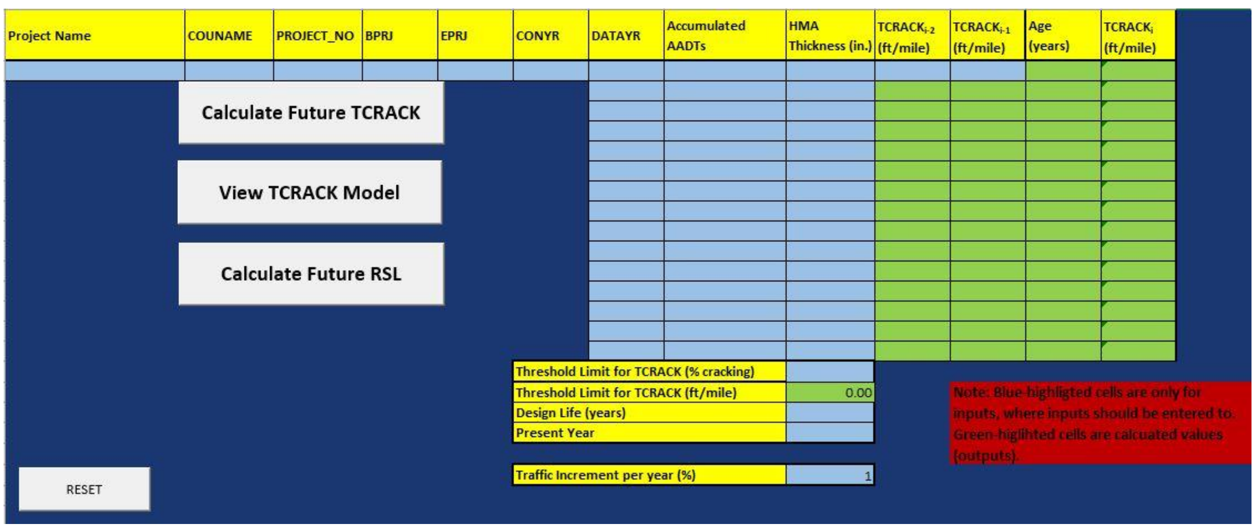


Figure 28. Sub-tool to predict TCRACK using AI-based county model for AC (launch tool 1 in main tool)

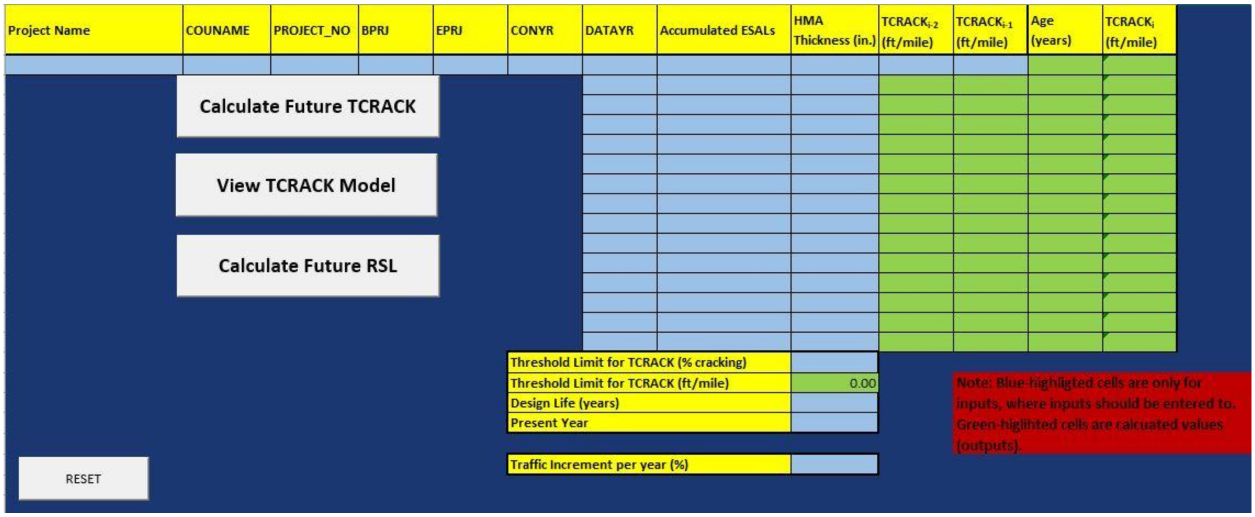


Figure 29. Sub-tool to predict TCRACK using AI-based PMIS model for AC (launch tool 2 in main tool)

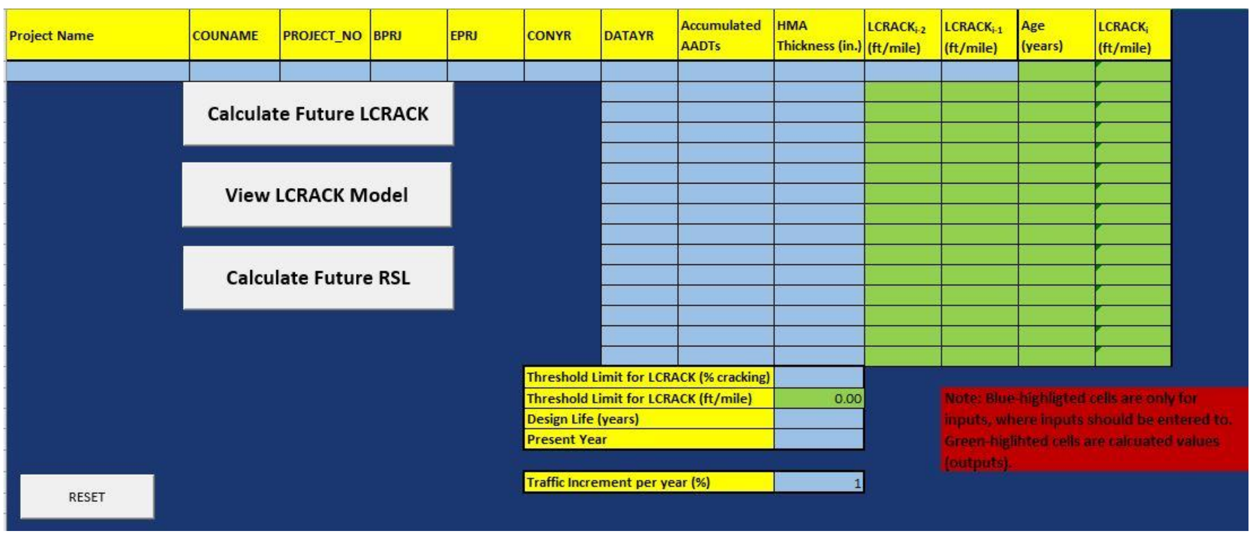


Figure 30. Sub-tool to predict LCRACK using AI-based county model for AC (launch tool 1 in main tool)

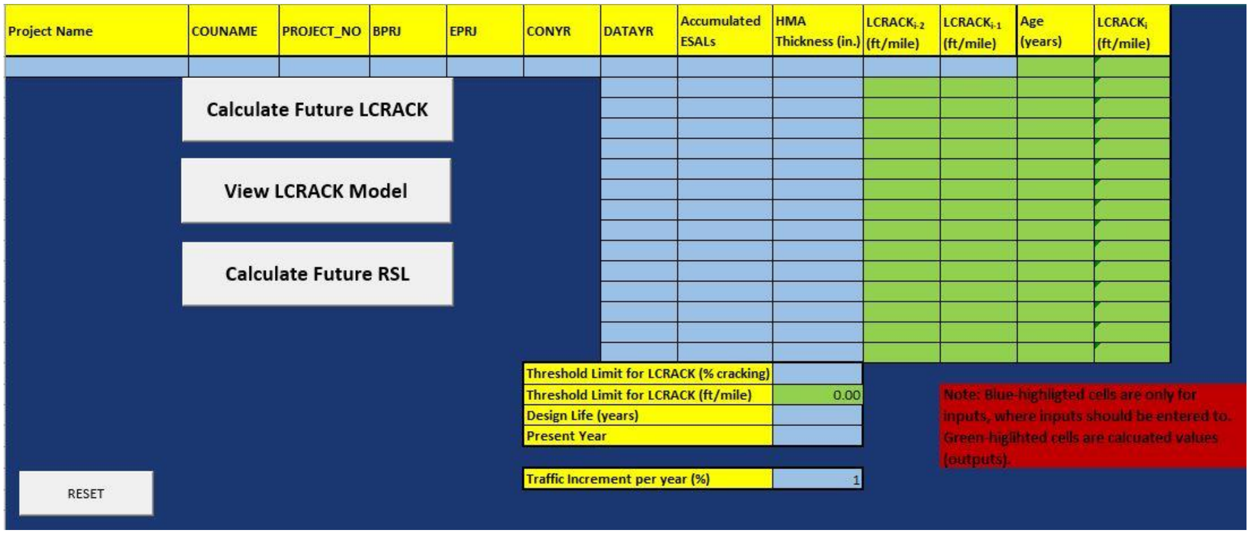


Figure 31. Sub-tool to predict LCRACK using AI-based PMIS model for AC (launch tool 2 in main tool)

Figure 32. Sub-tool to predict IRI using AI-based IRI approach 1 PMIS model for AC over JPCP (launch tool 1 in main tool)

Figure 33. Sub-tool to predict IRI using AI-based IRI approach 2 PMIS model for AC over JPCP (launch tool 2 in main tool)

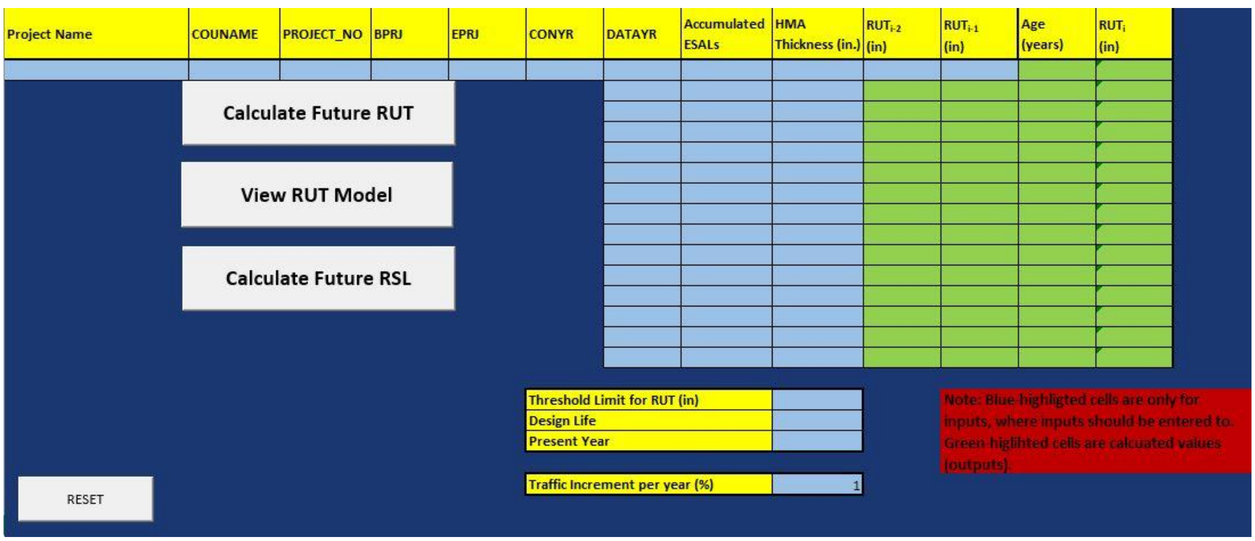


Figure 34. Sub-tool to predict RUT using AI-based PMIS model for AC over JPCP

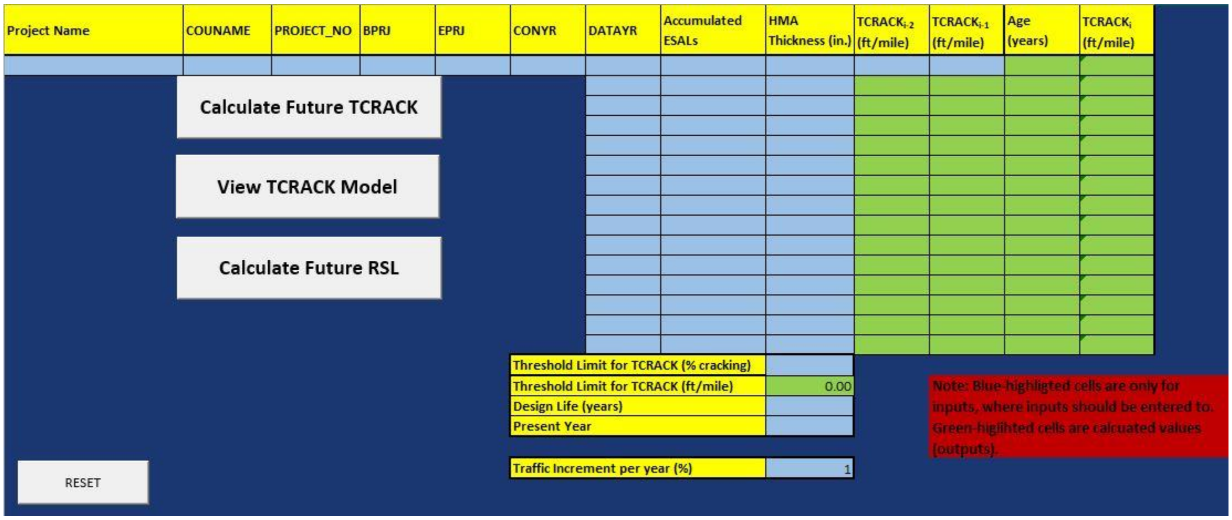


Figure 35. Sub-tool to predict TCRACK using AI-based PMIS model for AC over JPCP

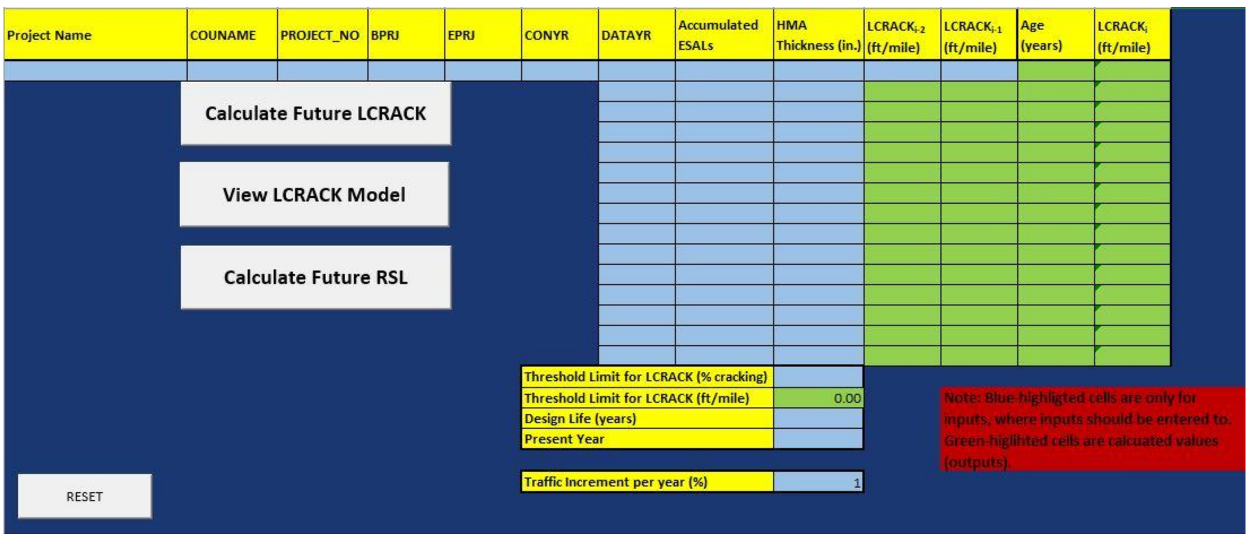


Figure 36. Sub-tool to predict LCRACK using AI-based PMIS model for AC over JPCP

Figure 37. Sub-tool to predict IRI using AI-based county model for PCC overlay

Within all sub-tool interfaces, the yellow cells indicate titles for inputs and outputs, light blue cells indicate that users should enter inputs, green cells indicate predicted outputs, and gray boxes indicate buttons that users should click based on their selections. The user is required to enter and/or edit data for only light blue cells and is not allowed to change yellow and green cells.

