INFRASTRUCTURE CONDITION EVALUATION

ICE TECHNICAL MEMO

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Updated October 2023

IOWA DOT

LIST OF FIGURES AND TABLES

1. INTRODUCTION

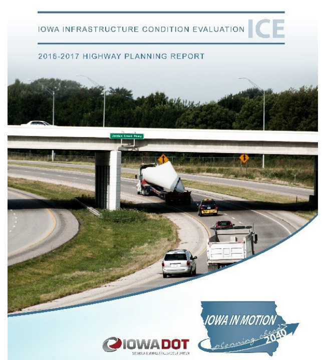
To aid in the evaluation of the Primary Highway System, the Iowa Department of Transportation's Systems Planning Bureau has developed a tool that measures the most recent known performance and condition data related to the roadway network.

This tool generates a composite rating that is calculated from the weighted scores of seven different criteria. The score of each individual criterion is calculated from a Linear Referencing System (LRS) overlay.

The overlay is completed using Transcend Spatial Solutions' Segment Analyzer, which generates a linear feature class with measures and geometries from the RAMS LRS network and places it within an enterprise geodatabase. A Structured Query Language (SQL) script generates new tables from the tabular data within the feature class and calculates new fields used for normalization, weighting, and composite rating. The maps, charts, and diagrams presented within this report present the information generated by the script.

1.1 Purpose and need for an annual report

Beginning with its initial development, the purpose of the ICE tool was to provide the Iowa DOT with an initial screening and relative prioritization of corridors/segments. This process now evaluates Iowa's Primary Highway System, independent of current financial constraints, using a select group of criteria weighted in terms of their relative significance. The resulting segments highlight areas that may be considered for further study. While this initial screening will aid the Iowa DOT in identifying those areas to be considered for further study, the report will not identify specific projects or alternatives that could be directly inputted into the programming process.



In 2016, the ICE tool was enhanced to include a more granular set of corridors while addressing an identical set of goals and objectives. This resulted in the definition of 467 corridors (previously 283), meant to provide a more accurate snapshot of current conditions across the Primary Highway System. Defined by logical breaks in the system, the updated corridors provide specific termini that should see limited change from year to year.

This analysis was again refined in 2019 (data year 2018). Analysis corridors were modified to reflect changes to the primary network. There are 465 active corridors as of the 2021 data year.

Enhancements to the project include:

- eliminating workarounds necessitated by the retirement of legacy systems,
- integrating more directly with enterprise data systems for storage and processing, and
- utilizing scripting and spatial ETL tools (Extract, Transform, Load) to enhance the repeatability of the analysis.

With the production of each annual report, Systems Planning Bureau attempts to provide objective data analysis using internal data sources to track and manage corridor level data. By maintaining consistency on an annual basis, the ICE tool can provide yearly trend data within each report. As stakeholder needs continue to evolve, the ICE tool attempts to provide flexibility and a means for studying the changes on Iowa's primary road network.

1.2 Current and future uses

The ICE data included in the annual report provides corridor level analysis and serves as a valuable input to several different processes within the Iowa DOT. The report and tool provide a simple summary of data to support the programming analysis that has traditionally been conducted. Other current and future uses of the ICE tool include the following.

VCAP

The Value, Condition, and Performance (VCAP) matrix is a highway analysis tool developed to leverage the multiple tools available at Iowa DOT to help identify and prioritize locations for highway freight improvements on the Primary Highway System. The analysis uses INRIX-identified bottlenecks to populate a list of candidate locations. These locations are ranked based on the bottleneck duration and/or prioritization and represent the performance portion of the VCAP tool. Then, locations are evaluated using the Iowa Travel Analysis Model (iTRAM) to measure the vehicle hours traveled (VHT) cost-reduction benefit. This component serves as the value portion of the VCAP analysis. Lastly, ICE is used to evaluate the current conditions at each location by selecting and analyzing the segmentation from the initial list of INRIX bottleneck locations.

After each location is assigned a Value, Condition, and Performance rating, they are ranked using values from the three categories. The average of these three rankings is calculated and the locations are assigned an overall priority rank. If two locations have the same average ranking, total truck traffic at the location is used as a tiebreak. The final list of locations in the VCAP matrix serves as a critical piece for prioritizing candidate locations for highway freight improvements in the Iowa State Freight Plan.

