Iowa DOT Pavement and Bridge Performance Measures

May 20, 2018

Performance measures

Through the Moving Ahead for Progress in the 21st Century (MAP-21) Act, Congress required the establishment of measures to assess performance in several areas, including pavement condition of the Interstate and non-Interstate National Highway System (NHS), now codified in 23 CFR 490.307, and bridge condition of the NHS, now codified in 23 CFR 490.407. The State Departments of Transportation (DOTs), as well as metropolitan planning organizations (MPOs) with applicable roadways within their metropolitan planning areas, will set targets for the following performance measures, known as "PM2".

1. Percentage of pavements of the Interstate System in Good condition
2. Percentage of pavements of the Interstate System in Poor condition
3. Percentage of pavements of the non-Interstate NHS in Good condition
4. Percentage of pavements of the non-Interstate NHS in Poor condition
5. Percentage of NHS bridges classified as in Good condition
6. Percentage of NHS bridges classified as in Poor condition

Targets are set for all roadways on the applicable system within a State or MPO, regardless of ownership. States must set 2- and 4-year targets for these measures by May 20, 2018. While targets will be set on this date and communicated to MPOs at that time, they will not be officially reported to FHWA until the submittal of State baseline performance period reports on October 1, 2018.

Pavements

Iowa has more than 240,000 lane-miles of roadway across State, county, and municipal systems. Iowa DOT is responsible for maintaining 22,804 lane-miles of highways, including highways on the Interstate System, the majority of the NHS, and other State highways. Local governments maintain the remaining pavements. Table 1 shows the number of lane-miles of Interstate System highways and non-Interstate NHS highways in Iowa, which are the systems that targets are being set for.

Table 1: Total lane miles of Interstates and non-Interstate NHS highways in Iowa

Highway system	Lane miles
Interstate	**3,305**
DOT NHS (Non-Interstate)	12,368
Local NHS	288
Non-Interstate NHS (DOT + Local)	**12,656**

Iowa DOT collects pavement data on all paved roads in the state every two years, and on Interstates every year. Data from these inspections form the basis for determining condition levels and help owners determine pavement maintenance needs. More information about NHS

pavements and how they are managed can be found in Iowa's Transportation Asset Management Plan (TAMP)[1].

Target setting methodology

Targets are to be set based on 0.1 mile sections of the through travel lanes of mainline highways on the applicable highway systems. The FHWA definitions of good, fair, and poor for pavement are determined based on the condition of three attributes - the pavement section's International Roughness Index (IRI), the pavement's cracking condition, and the pavement's rutting rating (concrete) or faulting rating (asphalt). Per FHWA's definitions, a pavement section is considered "poor" if two of these three ratings are poor. A pavement section is considered "good" if all three ratings are good. Otherwise, it is considered "fair". As part of the phase-in requirements for the FHWA rules, the first 4-year performance period will use an alternate measure for non-Interstate NHS pavement condition, and will base the condition solely on the IRI measure. Pavement that is part of a bridge deck is excluded from metric calculations. Missing, invalid, or unresolved data is also excluded from the calculations and is not to exceed five percent of the system's mileage. The good and poor measures are determined by summing the total lane-miles of good or poor highway segments and dividing by the total lane-miles of all highway segments on the applicable system[2].

Iowa DOT has a long history of collecting pavement condition data. However, there is a lack of historical data to use for forecasting condition per the new FHWA definitions, because past data collection did not include all elements now required. This has made developing a data-driven approach to target forecasting a challenge.

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[1] https://iowadot.gov/systems_planning/planning/federal-performance-management-and-asset-management
[2] More detail on the measure calculation can be found in this FHWA presentation:
https://www.fhwa.dot.gov/tpm/rule/170531pm2.pdf.

Pavement measures 1 and 2
1. Percentage of pavements of the Interstate System in Good condition
2. Percentage of pavements of the Interstate System in Poor condition

As discussed previously, there is a lack of historical data that Iowa DOT can translate to FHWA's new condition definitions. For the Interstate System, there are four years of data available. Figure 1 shows the historical performance for the Iowa DOT Interstate System from 2014 to 2017, and Table 2 shows the percentages of the condition categories for the same timeframe. Good, fair, and poor condition categories are shown, though targets are only required for the good and poor categories. The calculation of good, fair, and poor condition excludes unresolved/missing data.