The common input parameters for all sub-tools are listed below. The user has the option to enter this road information in the IPAT main tool that will be automatically transferred to the IPAT sub-tools. In the case of not entering the road information in the main tool, the user may enter and/or edit it in sub-tool. The input parameters are as follows:

- Project Name: Descriptions for the road, e.g., street name
- COUNAME: County name
- PROJECT_NO: Number (ID) of the project
- BPRJ: Beginning of the project
- EPRJ: Ending of the project
- CONYR: Year of the construction or reconstruction

The following parameters are the required inputs and the predicted outputs in IPAT sub-tools:

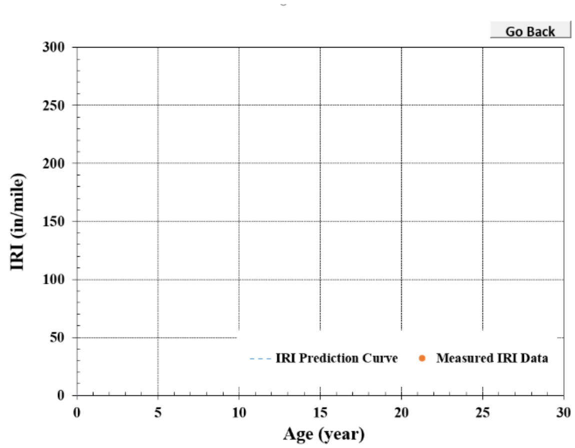
- DATAYR: Year of data collection
- Accumulated AADT: Accumulated annual average daily traffic data that are calculated by adding up current year AADT and previous year AADT
- Accumulated ESAL: Accumulated equivalent single axle load data that are calculated by adding up current year ESAL and previous year ESAL
- Age: Pavement age calculated by subtracting CONYR from DATAYR, in years
- PCC Thickness (in.): Portland cement concrete slab thickness, inch
- HMA Thickness (in.): Hot-mix asphalt concrete slab thickness, inch

- Overlay Thickness (in.): Portland cement concrete overlay thickness, inch
- PCI (%): Pavement condition index, 0–100 %
- Predicted PCI (%): PCI predicted by statistics-based model, in percentage
- IRI_{i-2} (in./mi): International roughness index two years ago, inch per mile
- IRI_{i-1} (in./mi): International roughness index one year ago, inch per mile
- IRI_{i} (in./mi): International roughness index at current year, inch per mile
- Predicted IRI (in./mi): IRI predicted by statistics-based model, inch per mile
- RUT_{i-2} (in.): Rutting depth two years ago, inch
- RUT_{i-1} (in.): Rutting depth one year ago, inch
- RUT_{i} (in.): Rutting depth at current year, inch
- $TCRACK_{i-2}$ (count/mi): Number of transverse cracks/mile two years ago, count per mile
- $TCRACK_{i-1}$ (count/mi): Number of transverse cracks/mile one year ago, count per mile
- $TCRACK_{i}$ (count/mi): Number of transverse cracks/mile at current year, count per mile
- $TCRACK_{i-2}$ (% slab cracked): Transverse cracking two years ago, percent of slab cracked
- $TCRACK_{i-1}$ (% slab cracked): Transverse cracking one year ago, percent of slab cracked
- $TCRACK_{i}$ (% slab cracked): Transverse cracking at current year, percent of slab cracked
- $TCRACK_{i-2}$ (ft/mi): Transverse cracking two years ago, foot per mile
- $TCRACK_{i-1}$ (ft/mi): Transverse cracking one year ago, foot per mile
- $TCRACK_{i}$ (ft/mi): Transverse cracking at current year, foot per mile
- $LCRACK_{i-2}$ (ft/mi): Longitudinal cracking two years ago, foot per mile
- $LCRACK_{i-1}$ (ft/mi): Longitudinal cracking one year ago, foot per mile
- $LCRACK_{i}$ (ft/mi): Longitudinal cracking at current year, foot per mile
- Joint spacing (ft): Distance between transverse joints on concrete pavements, foot
- Threshold Limit for PCI (%): Threshold PCI value representing pavement in poor condition, inch per mile (e.g., 40%)
- Threshold Limit for IRI (in./mi): Threshold IRI value representing pavement in poor condition, inch per mile (e.g., 170 in./mi)
- Threshold Limit for RUT (in.): Threshold RUT value representing pavement in poor condition, inch
- Threshold Limit for TCRACK (% slab cracked) for JPCP: Threshold TCRACK value representing pavement in poor condition, in percentage
- Threshold Limit for TCRACK (count/mi) for JPCP: Threshold TCRACK value representing pavement in poor condition, count per mile, calculated using the following equation: (% slab cracked/100) × (10 ft of lane width/2 ft of crack width) × (5,280 ft/mi) × (1/10 ft of lane width)
- Threshold Limit for TCRACK (% cracking) for AC and AC over JPCP: Threshold TCRACK value representing pavement in poor condition, in percentage
- Threshold Limit for TCRACK (ft/mi) for AC and AC over JPCP: Threshold TCRACK value representing pavement in poor condition, foot per mile, calculated using the following equation: (% cracking area/100) × (10 ft of lane width/2 ft of crack width) × (5,280 ft/mi)
- Threshold Limit for LCRACK (% cracking) for AC and AC over JPCP: Threshold LCRACK value representing pavement in poor condition, in percentage

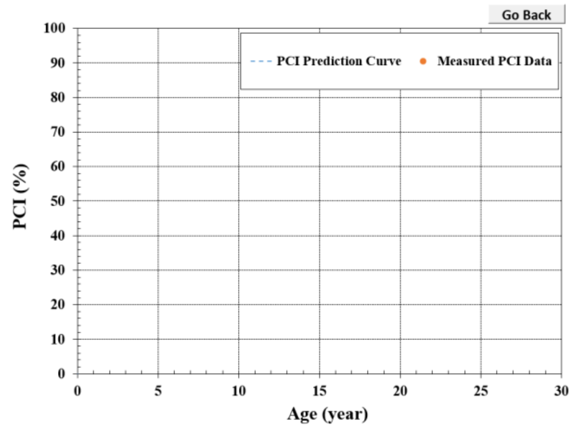
- Threshold Limit for LCRACK (ft/mi) for AC and AC over JPCP: Threshold LCRACK value representing pavement in poor condition, foot per mile, calculated using the following equation: (% cracking area/100) × (10 ft of lane width/2 ft of crack width) × (5,280 ft/mi)
- Design Life: Design life of pavement (e.g., 40 years)
- Present Year: Current year (e.g., 2010)
- Traffic Increment per Year (%): Traffic increment assumption per year to calculate future accumulated traffic data and then to predict future performance, in percentage (e.g., 1%)
- Coefficient Of Determination (R^2): Calculated coefficient of determination value (R^2) based on comparison of IRI_i and Predicted IRI, 0 to 1 indicating high accuracy in results
- Calculate Future IRI (or PCI, RUT, TCRACK, LCRACK): Button to click to predict future pavement performance indicator
- View IRI (or PCI, RUT, TCRACK, LCRACK) Model: Button to click to view deterioration curve in time by plotting pavement performance indicator versus age
- Calculate RSL Based on IRI (or PCI, RUT, TCRACK, LCRACK): Button to click to calculate RSL based on pavement performance indicator and the following parameters if asked:
  - Threshold Limit for IRI (or PCI, RUT, TCRACK, LCRACK)
  - Design Life
  - Present Year
- Reset: Button to click to reset the analysis and clean the spreadsheet for the next analysis

Predict Pavement Performance

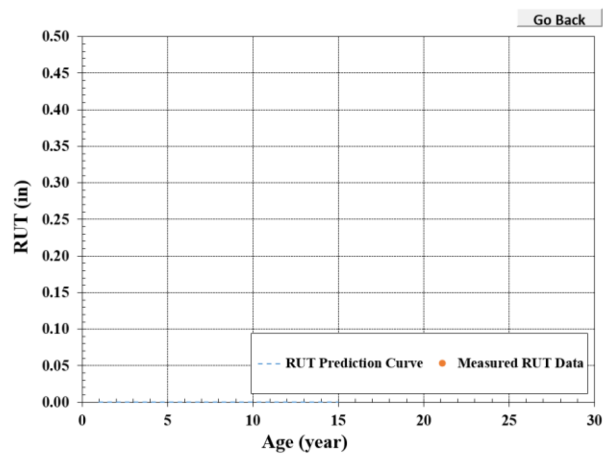
IPAT sub-tools predict pavement performance indicators based on the entered input data, indicate them in numeric value, and plot them in a graph. All green cells indicate the pavement performance predictions. The deterioration model is plotted based on a comparison of the entered field condition and distress data and predicted ones by clicking the View IRI (or PCI, RUT, TCRACK, LCRACK) Model button in the IPAT sub-tool sheets; sample empty graphs are shown in Figure 38. The Go Back button at the top right corner of the graphs should be clicked to return to the input and output sheet.



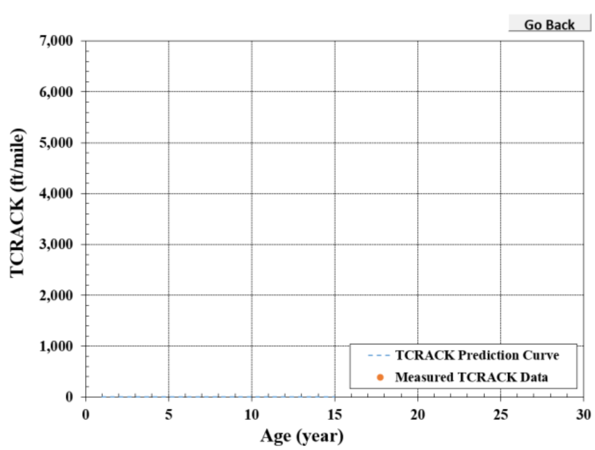
(a) IRI



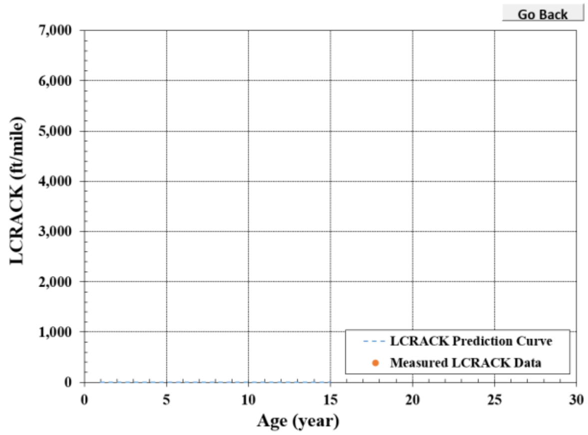
(b) PCI



(c) Rutting



(d) Transverse cracking



(e) Longitudinal cracking

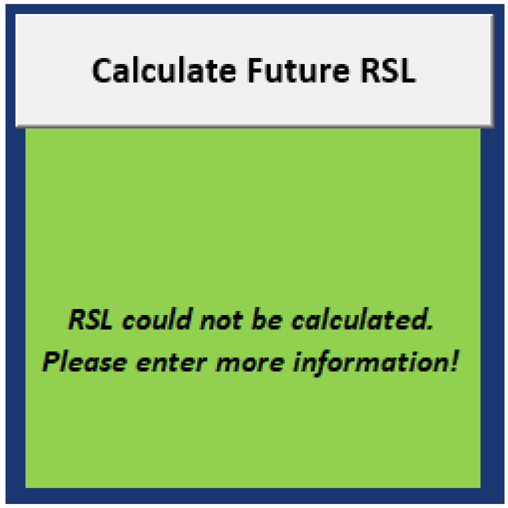
Figure 38. Sample deterioration model graphs (without data) when clicking various view options in IPAT sub-tools

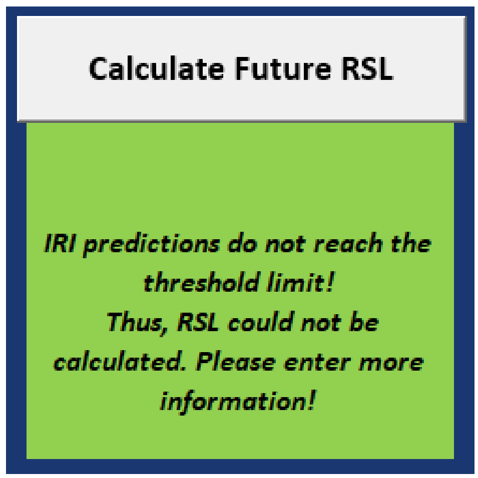
Predict Pavement RSL

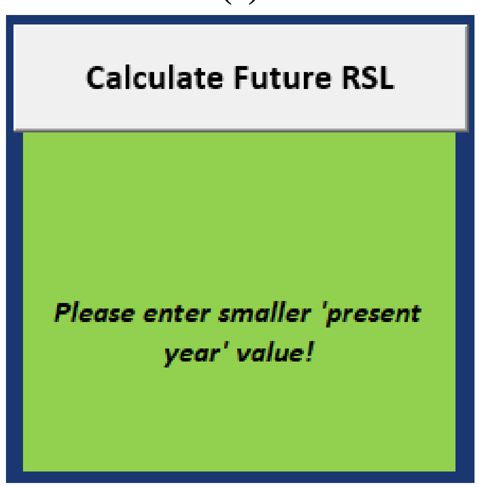
IPAT sub-tools predict RSL of pavement sections based on current and future predicted performance indicators. The RSL cannot be estimated without entering inputs and having pavement performance predictions. Clicking the Calculate Future RSL button estimates the RSL of a pavement section based on the following:

- Predicted pavement performance indicator (IRI, PCI, RUT, TCRACK, or LCRACK)
- Threshold limit for IRI (or PCI, RUT, TCRACK, or LCRACK)
- Design life
- Present year

Based on different scenarios with predicted performance and entered threshold values, a large green cell appears under the Calculate Future RSL button. The number seen at the top of the green cell is the RSL year of pavement (e.g., 10 years) and the text seen under the number describes the RSL (e.g., RSL is calculated based on design life). Figure 39 indicates a variety of sample RSL results based on the predicted and given information. Note that these results are for illustration purposes; thus, RSL numbers may not represent real values.