Transportation Systems Management and Operations

The Traffic Operations Bureau has developed a suite of Transportation Systems Management and Operations (TSMO) plans which utilize and expand upon the ICE methodology for data analysis. Originating from the ICE tool structure, the ICE-OPS concept utilizes a similar normalization and weighting structure and composite scoring approach to compare primary system corridors defined by the ICE tool. The tool is meant to provide a detailed analysis for highway corridors using ten different criteria, which include:

- Annual Average Daily Traffic (AADT)
- Annual bottleneck duration
- Incident Density
- Crash rate
- Buffer Time Index
- Event center proximity
- Flood event density
- Winter weather sensitive mileage
- Freight network mileage
- ICE composite rating

A final composite rating is then used to provide a relative ranking for each corridor. Like the ICE tool, raw data from each criterion is supported in an Excel table and summarized in a final output table using Feature Manipulation Engine (FME).

Corridor studies

Although the ICE corridors were defined by natural breaks in the primary highway network, corridor termini can be adjusted to meet any user-specific needs. Shortening or lengthening the corridors is a simple process that can be conducted with GIS software. The segments and corridor analysis can be shown spatially in addition to providing the data in an Excel spreadsheet. As a result, the ICE tool can provide comparative analysis for corridor study efforts.

Statewide Long Range Transportation Plan

In the most recent update of the Iowa DOT's Statewide Long Range Transportation Plan, the corridors defined by the ICE process provided the structure for evaluating the condition of Iowa's Primary Highway System. The expanded corridor list offers a corridor-level approach for identifying potential improvement needs in the plan. As part of the analysis structure, the lowest 25 percent of corridors by ICE rating were identified and serve as one layer of the needs identification process. Along with being identified in the plan, ICE output is incorporated into the DOT's project scoping tool, which enables project sponsors to use this information as they begin to scope projects.

Road Analyzer

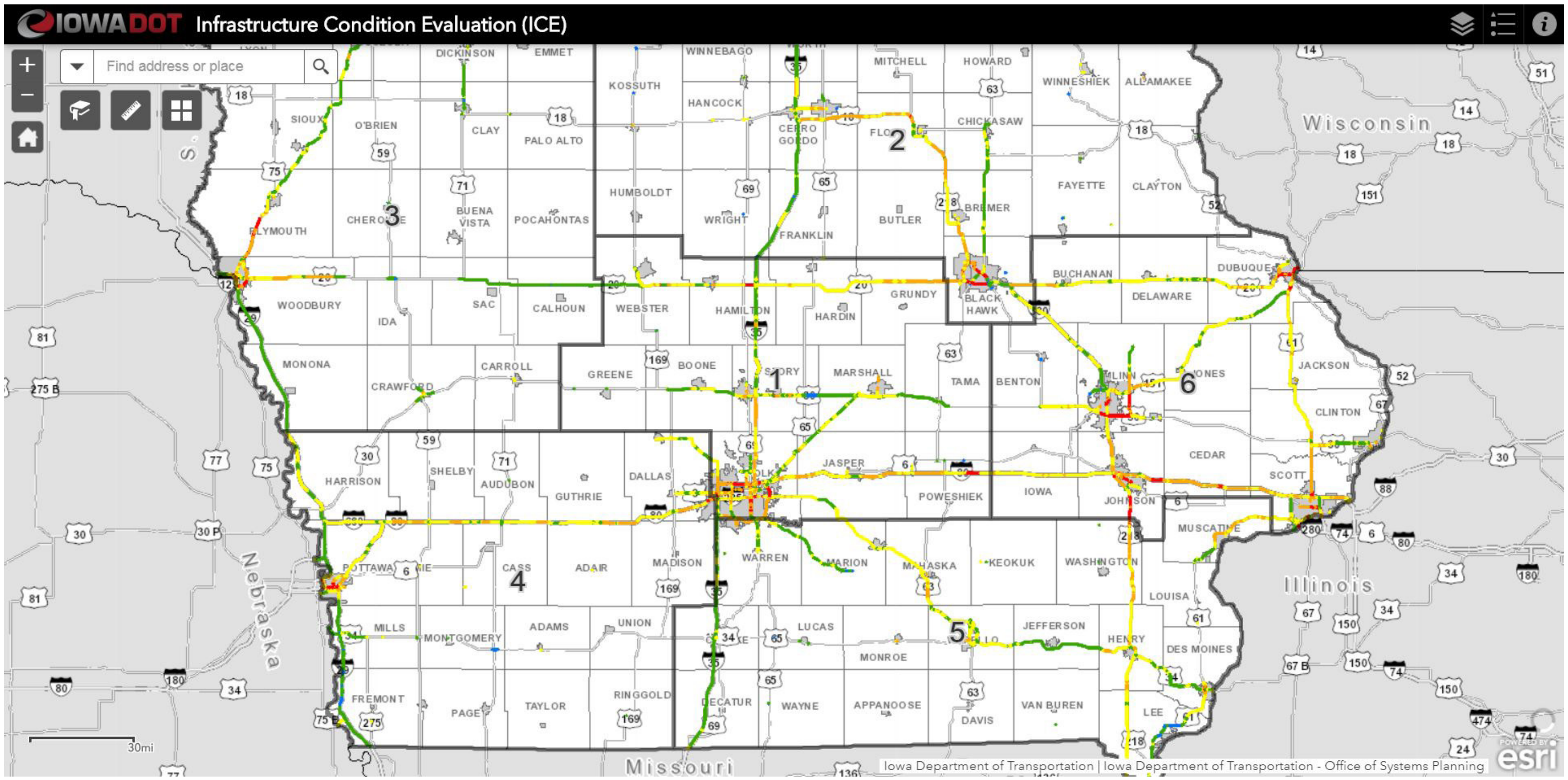
With the DOT's roadway asset management system (RAMS), one of the tools used to analyze data is called Road Analyzer, which provides the ability to visualize data using an interactive straight-line diagram. The tool is accessed online and provides the user flexibility to display data most relevant to them.