Figure 1: Iowa Interstate System condition based on FHWA definitions for PM2
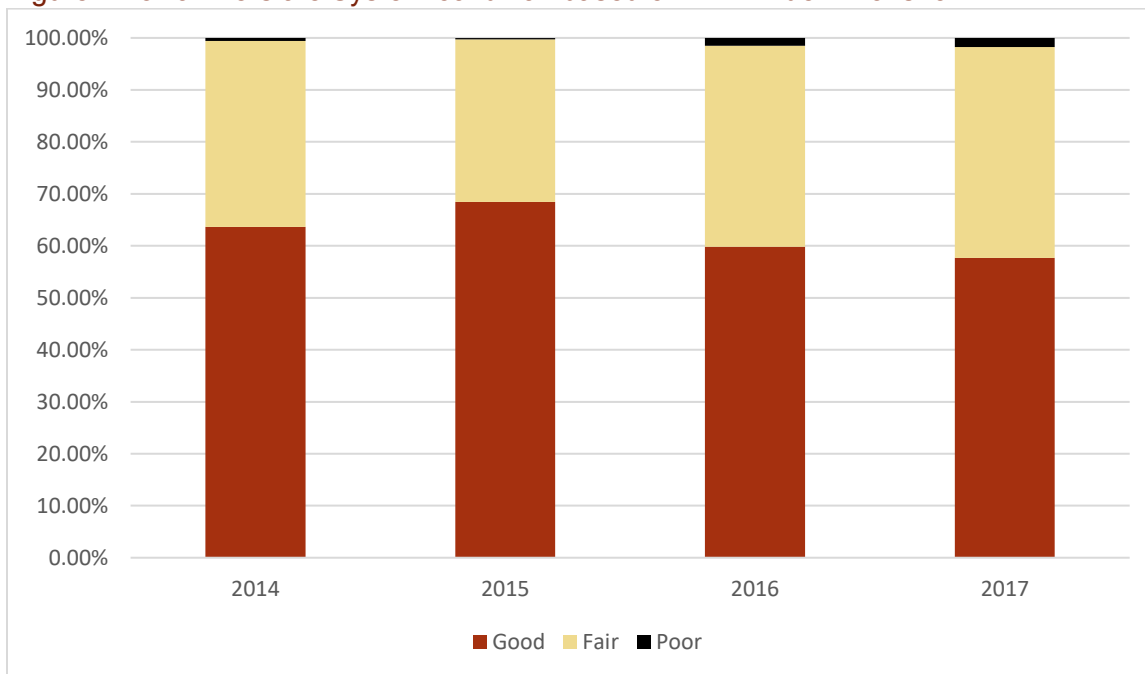

Table 2: Iowa Interstate System condition based on FHWA definitions for PM2

Year	Good	Fair	Poor	Unresolved/missing (excluded from calculation)
2014	63.63%	35.76%	0.61%	21.93%
2015	68.44%	31.27%	0.28%	22.46%
2016	59.84%	38.67%	1.49%	4.01%
2017	57.68%	40.57%	1.75%	1.66%

Iowa DOT used a hybrid approach to target setting, given that the FHWA data requirements are different from what Iowa DOT uses to manage pavements, particularly with respect to how the pavement sections are segmented. To establish targets, Iowa DOT used output from its pavement management system to forecast the percentage of all Interstate pavements in good,

fair, and poor condition annually through 2024, shown on Figure 2. This forecasting model is based on pavement management data and factors in committed projects.