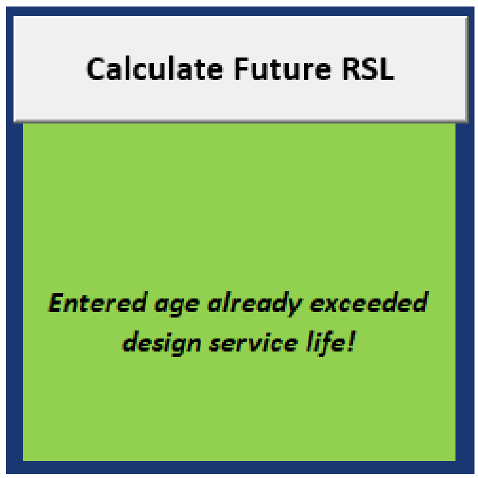

Calculate Future RSL
RSL could not be calculated.
Please enter more information!
(a)


Calculate Future RSL
IRI predictions do not reach the threshold limit!
Thus, RSL could not be calculated. Please enter more information!
(b)

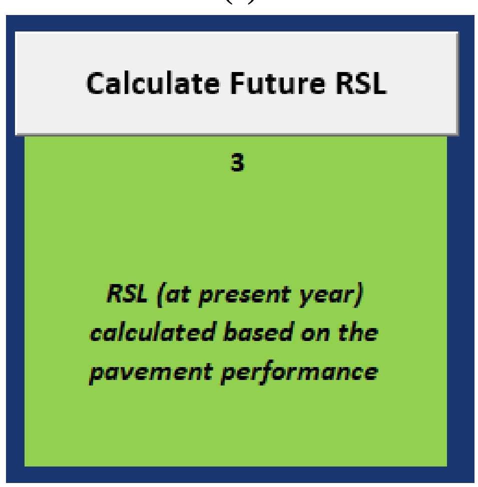

Calculate Future RSL
Please enter smaller 'present year' value!
(c)


Calculate Future RSL
Entered IRI already exceeded threshold limit!

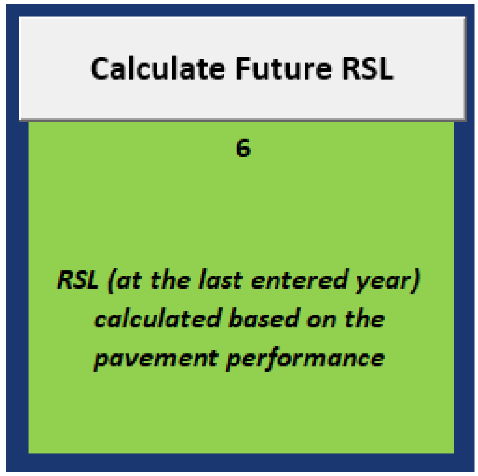
(d)


Calculate Future RSL
Entered age already exceeded design service life!

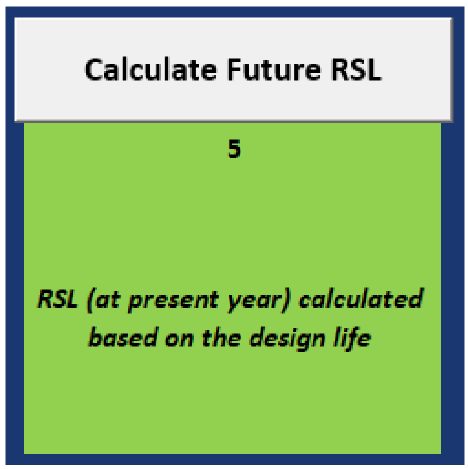
(e)


Calculate Future RSL
3
RSL (at present year) calculated based on the pavement performance

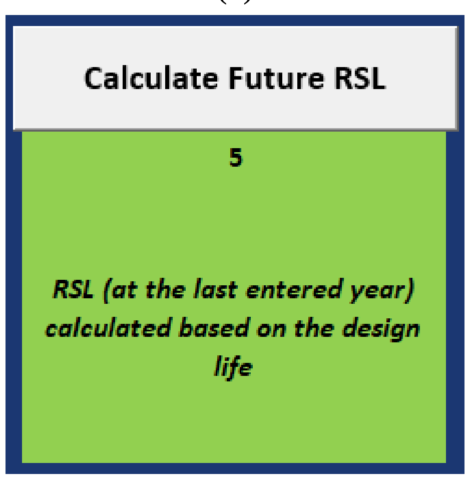
(f)


Calculate Future RSL
6
RSL (at the last entered year) calculated based on the pavement performance

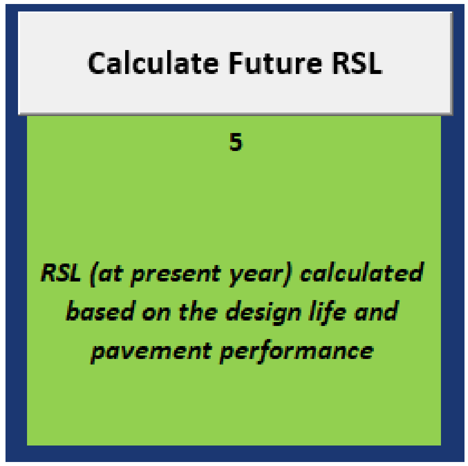
(g)


Calculate Future RSL
5
RSL (at present year) calculated based on the design life

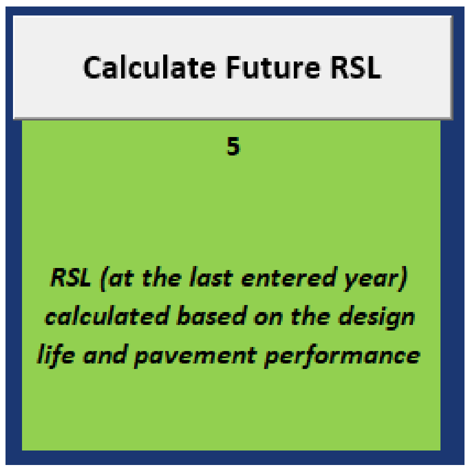
(h)


Calculate Future RSL
5
RSL (at the last entered year) calculated based on the design life

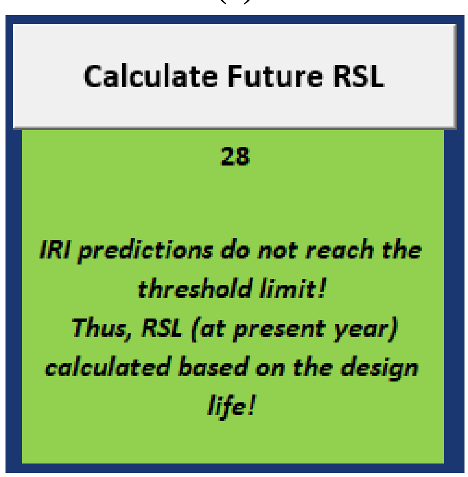
(i)


Calculate Future RSL
5
RSL (at present year) calculated based on the design life and pavement performance

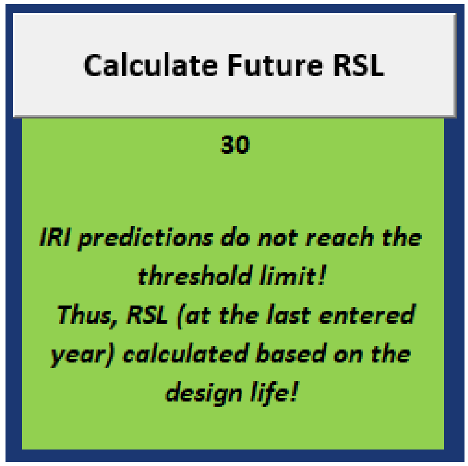
(j)


Calculate Future RSL
5
RSL (at the last entered year) calculated based on the design life and pavement performance

(k)


Calculate Future RSL
28
IRI predictions do not reach the threshold limit!
Thus, RSL (at present year) calculated based on the design life!

(l)



(m)

Figure 39. Sample RSL results when clicking the Calculate Future RSL button in sub-tools

The RSL results that might be obtained based on various scenarios are as follows:

- ***RSL could not be calculated. Please enter more information:*** If the user does not enter any threshold limit, design life, and present year data, RSL cannot be calculated (Figure 39a).
- ***IRI predictions do not reach the threshold limit! Thus, RSL could not be calculated. Please enter more information!:*** If the user enters only threshold limit and the performance predictions never reach the threshold limit, RSL cannot be calculated, and the user needs to enter more data such as design life (Figure 39b).
- ***Please enter smaller 'present year' value!:*** If the user enters all data and the age calculated at the entered present year is larger than the entered design life, RSL cannot be calculated, and the user needs to enter a smaller value for the present year (Figure 39c).
- ***Entered IRI already exceeded threshold limit!:*** When the user enters threshold limit for pavement condition and distress data that are smaller than the current pavement condition and distress data, pavement performance already exceeds the threshold limit (Figure 39d).
- ***Entered age already exceeded design service life!:*** When the user enters a design life that is smaller than the current pavement age, the pavement age already exceeds the design life (Figure 39e).
- ***RSL (at present year) calculated based on the pavement performance:*** When the user enters all data or only threshold limit and present year, RSL is calculated based on the entered present year if the performance predictions reach the threshold limit within the design life (Figure 39f).
- ***RSL (at the last entered year) calculated based on the pavement performance:*** When the user enters a threshold limit but not the present year, RSL is calculated based on the last entered year in the DATAYR column if the performance predictions reach the threshold limit within the design life (Figure 39g).
- ***RSL (at present year) calculated based on the design life:*** When the user enters all data or only design life and present year, RSL is calculated based on the entered present year if the pavement age exceeds the design life earlier than the age that the performance predictions reach the threshold limit (Figure 39h).

- ***RSL (at the last entered year) calculated based on the design life:*** When the user enters design life but not present year, RSL is calculated based on the last entered year in the DATAYR column if the pavement age exceeds the design life earlier than the age that the performance predictions reach the threshold limit (Figure 39i).
- ***RSL (at present year) calculated based on the design life and the pavement performance:*** When the user enters all data, RSL is calculated based on the entered present year if the pavement age exceeds the design life and the performance predictions reach the threshold limit at the same time (Figure 39j).
- ***RSL (at the last entered year) calculated based on the design life and the pavement performance:*** When the user enters all data but not present year, RSL is calculated based on the last entered year in the DATAYR column if the pavement age exceeds the design life and the performance predictions reach the threshold limit at the same time (Figure 39k).
- ***IRI predictions do not reach the threshold limit! Thus, RSL (at present year) calculated based on the design life!:*** When the user enters all data, RSL is calculated based on the entered present year if the pavement age exceeds the design life and the performance predictions never reach the threshold limit within the design life (Figure 39l).
- ***IRI predictions do not reach the threshold limit! Thus, RSL (at the last entered year) calculated based on the design life!:*** When the user enters all data but not present year, RSL is calculated based on the last entered year in the DATAYR column if the pavement age exceeds the design life and the performance predictions never reach the threshold limit within the design life (Figure 39m).

ILLUSTRATIVE EXAMPLES: PAVEMENT ANALYSIS USING THE IPAT TOOL

Examples of predicting IRI and RSL for each JPCP and AC pavement type using both statistics-based and AI-based models are examined in the following sections.

JPCP Case: Statistics-Based Model

Select Predictive Model Type

The statistics-based model was selected as shown in Figure 40.

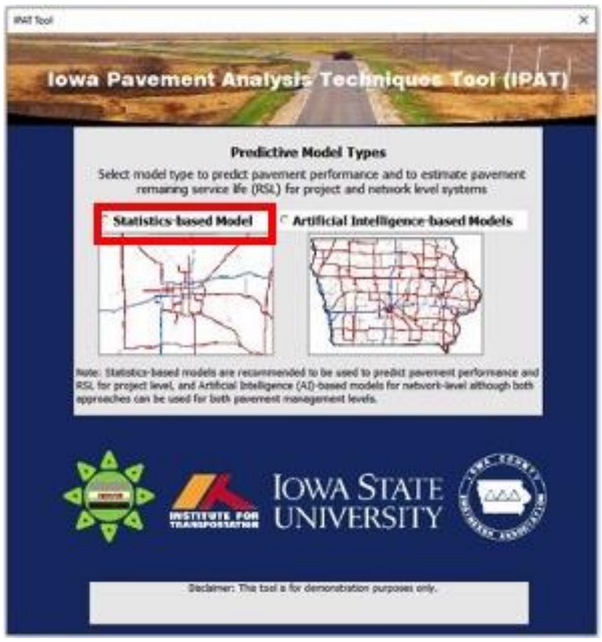


Figure 40. Select predictive model type: statistics-based model

Select Pavement Type

JPCP (concrete) pavement type was selected as shown in Figure 41.

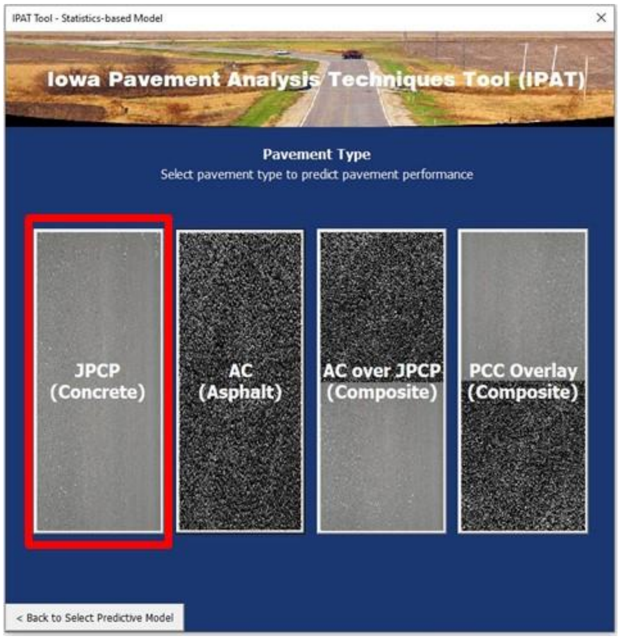


Figure 41. Select pavement type: JPCP (concrete)

Select Pavement Performance Indicator

IRI, as a pavement performance indicator, was selected, questions are answered (Figure 42) and required road information is entered (Figure 43). Then, the launch tool button is clicked to launch the sub-tool.

Figure 42. Select pavement performance indicator and prepare data: IRI (statistics-based model)

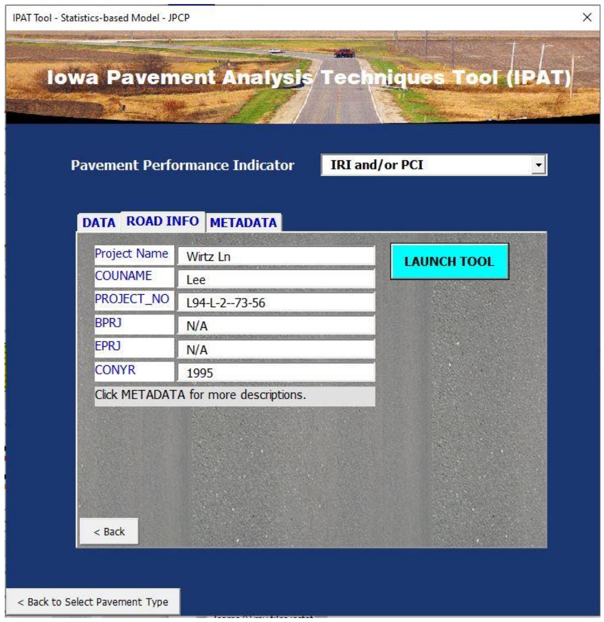


Figure 43. Enter required data information: county JPCP (statistics-based model)

Enter Inputs

The entered data information in the IPAT main tool were transferred into the IPAT sub-tool as shown in Figure 44.