This tool provides an opportunity for ICE users to better interact with the dataset giving more control for personalized viewing. Some of the other features include Google street view, dashboarding, data exports, and customizable display preferences. Each of the features included within Road Analyzer makes it a user-friendly method of consuming ICE data.

1.3 Data access

The primary location of the ICE data outside of the annual report is on the Iowa DOT Web map powered by ArcGIS online. Within this Web map, users can explore the ICE data across the entire system and display those results visually. By clicking on the line features within the Web map, the GIS platform displays a popup box that contains the route, county, length, and the normalization values of each of the seven criteria among others. Each of the data layers contains a description of the data and can be toggled on and off to display the ICE ratings by individual criteria attributes. Each of the data layers contains a description of the data and can be toggled on and off to display the ICE ratings by individual criterion.

The web map is intended to serve as a quick, visual reference for the public and internal users. For those seeking a simple answer to their condition questions across the state, the web map would be the recommended medium.



ICE web app

Data availability

Once processed, the tabular and spatial data is maintained as several database objects. When possible, geometries are maintained with tabular data. Approximately 35,000 segments are aggregated to the 465 corridors, defined later in the annual data report. A non-exhaustive list of fields that contribute to segmentation of the network can be found in Figure 1.1.

Figure 1.1 Factors Contributing to ICE Segmentation

- Federal Functional Class
- Planning Class
- City
- County
- Urban Area
- Interstate/ Divided/ Non-Divided
- Passenger, Single Unit, Combination Unit AADT
- BCI, PCI, IRI, V/C, AADT (Passenger, SU, Combo)
- ICE Corridor
- RAMS Compatible Routes and Measures for use in overlays
- National Hiqhway System

**Not exhaustive*

Data requests

To access any of the ICE data, the Iowa DOT's Systems Planning Bureau has created a series of tables and maps to house the data generated for the analysis. This data can be aggregated to address user requests and is maintained in such a way that queries can be utilized to fulfill requests in a timely manner.

Esri's ArcGIS Desktop / ArcGIS Pro, and Safe Software's FME was utilized during the development of the ICE tool and shapefiles or a compressed database containing relevant tables and feature classes can be requested by users who are interested in performing their own analysis.

PDF maps of all six DOT Districts, all 99 Counties, and all 63 Urban Areas are created with each annual update. Maps for all 497 incorporated areas that contain an ICE corridor will also be available. Map products beyond the scope of those contained within the annual data report or provided online may be requested.

ICE web map portal

2. EVALUATION CRITERIA & PROCESS

The following sections will summarize the evaluation criteria data that drives the final ICE composite rating.

2.1 Data selection and significance

The data available for use in evaluating highway segments includes many attributes and is maintained in several different locations with RAMS. Each category of data was considered in the evaluation, but ultimately only seven were selected to serve as the core evaluation criteria and foundation of this analysis. These criteria, which are defined in detail in the ensuing section, include the following.