Figure 2: Iowa Interstate System condition forecast based on FHWA definitions for PM2
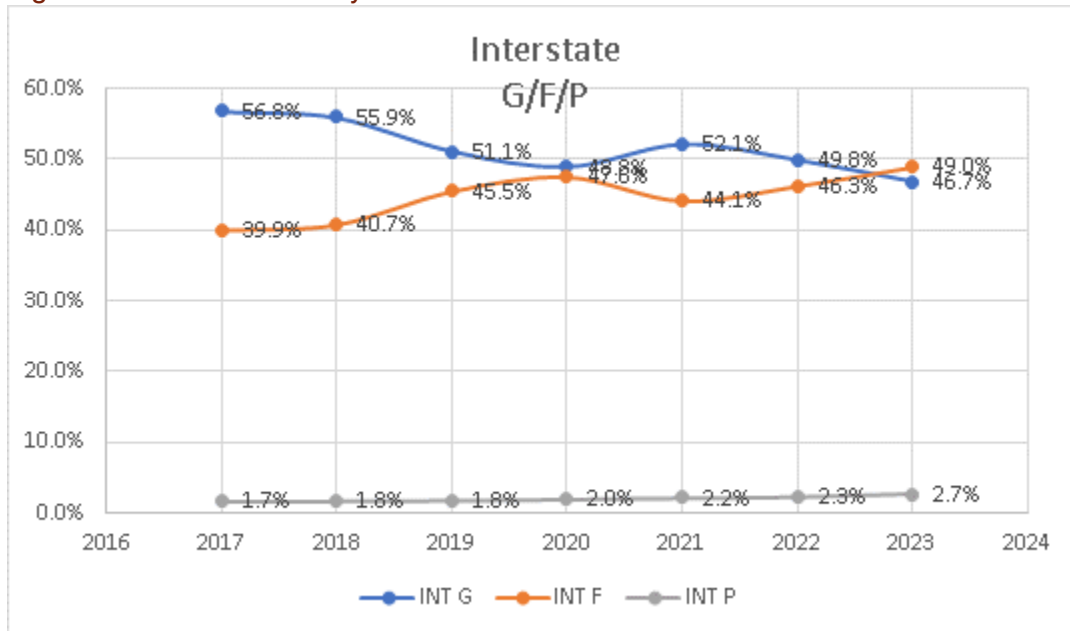
This forecast was augmented with information about the observed variability in annual measures in order to account for uncertainty in future values. This results in a probabilistic prediction interval which can give some information about the likelihood of observing specific values in the future. These probabilistic targets are calculated at various levels of confidence and are summarized in Table 3. Since data submitted in 2020 will have been collected in 2019, and data submitted in 2022 will have been collected in 2021, the forecasts for those collection years are used for the forecast baseline of the 2- and 4- year targets for Iowa DOT. The confidence level of 75 percent was used for target-setting and is highlighted. The Iowa DOT has had several working groups for the various federal performance measures, and 75 percent has generally been identified as a threshold for acceptable risk for federal performance measures by the working groups and management.

Table 3: Iowa Interstate condition forecast baseline and various confidence levels

	Interstate percent good		Interstate percent poor	
	2020	2022	2020	2022
Forecast baseline	51.10%	52.10%	1.80%	2.20%
Confidence level				
70 percent	49.02%	50.02%	2.14%	2.54%
75 percent	**48.43%**	**49.43%**	**2.24%**	**2.64%**
80 percent	47.77%	48.77%	2.35%	2.75%
85 percent	47.00%	48.00%	2.47%	2.87%
90 percent	46.03%	47.03%	2.63%	3.03%
95 percent	44.59%	45.59%	2.87%	3.27%

Pavement measures 3 and 4
Percentage of pavements of the non-Interstate NHS in Good condition
Percentage of pavements of the non-Interstate NHS in Poor condition

Table 4 shows the percentages of good, fair, poor, and unresolved/missing values for 2017 using the IRI-based non-Interstate NHS performance measure, as required by FHWA for the phase-in period. Due to the restructuring of past IRI data that is necessary to compute the measure per FHWA guidelines, only one year of data was available at the time the measure was constructed. Good, fair, and poor condition categories are shown, though targets are only required for the good and poor categories. The calculation of good, fair, and poor condition excludes unresolved/missing data.

Table 4: Iowa Non-Interstate NHS condition based on FHWA definitions for phase-in period of PM2

	Good	Fair	Poor	Unresolved/missing (excluded from calculation)
NHS – local	9.14%	33.05%	57.81%	1.16%
NHS – State	50.14%	36.81%	13.05%	1.37%
Non-Interstate NHS	49.06%	36.71%	14.22%	1.36%

Iowa DOT used a hybrid approach to target setting, given that the FHWA data requirements are different from what Iowa DOT uses to manage pavements, particularly with respect to how the pavement sections are segmented. To establish targets, Iowa DOT used output from its pavement management system to forecast the IRI of all non-Interstate NHS pavements and classify each segment as good, fair, or poor condition through 2024, shown on Figure 3. This forecasting model is based on pavement management data and factors in committed projects.