Figure 44. Transfer data information into IPAT sub-tool: JPCP (statistics-based model)

The columns of DATAYR and IRI_i were filled based on available data as shown in Figure 45.

Figure 45. Enter input parameters: JPCP (statistics-based model)

Predict Pavement Performance

The Calculate Future IRI button was clicked, and future IRI was predicted (Figure 46).

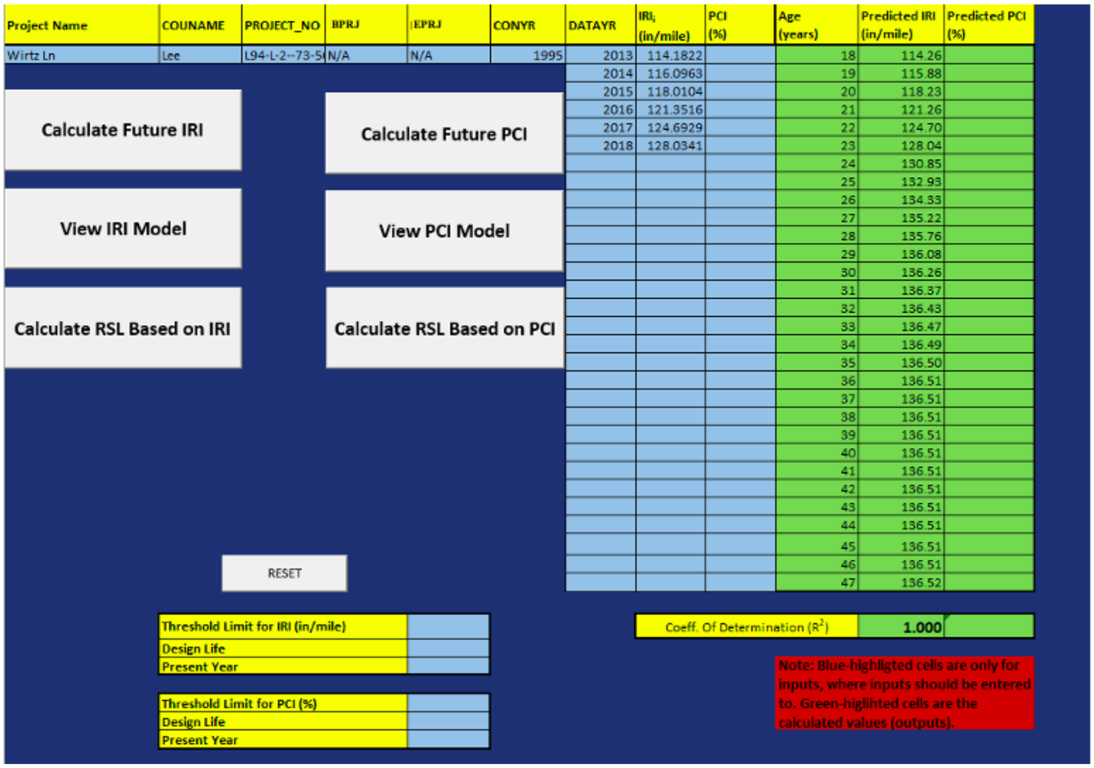


Figure 46. Calculate future IRI: JPCP (statistics-based model)

Then, the View IRI Model button was clicked, which shows the plotted deterioration curve based on the field and predicted IRI data (Figure 47).

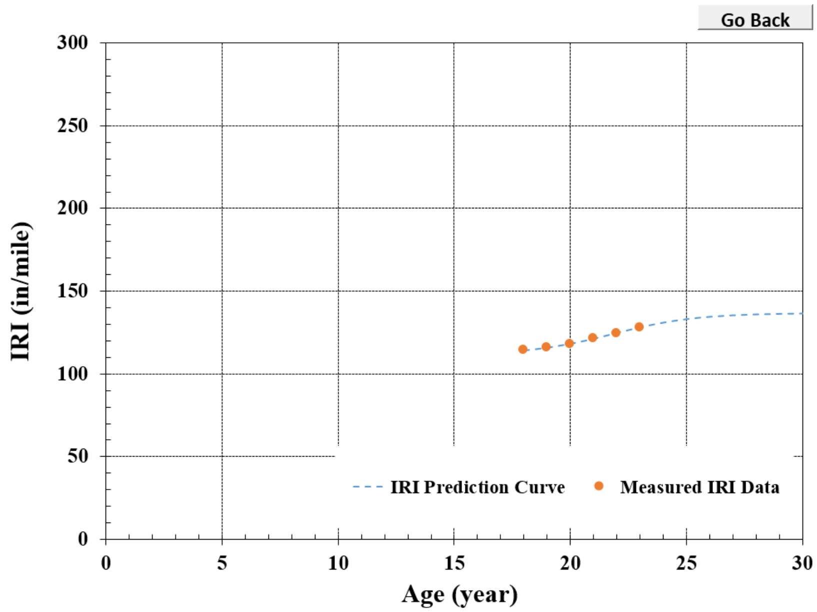


Figure 47. IRI model view: JPCP (statistics-based model)

Predict Pavement RSL

The threshold limit for IRI, design life, and present year parameters were defined, and then the Calculate RSL Based on IRI button was clicked to predict future IRI. The RSL results and descriptions appear under the Calculate RSL Based on IRI button when different scenarios were applied as follows:

- All parameters (170 in./mi, 40 years, 2021) were defined (Figure 48)

Figure 48. Threshold limit for IRI (170 in./mi), design life (40 years), and present year (2021): JPCP (statistics-based model)

- Threshold limit for IRI (170 in./mi) and design life (40 years) were defined (Figure 49)

Figure 49. Threshold limit for IRI (170 in./mi) and design life (40 years): JPCP (statistics-based model)

- Different threshold limit for IRI (130 in./mi) and design life (40 years) were defined (Figure 50)

Figure 50. Threshold limit for IRI (130 in./mi) and design life (40 years): JPCP (statistics-based model)

JPCP Case: AI-Based Model

Select Predictive Model Types

The AI-based model was selected as shown in Figure 51.

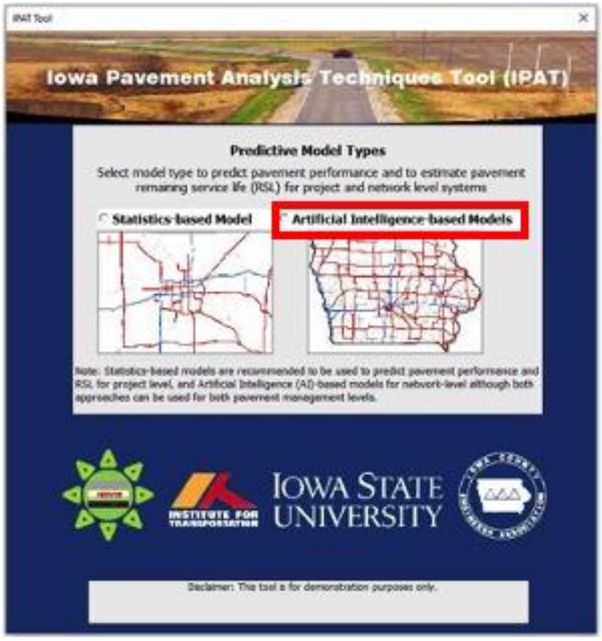


Figure 51. Select predictive model type: AI-based model

Select Pavement Type

JPCP (concrete) pavement type was selected as shown in Figure 52.

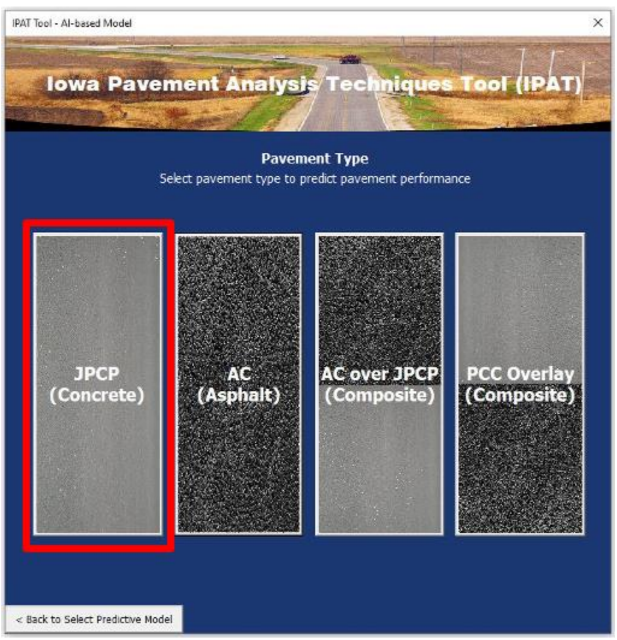


Figure 52. Select pavement type: JPCP (concrete)

Select Pavement Performance Indicator

IRI, as a pavement performance indicator, was selected, questions are answered (Figure 53) and required road information is entered (Figure 54). Then, the launch tool button is clicked to launch the sub-tool.

Figure 53. Select pavement performance indicator and prepare data: IRI (AI-based model)

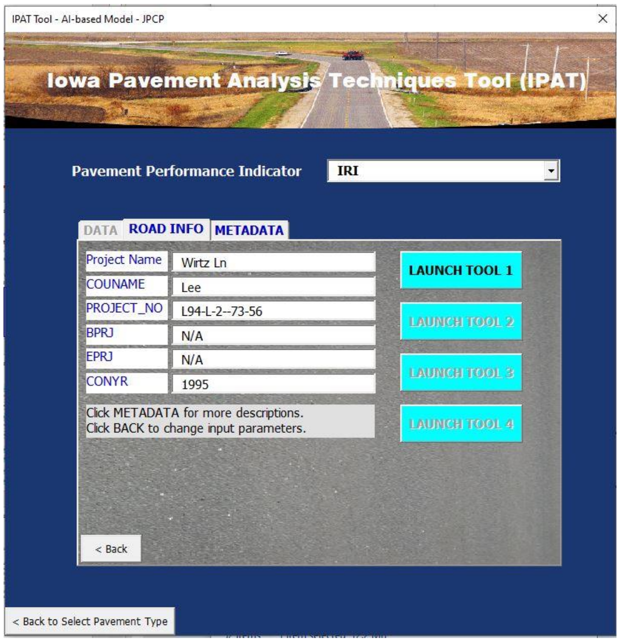


Figure 54. Enter required data information: county JPCP (AI-based model)

Enter Inputs

The entered data information in the IPAT main tool was transferred into the IPAT sub-tool as shown in Figure 55.

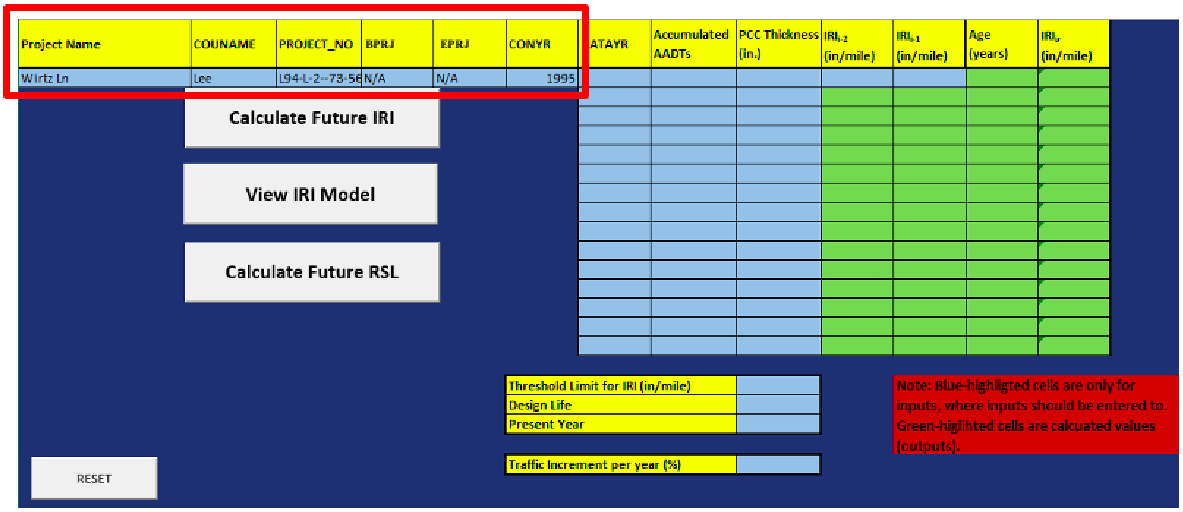


Figure 55. Transfer data information into IPAT sub-tool: JPCP (AI-based model)

The columns of DATAYR, Accumulated AADT, PCC Thickness, IRI$_{i-2}$, and IRI$_{i-1}$ were filled based on available data as shown in Figure 56 and Figure 57.

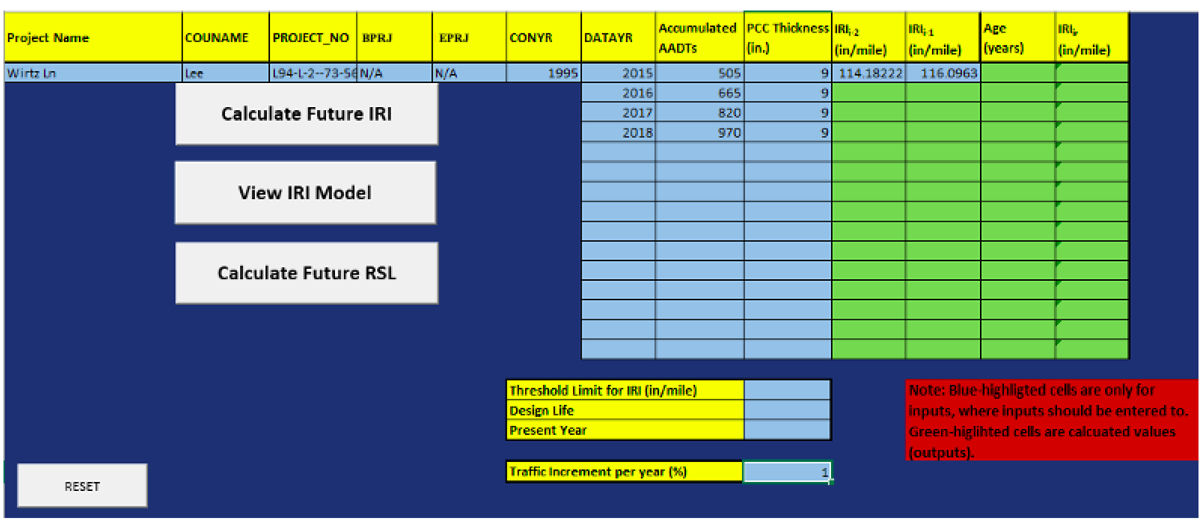


Figure 56. Option 1: Enter existing input parameters and traffic increment per year: JPCP (AI-based model)

Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	PCC Thickness (in.)	IRI_{i-2} (in/mile)	IRI_{i-1} (in/mile)	Age (years)	IRI_p (in/mile)
Wirtz Ln	Lee	L94-L-2--73-56	N/A	N/A	1995	2015	505	9	114.18222	116.0963		
						2016	665	9				
						2017	820	9				
						2018	970	9				
						2019	1115	9				
						2020	1255	9				
						2021	1390	9				
						2022	1520	9				
						2023	1645	9				
						2024	1765	9				
						2025	1880	9				
						2026	1990	9				
						2027	2095	9				
						2028	2195	9				
						2029	2290	9				

Figure 57. Option 2: Enter existing and prepared input parameters without defining traffic increment per year: JPCP (AI-based model)

Here, there are two options to enter future input parameters: (1) the existing input parameters and defining traffic increment per year (%) to calculate future input parameters (Figure 56), and (2) the existing and prepared future input parameters without defining traffic increment per year (%) (Figure 57).