- Annual average daily traffic (AADT), passenger count
- AADT, single-unit truck count
- AADT, combination truck count
- Congestion Index value (V/C)
- International Roughness Index (IRI) value
- Pavement Condition Index (PCI) rating
- Bridge Condition Index (BCI) rating

While each individual criterion offers a different component, they were chosen due to their collective utility in evaluating the service and condition of a roadway segment. Having a clear distinction aligned well with one of the initial goals for the evaluation tool, which was to derive a single composite condition rating for each roadway segment using the data most critical to the evaluation criteria.

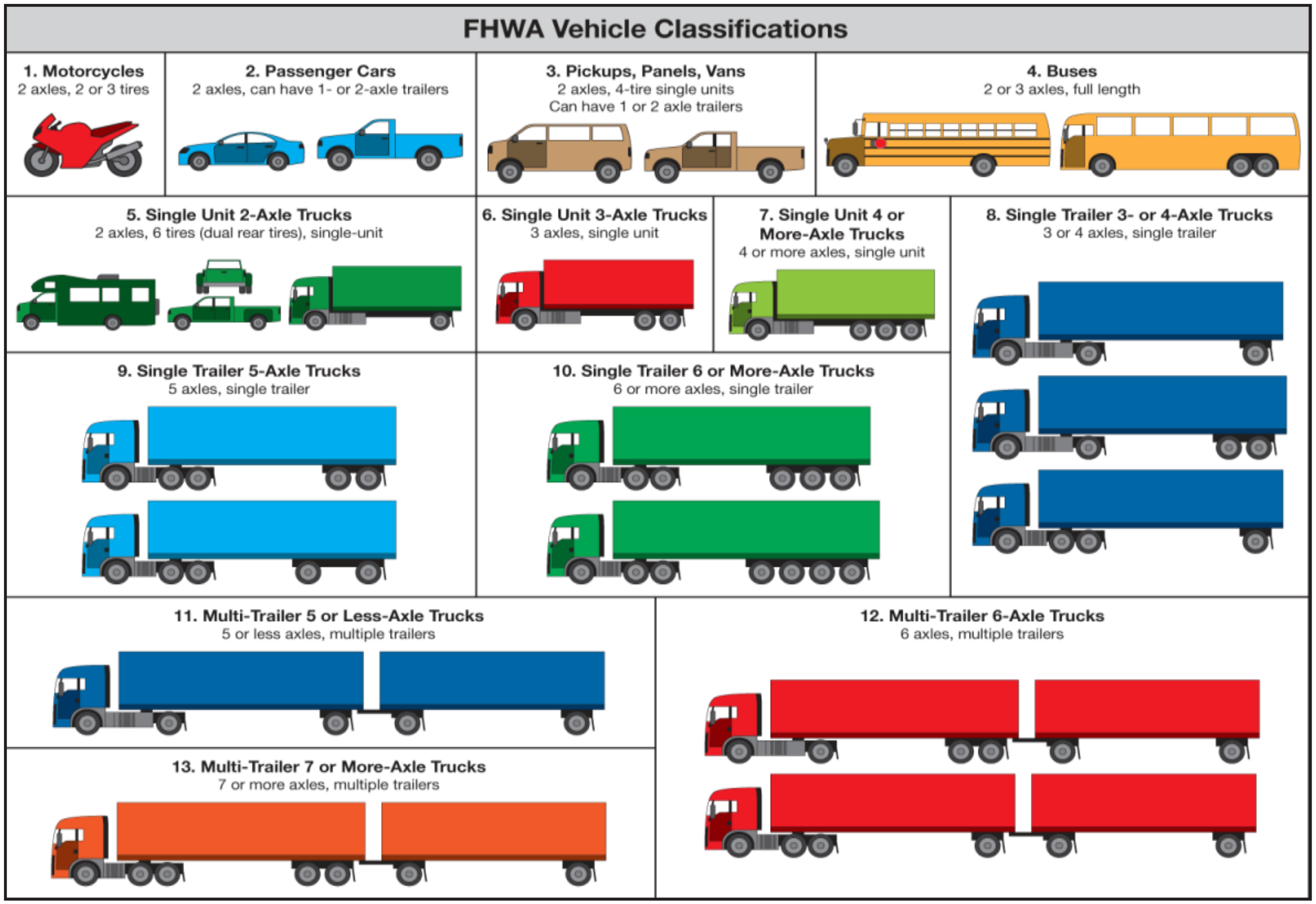
The following information includes a brief definition of the selected data and explains how it is collected and summarized.