Figure 3: Iowa non-Interstate NHS condition forecast based on FHWA definitions for phase-in period of PM2
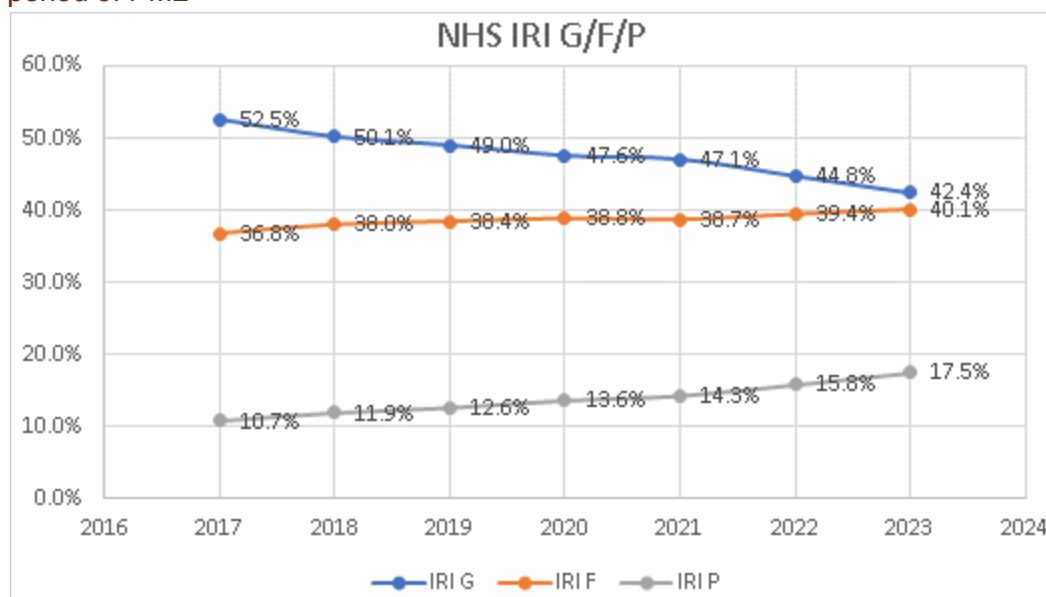
Given the small sample of data to work with, this forecast was augmented with information derived from a bootstrap estimate of variance[3] in order to estimate potential uncertainty in future values. The combined information results in a probabilistic prediction interval which can give some information about the likelihood of observing specific values in the future. These probabilistic targets are calculated at various levels of confidence and are summarized in Table 5. Since data submitted in 2020 will have been collected in 2019, and data submitted in 2022 will have been collected in 2021, the forecasts for those collection years are used for the forecast baseline of the 2- and 4- year targets for Iowa DOT. The confidence level of 75 percent was used for target-setting and is highlighted. The Iowa DOT has had several working groups for the various federal performance measures, and 75 percent has generally been identified as a threshold for acceptable risk for federal performance measures by the working groups and management.

Table 5: Iowa non-Interstate NHS condition forecast baseline and various confidence levels

	Non-Interstate NHS percent good		Non-Interstate NHS percent poor	
	2020	2022	2020	2022
Forecast baseline	49.00%	47.10%	13.04%	14.30%
Confidence level				
70 percent	48.86%	46.96%	13.13%	14.39%
75 percent	**48.82%**	**46.92%**	**13.16%**	**14.42%**
80 percent	48.78%	46.88%	13.19%	14.45%
85 percent	48.73%	46.83%	13.23%	14.49%
90 percent	48.66%	46.76%	13.27%	14.53%
95 percent	48.57%	46.67%	13.33%	14.59%

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[3] For more information about bootstrapping: https://en.wikipedia.org/wiki/Bootstrapping_(statistics)

Iowa DOT pavement performance targets

Targets for the pavement performance measures are established by the State DOTs for 4-year performance periods, with the first set of 2- and 4-year targets being set by May 20, 2018 for target years 2020 and 2022. Data reported and evaluated in these target years will be collected in 2019 and 2021. For the first performance period, a 2-year target is not required for the Interstate pavement measures as States were not previously required to collect data in the manner necessary for the performance measure. States will have the opportunity to revisit the 4-year targets halfway through the performance period, at which point changes can be made if additional data would result in revised assumptions.

Table 6 provides historical annual values for pavement condition for the current FHWA definitions of good, fair, and poor. Interstate values are based on the combination of three attributes (IRI, cracking, and rutting/faulting), and non-Interstate NHS values are based on IRI.

Table 6: Iowa Interstate and non-Interstate NHS condition based on FHWA definitions for PM2

Year	Good	Fair	Poor	Unresolved/missing
Interstate 2014	63.63%	35.76%	0.61%	21.93%
Interstate 2015	68.44%	31.27%	0.28%	22.46%
Interstate 2016	59.84%	38.67%	1.49%	4.01%
Interstate 2017	57.68%	40.57%	1.75%	1.66%
Non-Interstate NHS 2017	49.06%	36.71%	14.22%	1.36%

Table 7 provides the targets for pavement condition. Targets are rounded down to the nearest tenth of a percent for percent good, and rounded up to the nearest tenth of a percent for percent poor. The targets are being set at the 75 percent confidence level. The Iowa DOT has had several working groups for the various federal performance measures, and 75 percent has generally been identified as a threshold for acceptable risk for federal performance measures by the working groups and management.