Predict Pavement Performance

The Calculate Future IRI button was clicked and future IRI was predicted (Figure 58 and Figure 59).

Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	PCC Thickness (in.)	IRI_{i-2} (in/mile)	IRI_{i-1} (in/mile)	Age (years)	IRI_p (in/mile)
Wirtz Ln	Lee	L94-L-2--73-56	N/A	N/A	1995	2015	505	9	114.18222	116.0963	20	118.28796
						2016	665	9	116.0963	118.28796	21	120.57223
						2017	820	9	118.28796	120.57223	22	122.79682
						2018	970	9	120.57223	122.79682	23	124.84878
									122.79682	124.84878	24	126.6557
									124.84878	126.6557	25	128.18369
									126.6557	128.18369	26	129.43063
									128.18369	129.43063	27	130.4168
									129.43063	130.4168	28	131.17541
									130.4168	131.17541	29	131.74439
									131.17541	131.74439	30	132.16069
									131.74439	132.16069	31	132.45711
									132.16069	132.45711	32	132.66107
									132.45711	132.66107	33	132.79468
									132.66107	132.79468	34	132.87555

Figure 58. Option 1: Calculate future IRI: JPCP (AI-based model)

Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	PCC Thickness (in.)	IRI_{i-2} (in/mile)	IRI_{i-1} (in/mile)	Age (years)	IRI_i (in/mile)
Wirtz Ln	Lee	L94-L-2--73-56	N/A	N/A	1995	2015	505	9	114.18222	116.0963	20	118.28796
						2016	665	9	116.0963	118.28796	21	120.57223
						2017	820	9	118.28796	120.57223	22	122.79682
						2018	970	9	120.57223	122.79682	23	124.84878
						2019	1115	9	122.79682	124.84878	24	126.6564
						2020	1255	9	124.84878	126.6564	25	128.18636
						2021	1390	9	126.6564	128.18636	26	129.43694
						2022	1520	9	128.18636	129.43694	27	130.42875
						2023	1645	9	129.43694	130.42875	28	131.19529
						2024	1765	9	130.42875	131.19529	29	131.77483
						2025	1880	9	131.19529	131.77483	30	132.20478
						2026	1990	9	131.77483	132.20478	31	132.51856
						2027	2095	9	132.20478	132.51856	32	132.74442
						2028	2195	9	132.51856	132.74442	33	132.9056
						2029	2290	9	132.74442	132.9056	34	133.02118

Threshold Limit for IRI (in/mile)	
Design Life	
Present Year	

Traffic Increment per year (%)	

Figure 59. Option 2: Calculate future IRI: JPCP (AI-based model)

Then, the View IRI Model button is clicked, which shows the plotted deterioration curve based on the field and predicted IRI data (Figure 60).

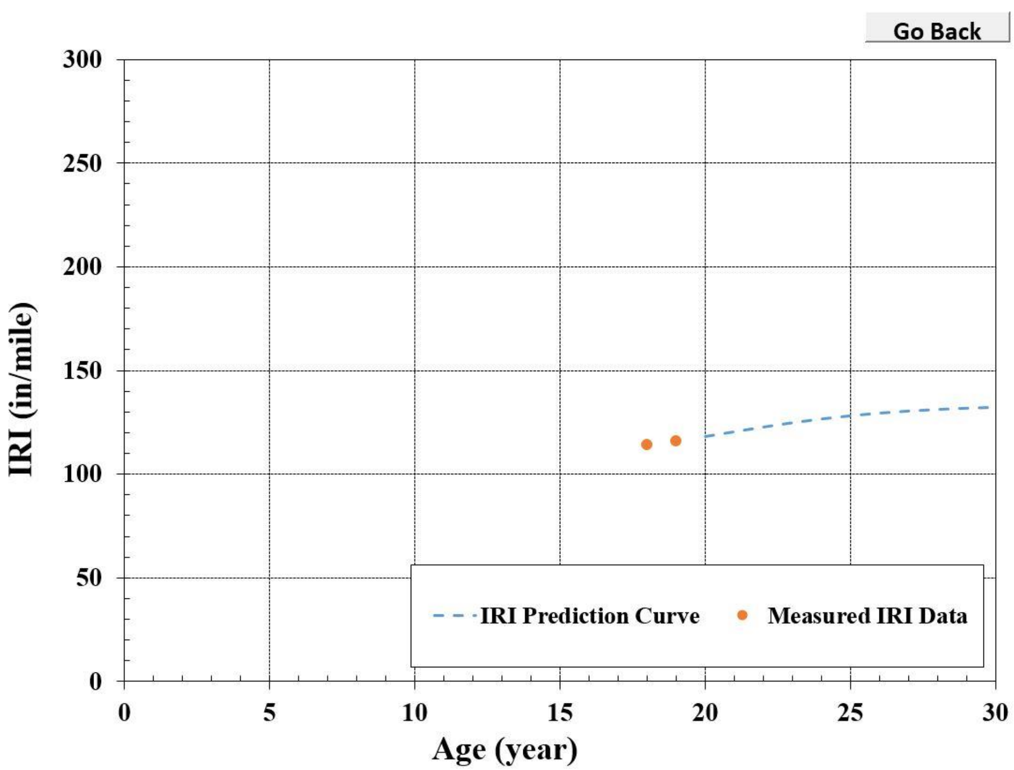
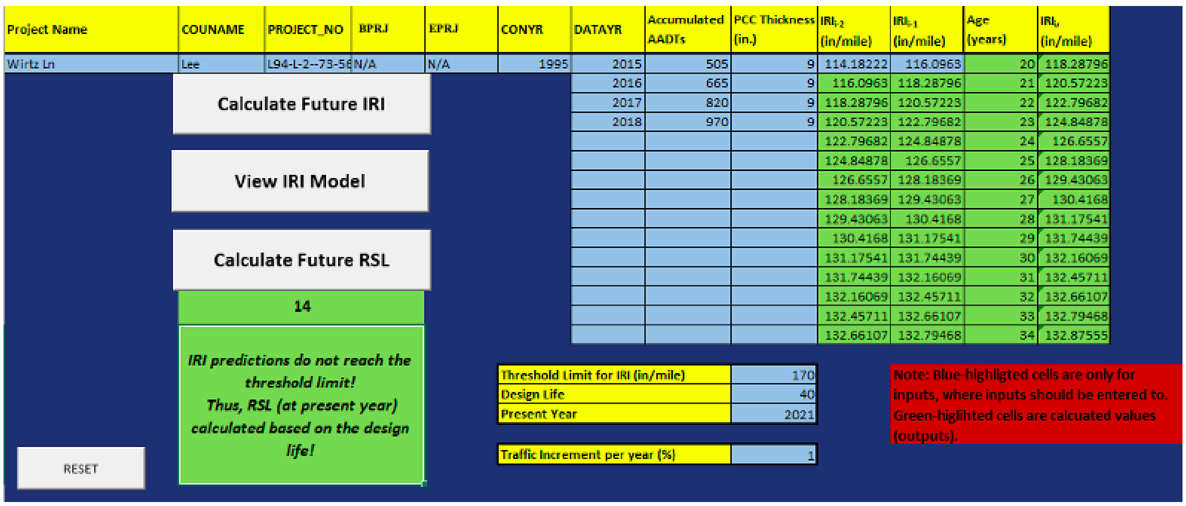


Figure 60. View IRI model (option 1): JPCP (AI-based model)

Predict Pavement RSL

The threshold limit for IRI, design life, and present year parameters were defined, and then the Calculate RSL Based on IRI button was clicked to predict future IRI. The RSL results and descriptions appear under the Calculate RSL Based on IRI button when different scenarios were applied as follows:

- All parameters (170 in./mi, 40 years, 2021) were defined (Figure 61)

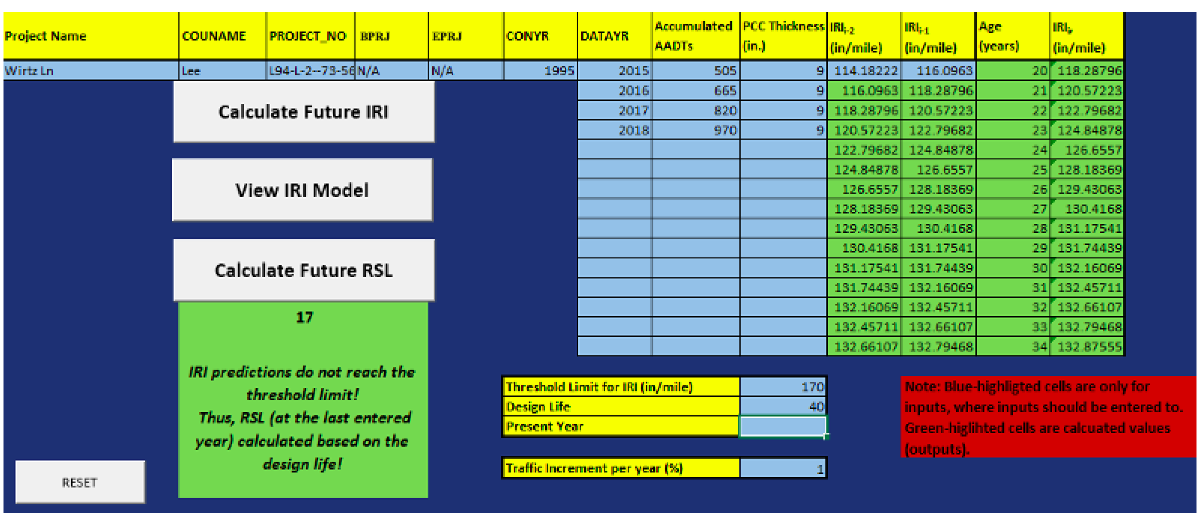


Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	PCC Thickness (in.)	IRI_{t-2} (in/mile)	IRI_{t-1} (in/mile)	Age (years)	IRI_t (in/mile)
Wirtz Ln	Lee	L94-L-2--73-56	N/A	N/A	1995	2015	505	9	114.18222	116.0963	20	118.28796
						2016	665	9	116.0963	118.28796	21	120.57223
						2017	820	9	118.28796	120.57223	22	122.79682
						2018	970	9	120.57223	122.79682	23	124.84878
									122.79682	124.84878	24	126.6557
									124.84878	126.6557	25	128.18369
									126.6557	128.18369	26	129.43063
									128.18369	129.43063	27	130.4168
									129.43063	130.4168	28	131.17541
									130.4168	131.17541	29	131.74439
									131.17541	131.74439	30	132.16069
									131.74439	132.16069	31	132.45711
									132.16069	132.45711	32	132.66107
									132.45711	132.66107	33	132.79468
									132.66107	132.79468	34	132.87555

Threshold Limit for IRI (in/mile)	170
Design Life	40
Present Year	2021
Traffic Increment per year (%)	1

Figure 61. Threshold limit for IRI (170 in./mi), design life (40 years), and present year (2021): JPCP (AI-based model)

- Threshold limit for IRI (170 in./mi) and design life (40 years) were defined (Figure 62)

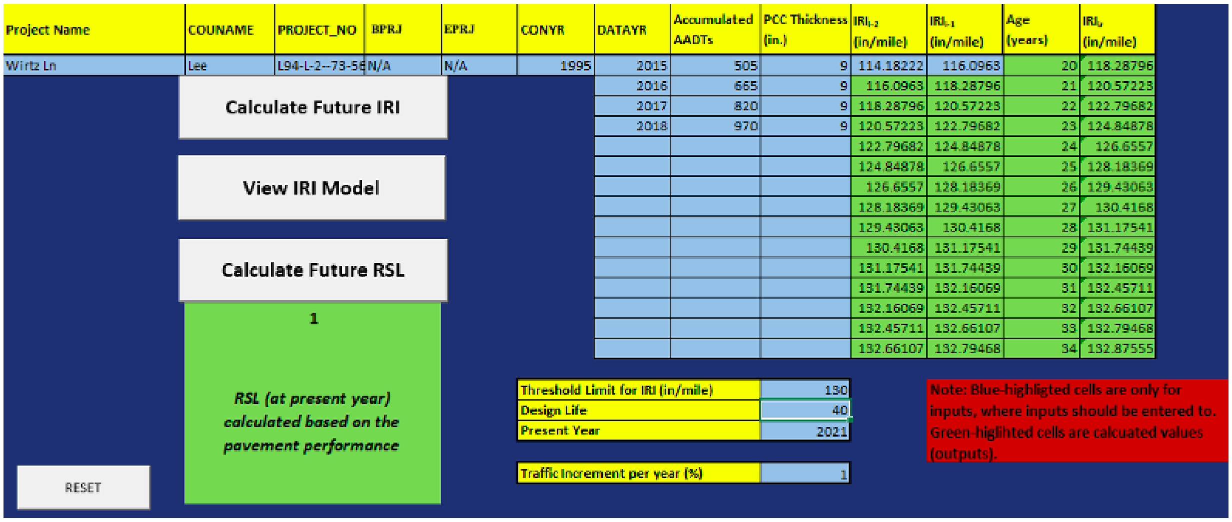


Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	PCC Thickness (in.)	IRI_{t-2} (in/mile)	IRI_{t-1} (in/mile)	Age (years)	IRI_t (in/mile)
Wirtz Ln	Lee	L94-L-2--73-56	N/A	N/A	1995	2015	505	9	114.18222	116.0963	20	118.28796
						2016	665	9	116.0963	118.28796	21	120.57223
						2017	820	9	118.28796	120.57223	22	122.79682
						2018	970	9	120.57223	122.79682	23	124.84878
									122.79682	124.84878	24	126.6557
									124.84878	126.6557	25	128.18369
									126.6557	128.18369	26	129.43063
									128.18369	129.43063	27	130.4168
									129.43063	130.4168	28	131.17541
									130.4168	131.17541	29	131.74439
									131.17541	131.74439	30	132.16069
									131.74439	132.16069	31	132.45711
									132.16069	132.45711	32	132.66107
									132.45711	132.66107	33	132.79468
									132.66107	132.79468	34	132.87555

Threshold Limit for IRI (in/mile)	170
Design Life	40
Present Year	
Traffic Increment per year (%)	1

Figure 62. Threshold limit for IRI (170 in./mi) and design life (40 years): JPCP (AI-based model)

- Different threshold limit for IRI (140 in./mi), design life (40 years), and present year (2021) were defined (Figure 63)



Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	PCC Thickness (in.)	IRI_{t-2} (in/mile)	IRI_{t-1} (in/mile)	Age (years)	IRI_t (in/mile)
Wirtz Ln	Lee	L94-L-2--73-56	N/A	N/A	1995	2015	505	9	114.18222	116.0963	20	118.28796
						2016	665	9	116.0963	118.28796	21	120.57223
						2017	820	9	118.28796	120.57223	22	122.79682
						2018	970	9	120.57223	122.79682	23	124.84878
									122.79682	124.84878	24	126.6557
									124.84878	126.6557	25	128.18369
									126.6557	128.18369	26	129.43063
									128.18369	129.43063	27	130.4168
									129.43063	130.4168	28	131.17541
									130.4168	131.17541	29	131.74439
									131.17541	131.74439	30	132.16069
									131.74439	132.16069	31	132.45711
									132.16069	132.45711	32	132.66107
									132.45711	132.66107	33	132.79468
									132.66107	132.79468	34	132.87555

Threshold Limit for IRI (in/mile)	130
Design Life	40
Present Year	2021
Traffic Increment per year (%)	1

Figure 63. Threshold limit for IRI (130 in./mi), design life (40 years), and present year (2021): JPCP (AI-based model)

AC Case: Statistics-Based Model

Select Predictive Model Types

The statistics-based model was selected as seen in Figure 64.