AADT

AADT is a general unit of measurement for traffic, which represents the annual average daily traffic that travels a roadway segment. Vehicular traffic counts are collected on a short-term duration using portable counting devices and on a long-term duration using permanent counting devices. Short duration counts ensure geographic diversity and coverage while long-term counts help with understanding time-of-day, day-of-week, and seasonal patterns. Long-term counts are also used to accurately adjust short duration counts into annual estimates of conditions.

The Federal Highway Administration (FHWA) Traffic Monitoring Guide classifies traffic into 13 categories that are illustrated in Figure 2.1. This analysis aggregates total passenger vehicles (1-3), single-unit truck traffic (4–7), and combination truck traffic (8–13).

Figure 2.1: FHWA 13 Classifications for Vehicles



Source: FHWA

Congestion index

The congestion index is a measure that characterizes operational conditions within the flow of traffic. This measure is expressed as a volume-to-capacity (V/C) ratio for a roadway segment. The ratio is an indicator of highway capacity sufficiency, where it is estimated that a facility is congesting as V/C approaches a value of 1. This index emphasizes the relative congestion of primary highway segments to one another.

For the purposes of this report, the Volume (V) is derived from the most recent observed or estimated AADT for segments on the Primary Highway System. Truck traffic is increased by a factor of 1.5 to account for this vehicle type's more significant impact on congestion. Total traffic is converted to a peak hourly rate by applying a peak-hour factor. The peak-hour factor is determined by whether the segment meets criteria to be treated as a rural, suburban, or urban segment.

Capacity (C) is calculated in a manner that is consistent with the method covered within the Iowa Standardized Model Structure (ISMS) Roadway Capacity section. The model establishes segment capacities by multiplying estimated lane capacity by the number of through lanes. Estimated lane capacities are calculated per segment based upon the presence of relevant criteria for that record.

IRI value

IRI is a numerical roughness index that is commonly used to evaluate and manage road systems. Lower IRI values indicate smoother pavements; there is no defined upper limit to IRI. In Iowa, IRI is primarily measured on a rotating two-year cycle and is collected by an outside vendor.

PCI rating

PCI, or Pavement Condition Index, is a value calculated to estimate the average pavement condition over a defined area based on surveyed surface distresses. This number helps identify locations where sections have pavement distresses or do not meet current DOT standards for stable pavements. Values range between 0 and 100.

BCI rating

The bridge condition index (BCI) provides a method of evaluating roadway bridge structures by calculating multiple factors to obtain a numeric value that is indicative of a structure's overall condition/sufficiency. These factors include structural condition, load carrying capacity, horizontal and vertical clearances, width, traffic levels, type of roadway it serves, and the length of out-of-distance travel if the bridge were closed. From there, various reductions are then factored into the rating. Table 2.2 highlights the information that factors into the rating.

The index rating is then calculated using the following formula: S1+S2+S3-S4. A value of 100 represents a wholly sufficient structure, while a value of zero represents an insufficiency or deficient structure. The full structure inventory contains dozens of fields of data, which are used to meet several federal reporting requirements that are set forth in the National Bridge Inspection Standards (23 CFR 640.3). The information is collected through on-site inspections, which are conducted year-round.

Prior to the 2017 analysis, the Federal Highway Administration's Structure Inventory and Appraisal (SIA) Sufficiency rating was used in ICE instead of BCI. However, due to the accuracy provided based on the tailored analysis and real-time inspection/survey updates by the Iowa DOT's Bridges and Structures Bureau staff, BCI has replaced this rating system.

Data snapshot

The project considers the known or estimated state of the primary highway system as of December 31 for each analysis year. PCI data is collected on a two-year cycle, and half of the state network is collected every year. BCI scores are generated from the annual FHWA bridge submittal. The bridge data is transmitted to FHWA in Q1 the *following* year (typically March).