Table 7: Targets for Interstate and non-Interstate NHS pavement condition at 75 percent confidence interval

Year	Interstate Pavements – Percent Good	Interstate Pavements – Percent Poor	Non-Interstate NHS Pavements – Percent Good	Non-Interstate NHS Pavements – Percent Poor
2020	Not required for first performance period		48.8%	13.2%
2022	49.4%	2.7%	46.9%	14.5%

It is important to note that these targets are based on FHWA definitions of good and poor, which have been nationally defined to achieve a standard measurement across States. These definitions of good and poor may not be the same as other pavement condition metrics used by the Iowa DOT to evaluate system condition, and may not be the best indicator of what a typical traveler considers to be good or poor pavement condition. These targets have also been set without the benefit of a long history of data to develop trends and forecasts.

Minimum level for condition of Interstate pavements

In addition to requiring performance targets, MAP-21 also set a minimum condition level for Interstate pavements. Per 23 CFR 490.315, States are required to maintain Interstate pavements so that the percentage of the lane-miles of the Interstate System classified as poor condition does not exceed 5.0 percent. FHWA annually determines whether a State exceeds this threshold. If a State's percentage of poor condition Interstate lane-miles exceeds 5.0 percent, in the following year the State will be subject to funding penalties that require a certain amount of National Highway Performance Program (NHPP) and Surface Transportation Block Grant (STBG) funding to be used for eligible projects on the Interstate System. The percentage of Iowa's Interstate lane-miles in poor condition is currently below the 5.0 percent threshold, and is forecast to remain below that threshold through the first performance period.

Bridges

Iowa has more than 24,000 bridges across State, county, and municipal systems. Iowa DOT is responsible for maintaining 4,141 of these bridges, including bridges on Interstate System, the majority of the NHS, and other State highways. Local governments maintain the remaining bridges. Table 8 shows the number of bridges and deck area of NHS bridges in Iowa, which is the system that targets are being set for.

Table 8: Total NHS bridges in Iowa

Highway system	Number of bridges	Deck area (ft^2)
Interstate	715	10,673,237
DOT NHS (Non-Interstate)	1,826	21,441,731
Total DOT NHS	**2,541**	**32,114,968**
Local NHS	39	733,003
Total NHS (DOT + Local)	**2,580**	**32,847,971**

Bridge owners are required to inspect bridges at least every 24 months. Data from these inspections form the basis for determining condition levels and help owners determine bridge maintenance needs. More information about NHS bridges and how they are managed can be found in Iowa's TAMP[4].

Target setting methodology

As part of the National Bridge Inventory (NBI) program, condition is rated for each bridge's deck, superstructure, and substructure using a scale of zero to nine. Per FHWA's definitions, a bridge is considered "poor" if one of these three ratings is less than or equal to four. A bridge is considered "good" if all the three ratings are greater than or equal to seven, and otherwise it is considered "fair". The performance measures are calculated based on the deck area for all bridges carrying the NHS, including highway bridges on ramps connected to the NHS and bridges that cross State borders. Bridges on State borders count toward both States' totals. The good and poor measures are determined by summing the total deck area of good or poor NHS bridges and dividing by the total deck area of the NHS[5].

In January 2018, the Iowa DOT began the process of reviewing data to set performance targets for the two NHS bridge performance measures required by FHWA. The Iowa DOT has historical data on overall bridge condition which was used to develop models to predict future condition. Because of the relatively short-term nature of the targets, the methodology being utilized focuses on historical information and creates a forecast based on trends. The approach relies on the use of prediction intervals around the trend model forecast to inform a "risk-based" target setting method.

A prediction interval is defined as: "In statistical inference, specifically predictive inference, a prediction interval is an estimate of an interval in which future observations will fall, with a certain probability, given what has already been observed."[6] A prediction interval approach enables a

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[4] https://iowadot.gov/systems_planning/planning/federal-performance-management-and-asset-management
[5] More detail on the measure calculation can be found in this FHWA presentation:
https://www.fhwa.dot.gov/tpm/rule/170531pm2.pdf.
[6] https://en.wikipedia.org/wiki/Prediction_interval, 2018-Mar-09

focus on the acceptable risk of meeting, or failing to meet a target, which allows stakeholders at all levels of the organization to understand the targets in better context. The bridge management and PM2 working groups evaluated several prediction intervals and recommended a prediction interval of 75%, meaning that there would be 75% confidence that the actual percentage of the total bridge deck area in good condition would be higher than the targets and the actual percentage of the total bridge area in poor condition would be lower than the targets.