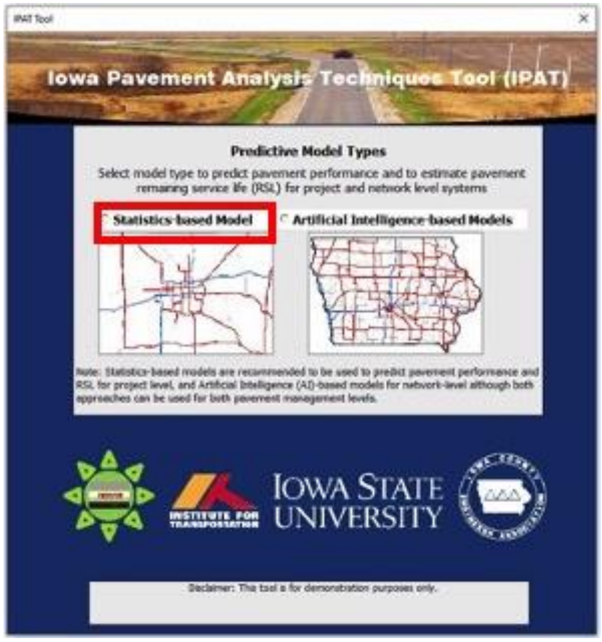


Figure 64. Select predictive model type: statistics-based model

Select Pavement Type

AC (asphalt) pavement type was selected as shown in Figure 65.

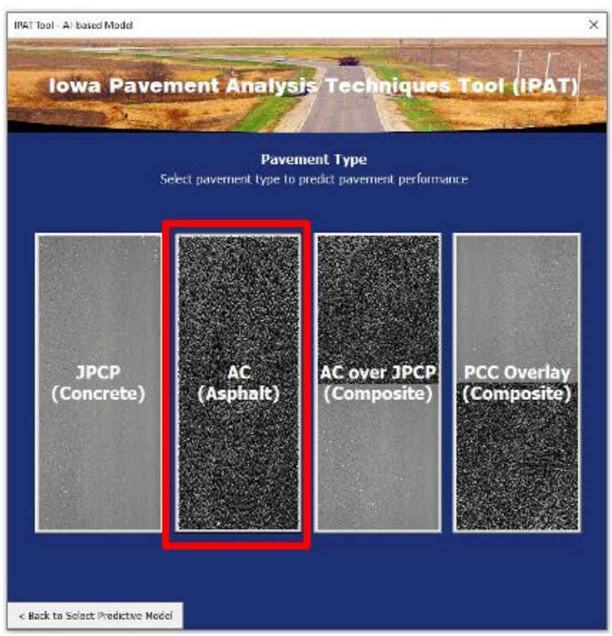


Figure 65. Select pavement type: AC (asphalt)

Select Pavement Performance Indicator

IRI, as a pavement performance indicator, was selected, questions are answered (Figure 66) and required road information is entered (Figure 67). Then, the launch tool button is clicked to launch the sub-tool.

Figure 66. Select pavement performance indicator and preparation of data: IRI (statistics-based model)

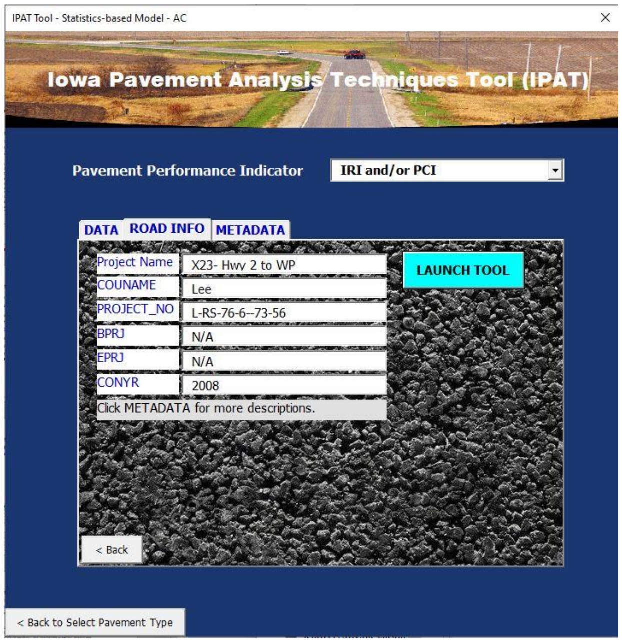


Figure 67. Enter required data information: county AC (statistics-based model)

Enter Inputs

The entered data information in IPAT main tool was transferred into the IPAT sub-tool as shown in Figure 68.

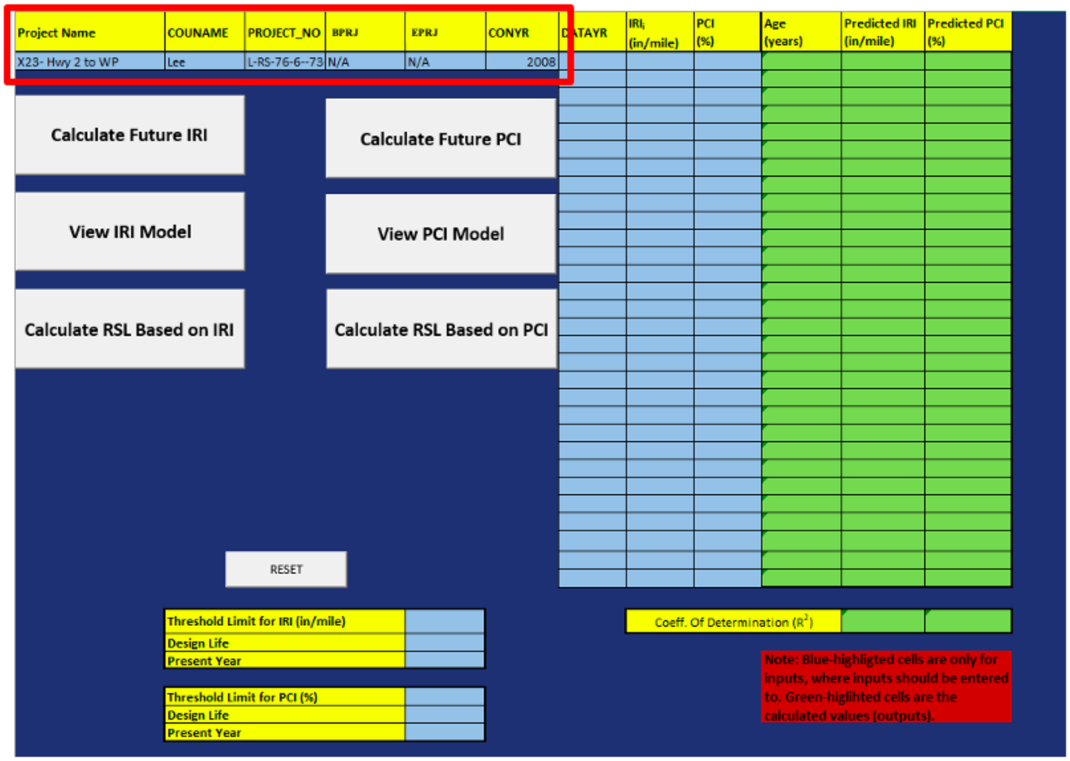


Figure 68. Transfer data information into IPAT sub-tool: AC (statistics-based model)

The columns of DATAYR and IRI_i were filled based on available data as shown in Figure 69.

Figure 69. Calculate future IRI: AC (statistics-based model)

Predict Pavement Performance

The Calculate Future IRI button was clicked and future IRI was predicted (Figure 70).

Figure 70. Calculate future IRI: AC (statistics-based model)

Then, the View IRI Model button is clicked, which shows the plotted deterioration curve based on the field and predicted IRI data (

Figure 71).

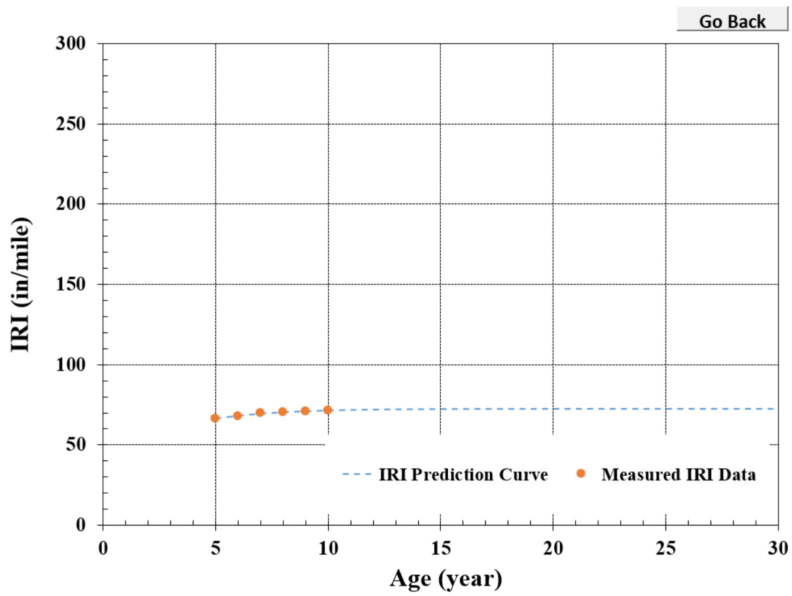


Figure 71. View IRI model: AC (statistics-based model)

Predict Pavement RSL

The threshold limit for IRI, design life, and present year parameters were defined, and then the Calculate RSL Based on IRI button was clicked to predict future IRI. The RSL results and descriptions appear under the Calculate RSL Based on IRI button when different scenarios were applied as follows:

- All parameters (170 in./mi, 40 years, 2021) were defined (Figure 72)

Figure 72. Threshold limit for IRI (170 in./mi), design life (40 years), and present year (2021): AC (statistics-based model)

- Threshold limit for IRI (170 in./mi) and design life (40 years) were defined (Figure 73)

Figure 73. Threshold limit for IRI (170 in./mi) and design life (40 years): AC (statistics-based model)

AC Case: AI-Based Model

Select Predictive Model Types

The AI-based model was selected as shown in Figure 74.

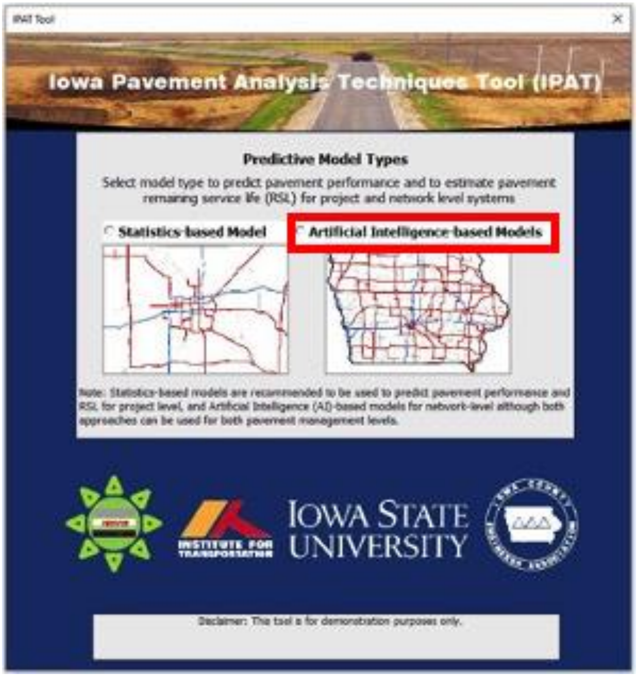


Figure 74. Select predictive model type: AI-based model

Select Pavement Type

AC (asphalt) pavement type was selected as seen in Figure 75.

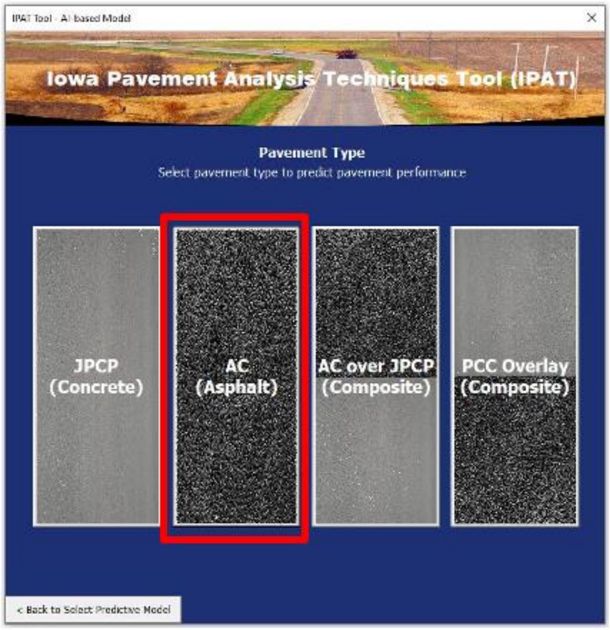


Figure 75. Select pavement type: AC (asphalt)

Select Pavement Performance Indicator

IRI, as a pavement performance indicator, was selected, questions are answered (Figure 76), and required road information is entered (Figure 77). Then, the launch tool button is clicked to launch the sub-tool.