Table 2.2: Bridge Condition Index Rating

Summary	Alias	Weight	Item description
Structural Adequacy & Safety	S1	55%	Superstructure
			Substructure
			Deck
			Culvert
			Inventory Ranking
Serviceability and Functional Obsolescence	S2	30%	Bridge Roadway Width
			Under Clearances
			Waterway Adequacy
Essentiality for Public Use	S3	15%	Detour Length
			AADT
			Highway System Designation
Special Reductions	S4	11%	Fracture Critical
			Fatigue Vulnerability
			Channel Protection

Source: Iowa DOT Bridges and Structures Bureau

2.2 Linear overlay and system segmentation

The core of the annual data report contains results from the evaluation tool itself. It combines data from both the Iowa DOT's RAMS and Pavement Management Information System (PMIS) and merges the data using overlays to create a feature class. The feature class is output to an Oracle database.

The feature class is then analyzed with a SQL script to achieve the data normalization, weighting, and the composite ratings outlined in the following section. Maps of the data are prepared using ArcGIS Pro.

System segmentation

The linear overlay process segments the network based on specified attributes when more than one data set are used. Original data is stored within tables with routes and measures, which are used to relate that data to locations on the centerline network (see Figure 2.3). In applying the analysis used in the annual data report, the primary system was divided into approximately 35,000 segments (segments less than 1 ft. long are later removed. (see Figure 2.4)

Figure 2.3: Linear Overlay Data Model, ESRI

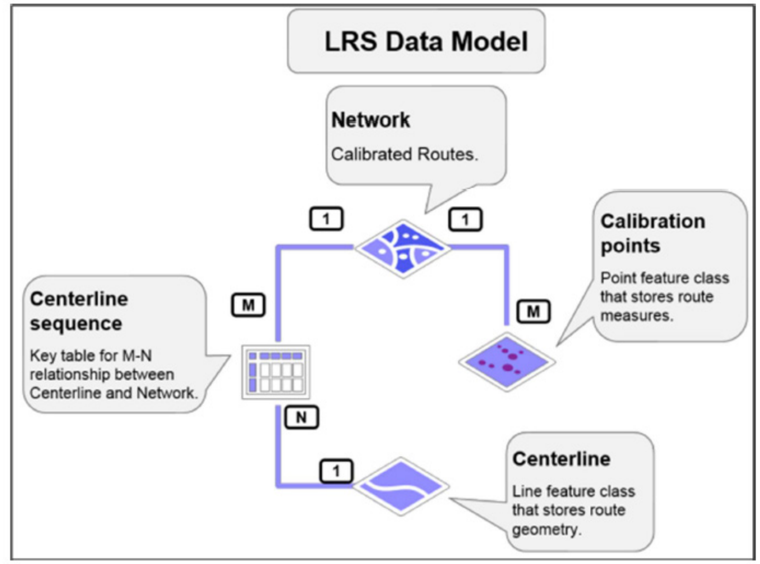


Figure 2.4: Linear Overlay Functions

Operator	ID	Returns	Visual definition
Difference	1	Linear portion of an input event and reference event that do not overlay each other.	 Return portion
Intersection	2	Linear portion of an input event that completely overlays the reference event.	 Return portion
Union	3	Union of the difference and intersection sets.	 Return portion

2.3 Normalization and weighting

When developing a composite rating that could be assigned to roadway segments, a statistical process was used that normalized criteria values to a common scale. The resulting values were then combined into a composite rating by using an appropriate weighting or numeric multiplier. This process is described below and highlighted in Table 2.5.

Value ranges

Values for criteria were normalized on a 1-10 scale, with 1 representing the most need or deficiency. The first step in the process was to examine the range of possible values for the seven evaluation criteria identified in Section 2.1. For three of the seven criteria, a logical and fixed scale was used to divide the data into ten equal ranges for normalization. The ranges for these criteria are noted below.

- Congestion index: 0 - 1.00+
- PCI: 0 - 100
- BCI: 0 - 100

For the remaining four criteria, the range of possible values did not necessarily have a strict upper bound. For these criteria, the uppermost normalized value was derived by calculating the value at which five percent of the network mileage would exceed the value. The remaining nine normalization values would be calculated by subdividing the remainder of the range (95 percent) into nine equal intervals. The actual maximum and minimum calculated values within each normalization range are shown within the table in Appendix 2 of the annual data report. Some of these ranges will vary between each report update.

Interpolation of Missing Data

The network changes every year and data for a small portion of the Primary network will always be missing or incomplete. The impact of missing data affects some planning corridors more than others.

Most corridors have at least 95 percent of needed data in all categories A composite score cannot be calculated for segments with missing data, so the weighted average corridor normalization is applied for missing criteria. The average value is included for that segment when all segments are aggregated to corridors.