For each category, a time-series model was developed. An integrated moving average (IMA) model was used to predict the values for the next 5 years. The following pages show the model's output and predictions at various confidence levels for each measure. This helps illustrate the level of risk associated with various confidence levels, as well as the fact that higher confidence levels lead to more conservative targets. The NBI Bridge data used for this analysis can be obtained from the following URL: https://www.fhwa.dot.gov/bridge/nbi/ascii.cfm.

Bridge measure 1: Percentage of NHS bridges classified as in Good condition

Figure 4 shows the historical series (black line), the IMA model (red line), the model's forecast values (black dots), and a set of prediction interval bounds (blue lines). The blue lines shown in this figure correspond to the 75% confidence level used for targets. Table 9 shows the model's forecast of total deck area of NHS bridges in good condition from 2018 – 2022 and the lower prediction interval value at different confidence levels, and Figure 5 shows historical data and forecast prediction values at various confidence levels.

Figure 4: Past data, IMA model, and forecast for NHS bridges' total deck area in good condition
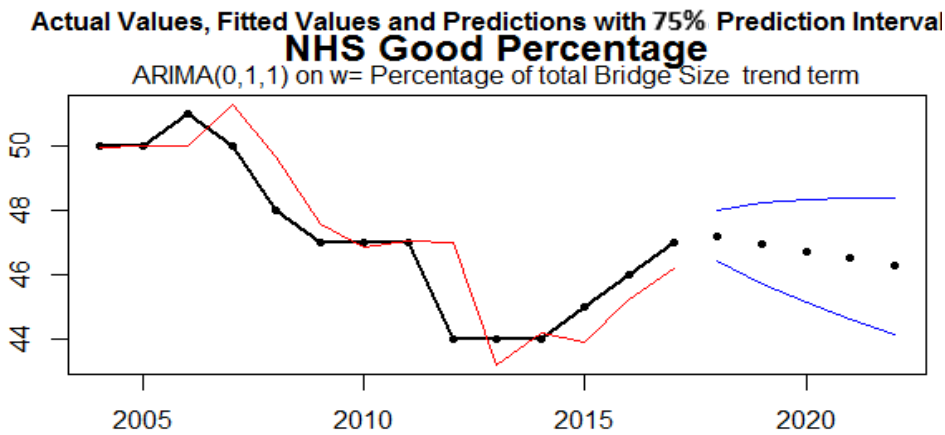

Table 9: Forecast for NHS bridges' total deck area in good condition and lower prediction values at selected probability levels

Year	Forecast	70%	75%	80%	85%	97.50%
2018	47.21%	46.60%	46.42%	46.23%	46.00%	44.93%
2019	46.98%	46.00%	45.72%	45.41%	45.04%	43.32%
2020	46.75%	45.50%	45.15%	44.75%	44.29%	42.10%
2021	46.51%	45.06%	44.64%	44.17%	43.63%	41.06%
2022	46.28%	44.64%	44.16%	43.64%	43.03%	40.12%

Figure 5: Trend and forecast for NHS bridges' total deck area in good condition
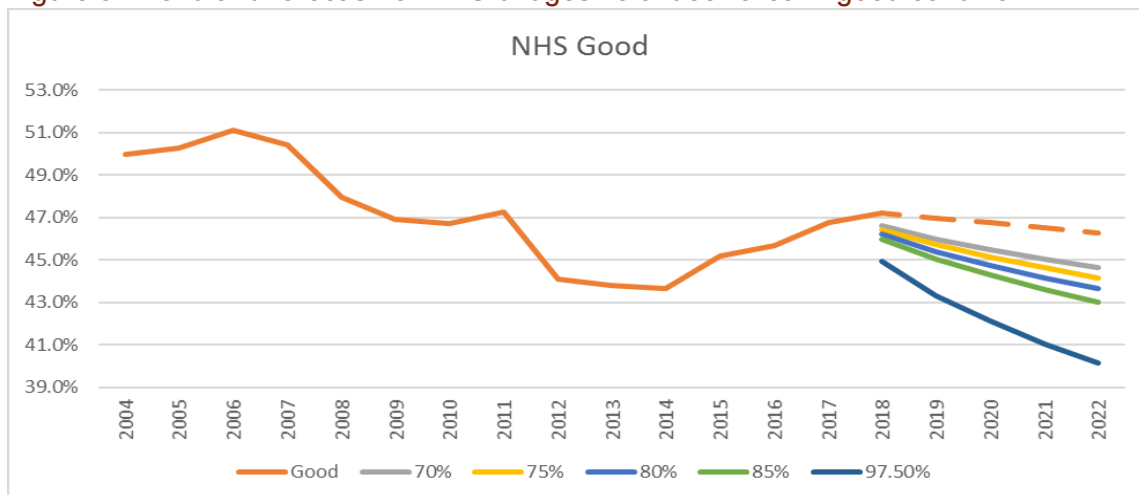
Bridge measure 2: Percentage of NHS bridges classified as in Poor condition