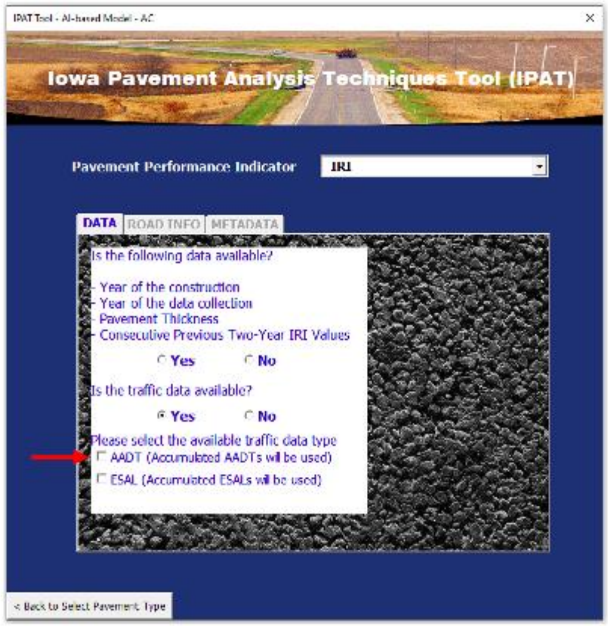


Figure 76. Select pavement performance indicator and preparation of data: IRI (AI-based model)

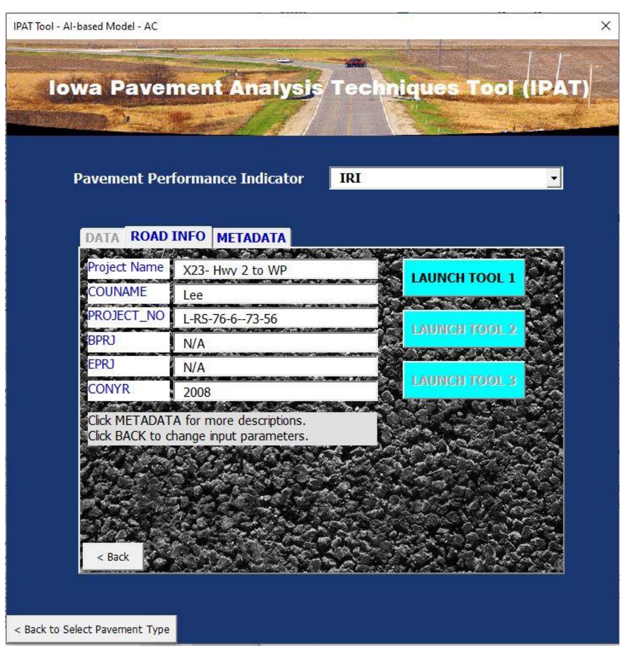


Figure 77. Enter required data information: county AC (AI-based model)

Enter Inputs

The entered data information in the IPAT main tool was transferred into the IPAT sub-tool as shown in Figure 78.

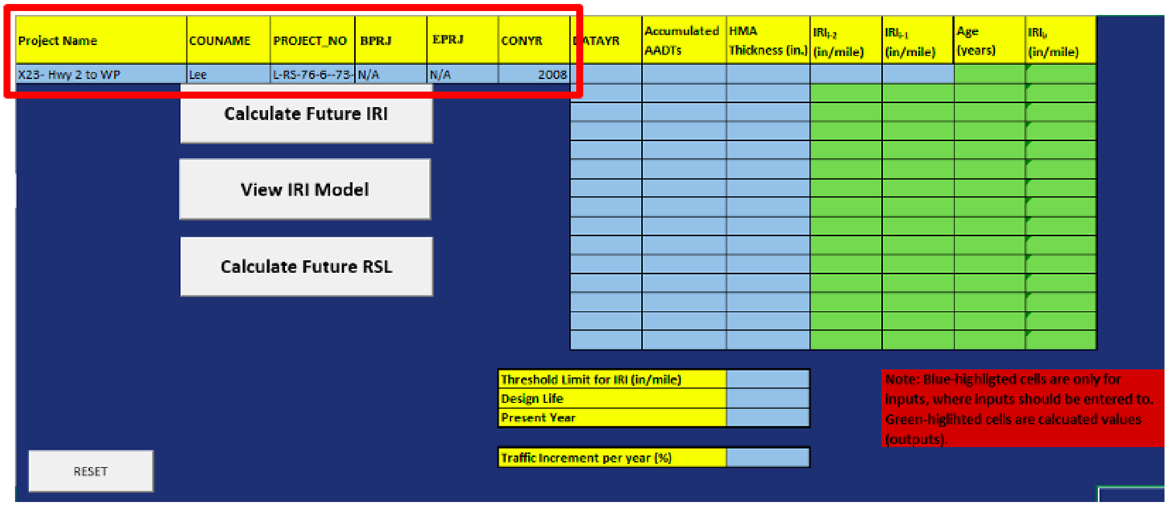


Figure 78. Transfer data information into IPAT sub-tool: AC (AI-based model)

The columns of DATAYR, Accumulated AADT, HMA Thickness, IRI_{i-2}, and IRI_{i-1} were filled based on available data as shown in Figure 79 and Figure 80.

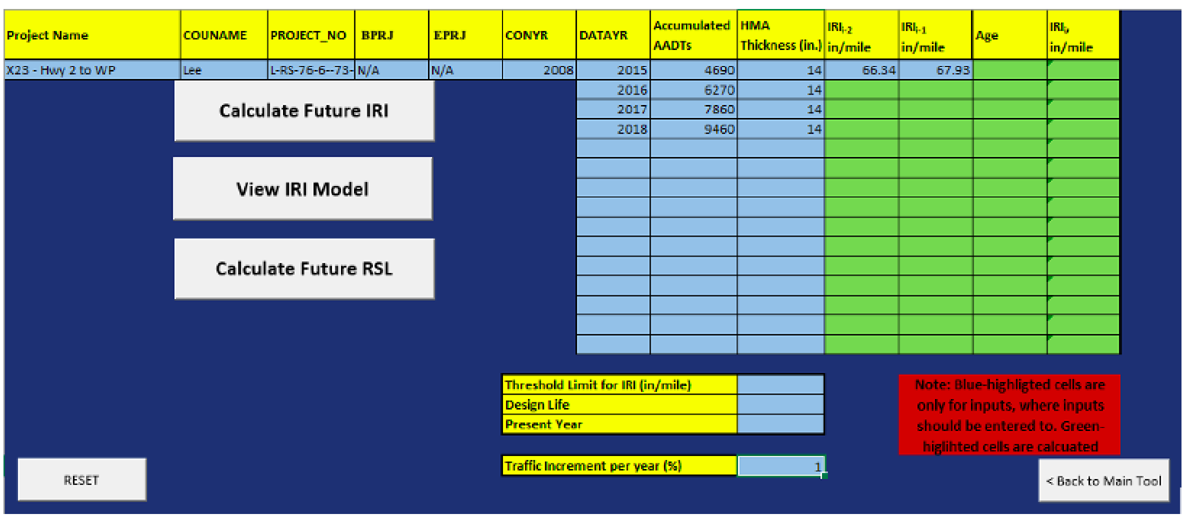


Figure 79. Option 1: Enter existing input parameters and traffic increment per year: AC (AI-based model)

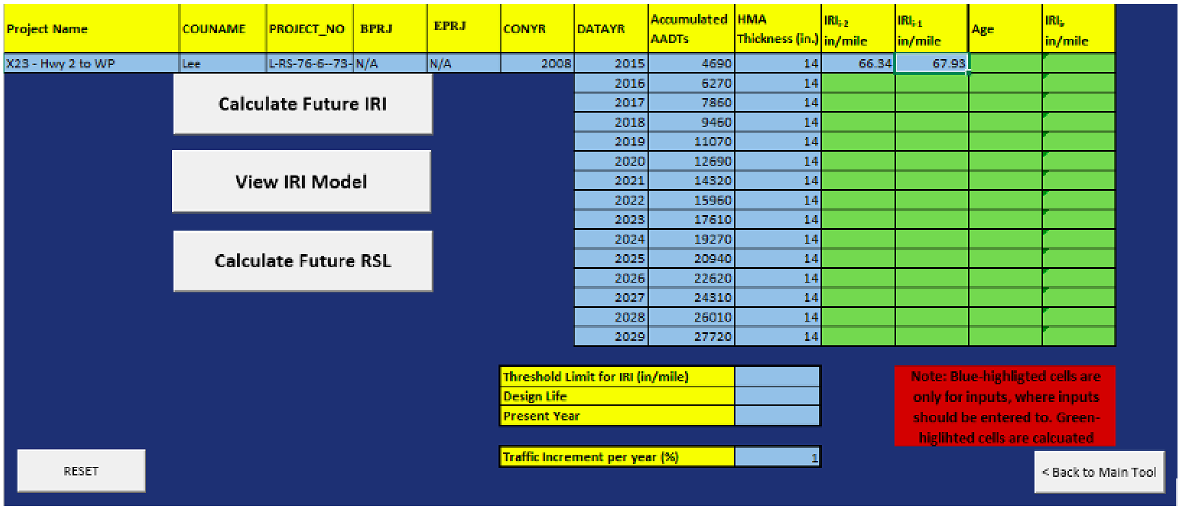


Figure 80. Option 2: Enter existing and prepared input parameters without defining traffic increment per year: AC (AI-based model)

Here, there are two options to enter future input parameters: (1) the existing input parameters and defining traffic increment per year (%) to calculate future input parameters (Figure 81), and (2) the existing and prepared future input parameters without defining traffic increment per year (%) (Figure 80).

Predict Pavement Performance

The Calculate Future IRI button was clicked and future IRI was predicted (Figure 81 and Figure 82).

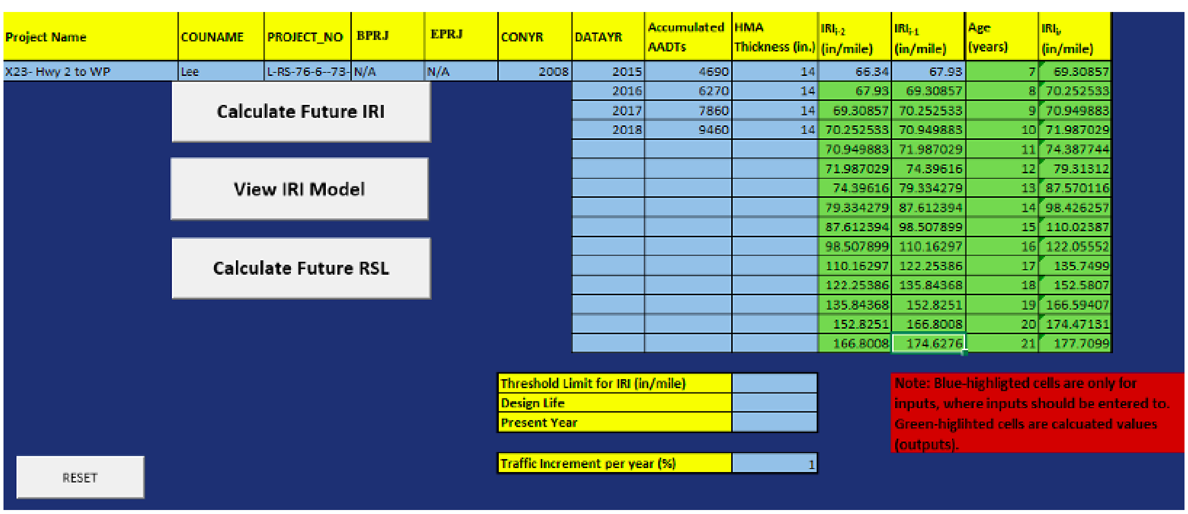
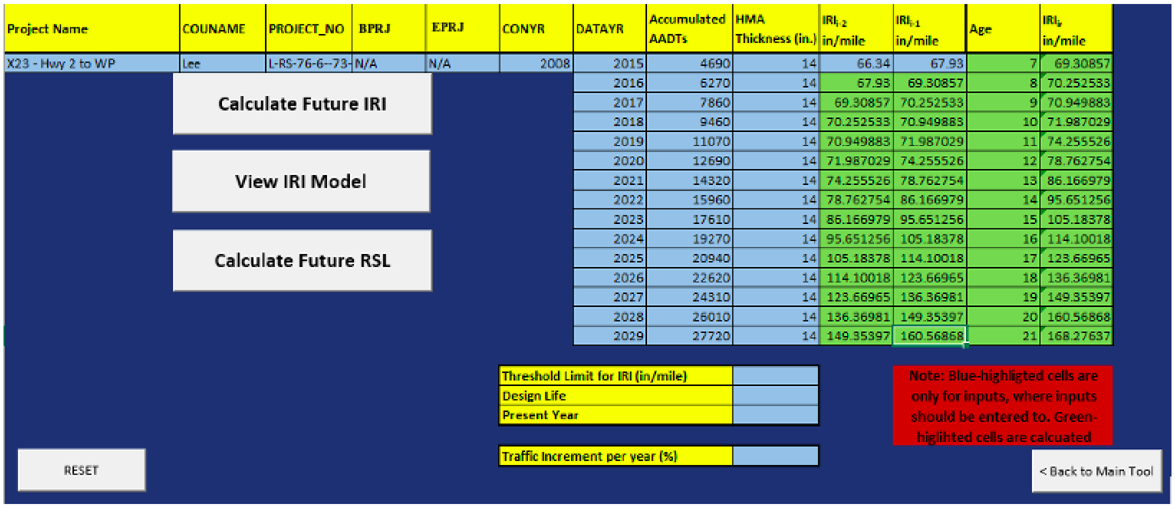


Figure 81. Option 1: Calculate future IRI: AC (AI-based model)



Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	HMA Thickness (in.)	IRI_{i-2} in/mile	IRI_{i-1} in/mile	Age	IRI_i in/mile
X23 - Hwy 2 to WP	Lee	L-RS-76-6--73-	N/A	N/A	2008	2015	4690	14	66.34	67.93	7	69.30857
						2016	6270	14	67.93	69.30857	8	70.252533
						2017	7860	14	69.30857	70.252533	9	70.949883
						2018	9460	14	70.252533	70.949883	10	71.987029
						2019	11070	14	70.949883	71.987029	11	74.255526
						2020	12690	14	71.987029	74.255526	12	78.762754
						2021	14320	14	74.255526	78.762754	13	86.166979
						2022	15960	14	78.762754	86.166979	14	95.651256
						2023	17610	14	86.166979	95.651256	15	105.18378
						2024	19270	14	95.651256	105.18378	16	114.10018
						2025	20940	14	105.18378	114.10018	17	123.66965
						2026	22620	14	114.10018	123.66965	18	136.36981
						2027	24310	14	123.66965	136.36981	19	149.35397
						2028	26010	14	136.36981	149.35397	20	160.56868
						2029	27720	14	149.35397	160.56868	21	168.27637

Figure 82. Option 2: Calculate future IRI: AC (AI-based model)

Then, the View IRI Model button was clicked, which shows the plotted deterioration curve based on the field and predicted IRI data (Figure 83).