Weighting and multipliers

After completing the above process, weighting is applied. Since the goal was to create a maximum composite rating of 100, weighting was initially viewed in terms of a percentage. The criteria that would have greater influence on the composite rating were assigned a higher percentage, and vice versa. These percentages were identified through working group and internal stakeholder discussions.

From the percentages, which summed to 100, multipliers were derived to allow for a maximum composite rating of 100. The percent weighted values were divided by 10 to identify the multipliers for each criterion. For example, if a criterion was given a weighting of 25 percent, its multiplier value would be 2.5. These multipliers would then be applied to the normalized value from the 1 to 10 scale for each criterion. For segments without a bridge, BCI received a normalized value of 10, meaning a segment with no structures would receive no additional priority for that criterion.

After the multipliers are applied to each normalized value across all seven criteria, the values are summed to calculate the composite rating. The process was then applied to every segment of the Primary Highway System, allowing for comprehensive screening and further prioritization.

It should be noted that, as part of the original vetting process outlined in this section, a basic sensitivity analysis was conducted to measure the effects of different weighting. While the working group was pleased with the output that resulted from the weighting identified, there was a desire to examine other weighting options and the effects of shifting weight from the condition criteria to the traffic and congestion criteria.

Generally, the results were not desirable as this shift resulted in an unreasonable bias toward urban areas. From these discussions, the working group concluded that the weighting presented in Table 2.5 was most appropriate.

AADT normalization and weighting structure

Due to the variation of AADT across the statewide primary system, a one size fits all approach was avoided for developing a range of values used to calculate the normalized values. To address the variation of AADT across the state, the range values were broken up by the following route types.

- Interstate
- Non-Interstate divided
- Non-divided

Each range for the three different route types was calculated based off of the top five percent of segments by mileage. After sorting largest to smallest by AADT, a cumulative sum was calculated up to the five percent value of the total mileage. The associated AADT value at the five percent mark became the upper threshold. That AADT value was then divided by nine to define the ten different normalization breaks.

Table 2.5: ICE Scoring Structure

ICE Criteria	% of ICE Score
PCI	25%
BCI	25%
IRI	15%
Combination Truck AADT	15%
Single-Unit Truck AADT	5%
Passenger AADT	5%
Congestion Index (V / C)	10%
Safety	0%

2.4 Corridor definition

To enable corridor-level analysis, individual segments were combined into logical planning corridors. The termini of the corridors were defined using a set of general guidelines driven by logical geographic breaks in the system. Some of the other factors considered in the corridor designation included the following.

- Breaks at US and Iowa route interchanges
- Transition to and from National Highway System (NHS) designated routes
- Interstate breaks at major interchanges
- Urban, rural, and suburban route transitions
- Incorporated areas
- Lane capacity transitions
- Corridor length
- Duplicate routes if current corridor is not the “primary through route”

  Criteria for duplicate primary through routes:

  - Interstate routes take precedence over US routes.
  - US routes take precedence over Iowa routes.
  - Lower route numbers take precedence over higher route numbers.

These corridors serve as an analytical tool for evaluating roadways between natural breaks on the primary system.

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3. LOOKING TO THE FUTURE

3.1 Periodic re-evaluation

As a planning tool, it is critical that the most recent data available be routinely incorporated into the annual data report. Since the majority of the data used in this analysis is updated on an annual basis, an annual update provides a logical time frame.

Input from the involved stakeholders over the past years is reflected in the analysis as well as the report itself. Moving forward, this process will continually seek input to facilitate the annual update and address any new stakeholder needs.

Annual schedule

The working group identified an approximate date when all relevant annual data updates should be expected to be completed. In a typical year, all new data could be expected to be available by July 1. Table 3.1 builds from this date, and presents a timeline that ultimately defines when the primary outputs of the annual data report (i.e., maps and corridor listings) would be updated and available for review.

Table 3.1: Annual Re-evaluation and Update Timeline

Milestone	August	September	October	November	December	January
Updated data available	■					
Update / Modify / Maintain Corridors		■				
Linear overlay process		■	■			
Data processing			■			
Data analysis				■		
Web map update complete					■	
Planning report update			■	■	■	
Final report release						■

With an anticipated data analysis completion date in November, this information would be made available for each new programming cycle in an annual report initiated towards the end of the calendar year. In addition to providing another tool for facilitating programming discussions, the annual update cycle will continue to include trend analysis.