Figure 6 shows the historical series (black line), the IMA model (red line), the model's forecast values (black dots), and a set of prediction interval bounds (blue lines). The blue lines shown in this figure correspond to the 75% confidence level used for targets. Table 10 shows the model's forecast of total deck area of NHS bridges in poor condition from 2018 – 2022 and the higher prediction interval value at different confidence levels, and Figure 7 shows historical data and forecast prediction values at various confidence levels.

Figure 6: Past data, IMA model, and forecast for NHS bridges' total deck area in poor condition
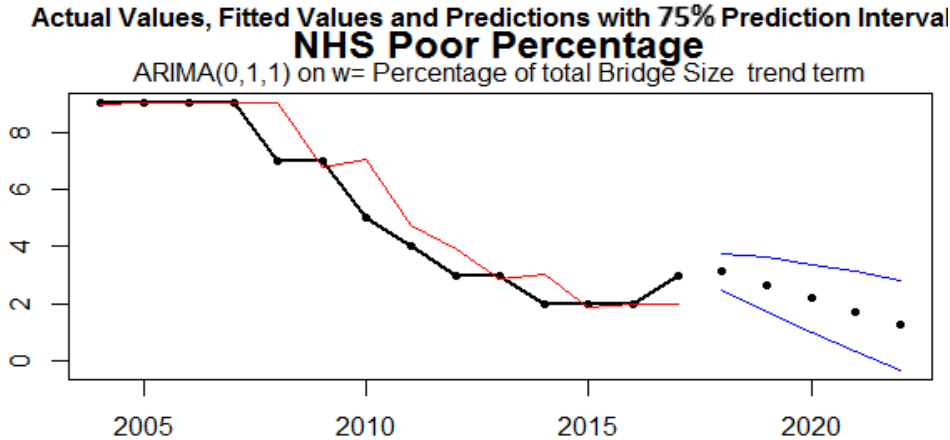

Table 10: Forecast for NHS bridges total deck area' in poor condition and upper prediction values at selected probability levels

Year	Forecast	70%	75%	80%	85%	97.50%
2018	3.12%	3.62%	3.76%	3.92%	4.10%	4.97%
2019	2.66%	3.40%	3.62%	3.85%	4.13%	5.44%
2020	2.20%	3.13%	3.39%	3.69%	4.03%	5.67%
2021	1.74%	2.82%	3.13%	3.47%	3.87%	5.78%
2022	1.27%	2.49%	2.84%	3.23%	3.68%	5.82%

Figure 7: Trend and forecast for NHS bridges' total deck area in poor condition
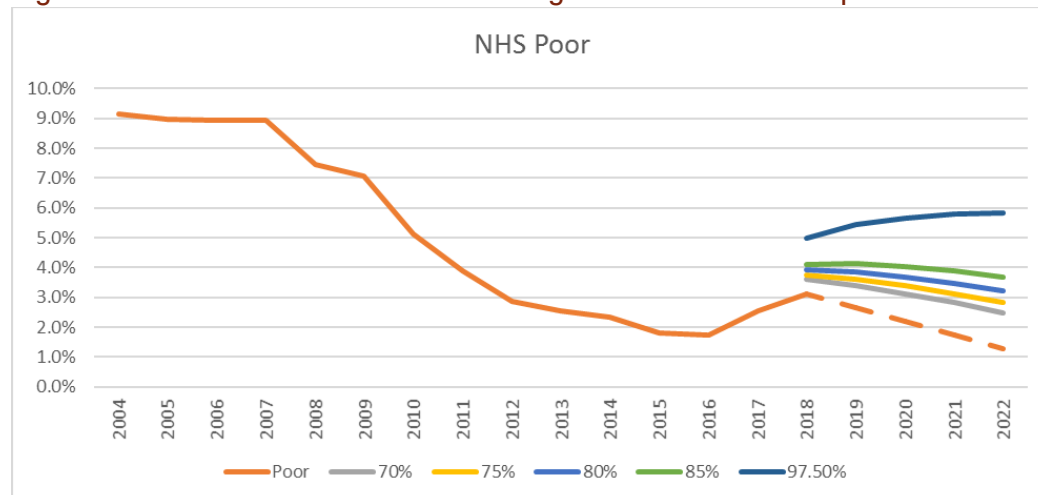
Iowa DOT bridge performance targets