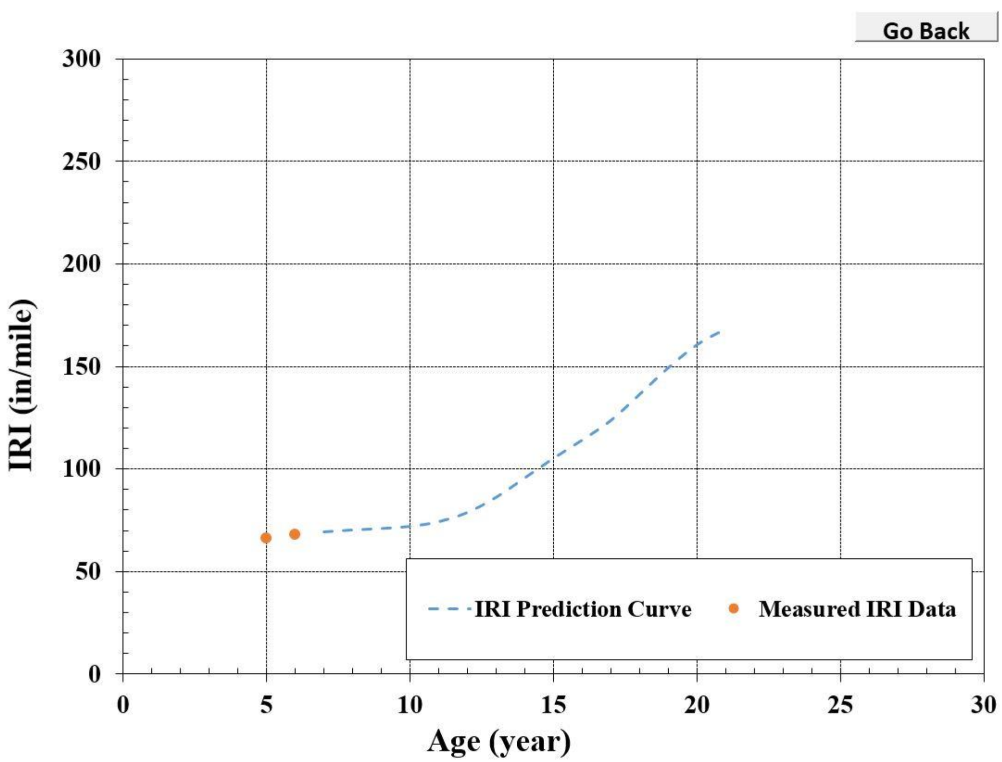
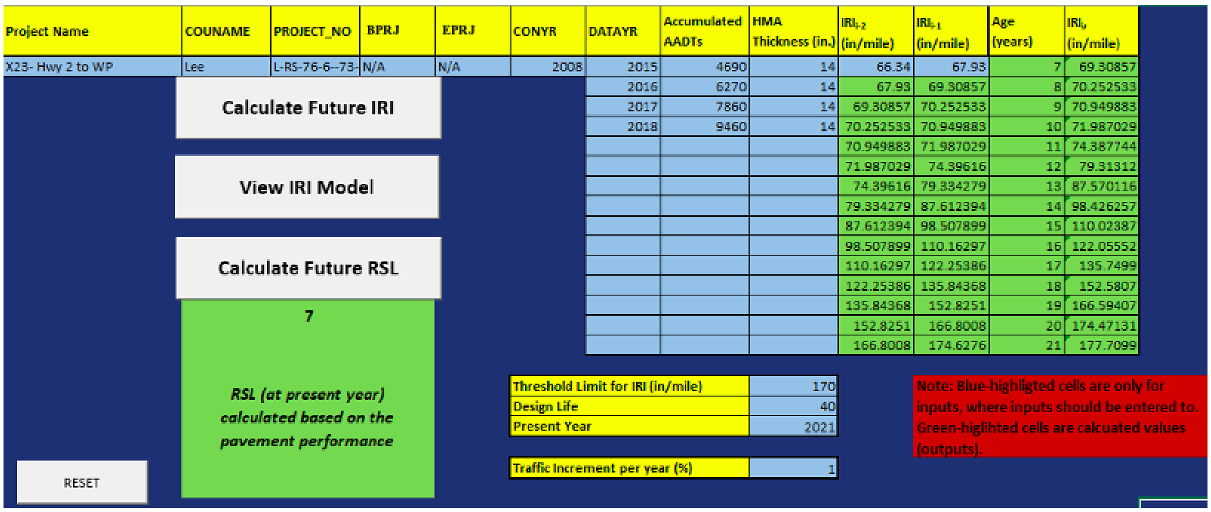


Figure 83. View IRI model (option 1): AC (AI-based model)

Predict Pavement RSL

The threshold limit for IRI, design life, and present year parameters were defined, and then the Calculate RSL Based on IRI button was clicked to predict future IRI. The RSL results and descriptions appear under the Calculate RSL Based on IRI button when different scenarios were applied as follows:

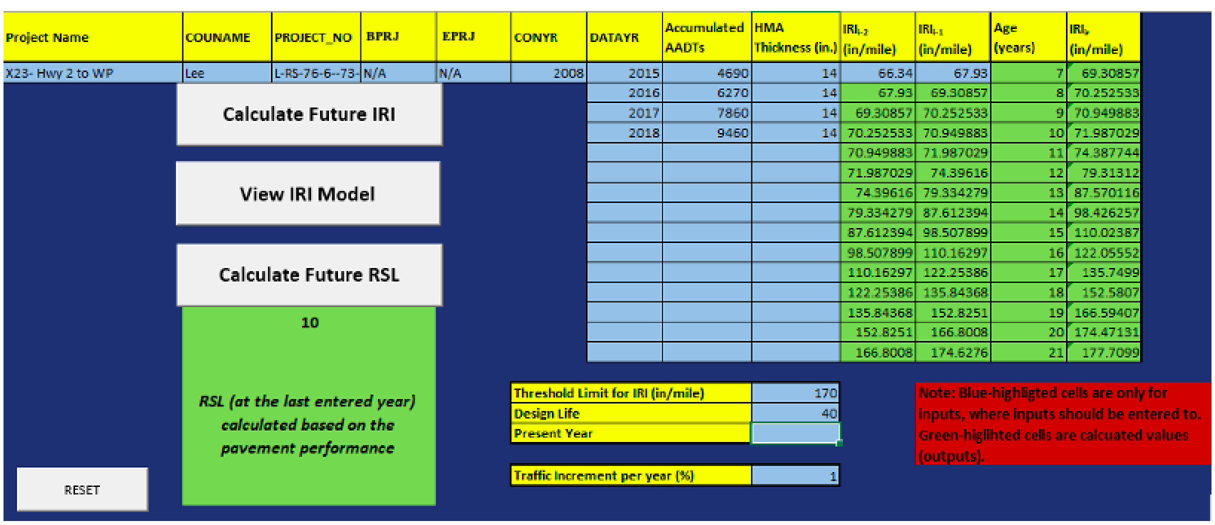
- All parameters (170 in./mi, 40 years, 2021) were defined (Figure 84)



Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	HMA Thickness (in.)	IRI_{t-2} (in/mile)	IRI_{t-1} (in/mile)	Age (years)	IRI_t (in/mile)
X23- Hwy 2 to WP	Lee	L-RS-76-6--73-	N/A	N/A	2008	2015	4690	14	66.34	67.93	7	69.30857
						2016	6270	14	67.93	69.30857	8	70.252533
						2017	7860	14	69.30857	70.252533	9	70.949883
						2018	9460	14	70.252533	70.949883	10	71.987029
									70.949883	71.987029	11	74.387744
									71.987029	74.39616	12	79.31312
									74.39616	79.334279	13	87.570116
									79.334279	87.612394	14	98.426257
									87.612394	98.507899	15	110.02387
									98.507899	110.16297	16	122.05552
									110.16297	122.25386	17	135.7499
									122.25386	135.84368	18	152.5807
									135.84368	152.8251	19	166.59407
									152.8251	166.8008	20	174.47131
									166.8008	174.6276	21	177.7099

Figure 84. Threshold limit for IRI (170 in./mi), design life (40 years), and present year (2021): AC (AI-based model)

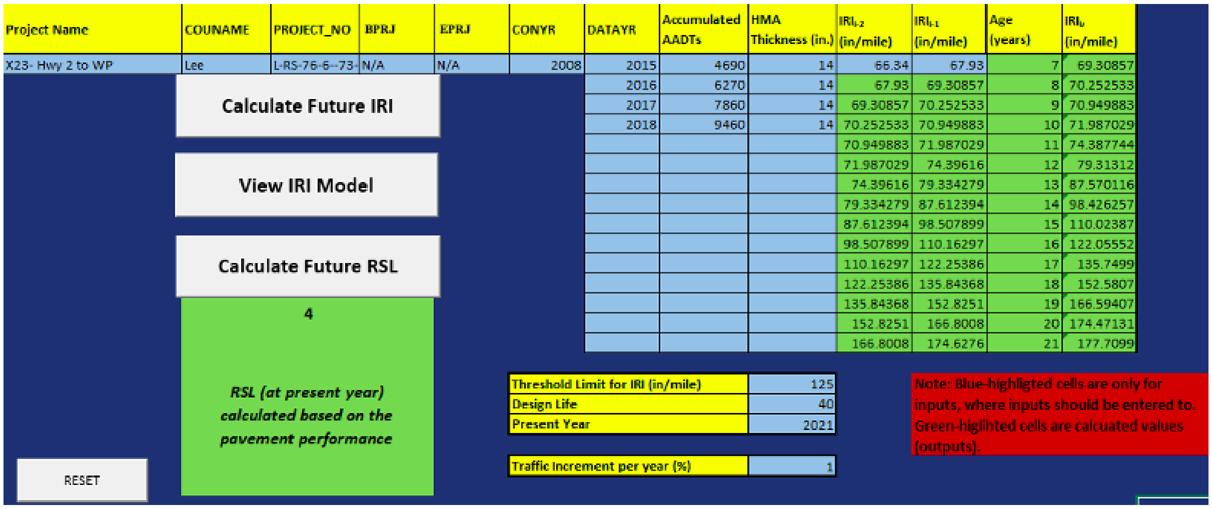
- Threshold limit for IRI (170 in./mi) and design life (40 years) were defined (Figure 85)



Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	HMA Thickness (in.)	IRI_{t-2} (in/mile)	IRI_{t-1} (in/mile)	Age (years)	IRI_t (in/mile)
X23- Hwy 2 to WP	Lee	L-RS-76-6--73-	N/A	N/A	2008	2015	4690	14	66.34	67.93	7	69.30857
						2016	6270	14	67.93	69.30857	8	70.252533
						2017	7860	14	69.30857	70.252533	9	70.949883
						2018	9460	14	70.252533	70.949883	10	71.987029
									70.949883	71.987029	11	74.387744
									71.987029	74.39616	12	79.31312
									74.39616	79.334279	13	87.570116
									79.334279	87.612394	14	98.426257
									87.612394	98.507899	15	110.02387
									98.507899	110.16297	16	122.05552
									110.16297	122.25386	17	135.7499
									122.25386	135.84368	18	152.5807
									135.84368	152.8251	19	166.59407
									152.8251	166.8008	20	174.47131
									166.8008	174.6276	21	177.7099

Figure 85. Threshold limit for IRI (170 in./mi) and design life (40 years): AC (AI-based model)

- Different threshold limit for IRI (125 in./mi), design life (40 years), and present year (2021) were defined (Figure 86)

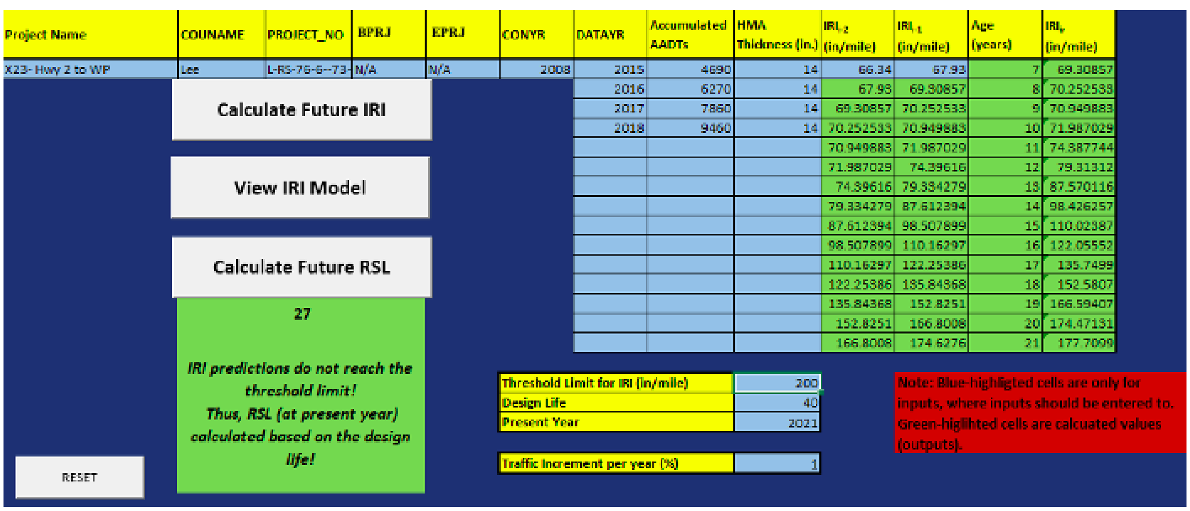


Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	HMA Thickness (in.)	IRI_{t-2} (in/mile)	IRI_{t-1} (in/mile)	Age (years)	IRI_t (in/mile)
X23- Hwy 2 to WP	Lee	L-RS-76-6--73-	N/A	N/A	2008	2015	4690	14	66.34	67.93	7	69.30857
						2016	6270	14	67.93	69.30857	8	70.252533
						2017	7860	14	69.30857	70.252533	9	70.949883
						2018	9460	14	70.252533	70.949883	10	71.987029
									70.949883	71.987029	11	74.387744
									71.987029	74.39616	12	79.31312
									74.39616	79.334279	13	87.570116
									79.334279	87.612394	14	98.426257
									87.612394	98.507899	15	110.02387
									98.507899	110.16297	16	122.05552
									110.16297	122.25386	17	135.7499
									122.25386	135.84368	18	152.5807
									135.84368	152.8251	19	166.59407
									152.8251	166.8008	20	174.47131
									166.8008	174.6276	21	177.7099

Threshold Limit for IRI (in/mile)	125
Design Life	40
Present Year	2021
Traffic Increment per year (%)	1

Figure 86. Threshold limit for IRI (125 in./mi), design life (40 years), and present year (2021): AC (AI-based model)

- Different threshold limit for IRI (200 in./mi), design life (40 years), and present year (2021) were defined (Figure 87)



Project Name	COUNAME	PROJECT_NO	BPRJ	EPRJ	CONYR	DATAYR	Accumulated AADTs	HMA Thickness (in.)	IRI_{t-2} (in/mile)	IRI_{t-1} (in/mile)	Age (years)	IRI_t (in/mile)
X23- Hwy 2 to WP	Lee	L-RS-76-6--73-	N/A	N/A	2008	2015	4690	14	66.34	67.93	7	69.30857
						2016	6270	14	67.93	69.30857	8	70.252533
						2017	7860	14	69.30857	70.252533	9	70.949883
						2018	9460	14	70.252533	70.949883	10	71.987029
									70.949883	71.987029	11	74.387744
									71.987029	74.39616	12	79.31312
									74.39616	79.334279	13	87.570116
									79.334279	87.612394	14	98.426257
									87.612394	98.507899	15	110.02387
									98.507899	110.16297	16	122.05552
									110.16297	122.25386	17	135.7499
									122.25386	135.84368	18	152.5807
									135.84368	152.8251	19	166.59407
									152.8251	166.8008	20	174.47131
									166.8008	174.6276	21	177.7099

Threshold Limit for IRI (in/mile)	200
Design Life	40
Present Year	2021
Traffic Increment per year (%)	1

Figure 87. Threshold limit for IRI (200 in./mi), design life (40 years), and present year (2021): AC (AI-based model)

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