3.2 Future enhancements

Conflation of Current and Previous Data Sets

The Primary Roadway network changes every year. ICE data is maintained, aggregated to corridors, and spatial data is maintained as a separate table. While comparison between aggregated data is currently possible when corridor and corridor identifiers are unchanged between years, determining the past performance of network sections where any realignment has occurred is not feasible. In other words, we can determine changes between corridors year-to-year, but we do not have a method to determine the location of scored criteria within the corridor in a consistent, measured manner. In the future, advanced analytical methods may allow this to be done more accurately.

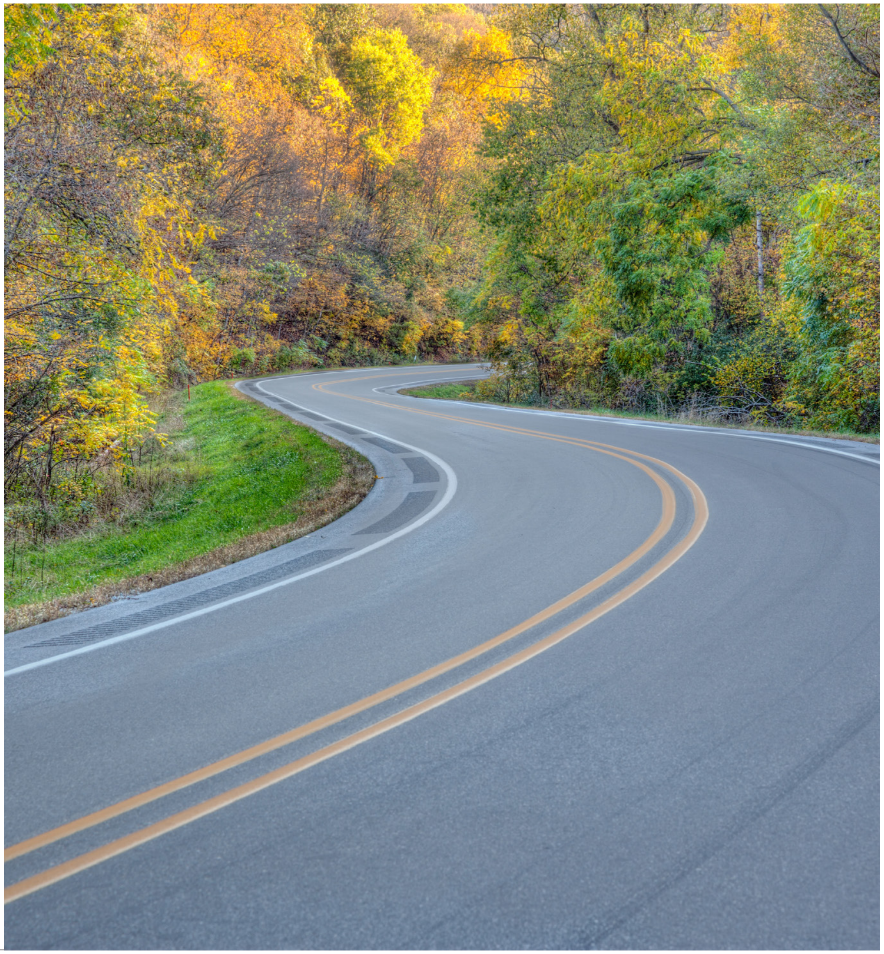
ITRAM data forecasting

With the development of the third generation iTRAM model completed, the idea of forecasting the ICE criteria has been discussed as a potential enhancement. To forecast the future traffic conditions, the ICE segmentation could be integrated into iTRAM, which would then be utilized to perform model runs to estimate AADT on the system in the forecast year.

This is also a possibility for forecasting future pavement condition data, including PCI and IRI. To do so the Iowa DOT will need formulas to help estimate the deterioration of the pavement and structures under various scenarios.

Inclusion of the entire public roadway system

With the adoption of the Iowa DOT's new LRS system, the new linear overlay process allows for a more streamlined approach to reporting the business data that makes up Iowa's roadway network. By including the entire public roadway system, a more granular examination could provide beneficial data for metropolitan planning organizations, regional planning associations, and local jurisdictions. However, before future ICE iterations can consider the addition of county and local roads, the methods used by organizations to collect and process data must be aligned to ensure compatibility.



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