Targets for the bridge performance measures are established by the State DOTs for 4-year performance periods, with the first set of 2- and 4-year targets being set by May 20, 2018 for target years 2020 and 2022. Data reported and evaluated in these target years will be collected in 2019 and 2021. States will have the opportunity to revisit the 4-year targets halfway through the performance period, at which point changes can be made if additional data would result in revised assumptions.

Table 11 provides historical annual values for NHS bridge condition for the current FHWA definitions of good, fair, and poor. As evidenced, there was a substantial increase in bridge deck area between 2012 and 2013. This is due to the expansion of the NHS as part of MAP-21, which added to the NHS those roads that were functionally classified as principal arterials but not already part of the NHS.

Table 11: Annual values for NHS bridges' total deck area (ft^2) in good, fair and poor condition

Year	Good	Fair	Poor	Total	Percent Good	Percent Fair	Percent Poor
2007	11,597,459	9,357,361	2,052,238	23,007,057	50.4%	40.7%	8.9%
2008	11,430,106	10,638,781	1,776,024	23,844,912	47.9%	44.6%	7.4%
2009	11,339,519	11,135,264	1,706,477	24,181,260	46.9%	46.0%	7.1%
2010	11,370,979	11,720,073	1,247,478	24,338,530	46.7%	48.2%	5.1%
2011	12,056,587	12,458,160	990,627	25,505,374	47.3%	48.8%	3.9%
2012	10,957,170	13,174,532	710,648	24,842,350	44.1%	53.0%	2.9%
2013	13,726,960	16,802,681	798,504	31,328,145	43.8%	53.6%	2.5%
2014	13,663,129	16,911,810	732,321	31,307,260	43.6%	54.0%	2.3%
2015	14,475,333	16,976,437	581,604	32,033,374	45.2%	53.0%	1.8%
2016	14,798,279	17,041,896	560,540	32,400,715	45.7%	52.6%	1.7%
2017	15,360,006	16,648,097	839,867	32,847,971	46.8%	50.7%	2.6%

Table 12 provides the forecast values for 2018-2022. Targets are rounded down to the nearest tenth of a percent for percent good, and rounded up to the nearest tenth of a percent for percent poor. The targets are being set at the 75 percent confidence level. The Iowa DOT has had several working groups for the various federal performance measures, and 75 percent has generally been identified as a threshold for acceptable risk for federal performance measures by the working groups and management. Since data submitted in 2020 will have been collected in 2019, and data submitted in 2022 will have been collected in 2021, the forecasts for those collection years are highlighted as the 2- and 4- year targets for Iowa DOT.

Table 12: Targets for NHS bridge condition at 75 percent confidence interval

Year	NHS Bridges – Percent Good	NHS Bridges – Percent Poor	
2018	46.4%	3.8%	
2019	45.7%	3.7%	**Iowa 2020 targets**
2020	45.1%	3.4%	
2021	44.6%	3.2%	**Iowa 2022 targets**
2022	44.1%	2.9%	

It is important to note that these targets are based on FHWA definitions of good and poor, which have been nationally defined to achieve a standard measurement across States. These definitions of good and poor may not be the same as other bridge condition metrics the Iowa DOT uses to evaluate system condition, and may not be the best indicator of what a typical traveler considers to be good or poor bridge condition.

Minimum level for condition of NHS bridges

In addition to requiring performance targets, MAP-21 also set a minimum condition level for NHS bridges. Per 23 CFR 490.411, States are required to maintain NHS bridges so that the percentage of the deck area of bridges classified as structurally deficient (also referred to as "poor" for the performance measures and targets) does not exceed 10.0 percent. FHWA annually determines whether a State exceeds this threshold. If, for three consecutive years, a State's percentage of NHS bridge deck area in poor condition exceeds 10.0 percent, in the following year the State will be subject to funding penalties that require a certain amount of NHPP funding to be used for eligible bridge projects on the NHS. The percentage of Iowa's NHS bridges in poor condition is currently below the 10.0 percent threshold, and is forecast to remain below that threshold through the first performance period.