DEPARTMENT OF TRANSPORTATION

Highway Construction Costs and Cost Inflation Study

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Legislative Request

This report is issued to comply with language in Laws of Minnesota 2017, 1st Spec. Sess., Chapter 3, Section 133, Subdivision 1 of the Omnibus Transportation Finance Bill signed into law on May 30, 2017.

HIGHWAY CONSTRUCTION COSTS AND COST INFLATION STUDY.

Subdivision 1. Highway construction cost study; requirements.

(a) The commissioner of transportation must enter into an agreement with an organization or entity having relevant expertise to conduct a study on highway construction costs, inflation, and cost estimating. The study must be designed to

(b) At a minimum, the study must:

   (1) include an overview of highway construction cost and cost estimation issues;
   (2) establish benchmarks to compare costs in Minnesota to at least four other states that are comparable based on climate and construction characteristics, including historical state-by-state review of at least the following cost factors: (i) direct input costs associated with highway construction, (ii) cost impacts from construction standards and requirements established in law, and (iii) cost impacts from use of alternative methods of contracting and project management;
   (3) identify factors specific to Minnesota, if any, that contribute to cost differences, based on the benchmarks established in clause (2);
   (4) evaluate the methodology used for highway construction cost calculation and indexing in Minnesota, including (i) review of associated best practices, (ii) comparison of federal and Minnesota state highway construction cost index methodologies utilizing historical cost data for Minnesota, (iii) identification of the reasons for any past discrepancies or differences between state and federal highway construction cost indexing, and (iv) analysis of the historical accuracy of the Minnesota highway construction cost index compared to actual costs; and
   (5) provide specific recommendations for road authorities and legislative changes to reduce highway construction costs.

(c) By February 15, 2018, the commissioner must submit a report on the study to the chairs, ranking minority members, and staff of the legislative committees with jurisdiction over transportation policy and finance.

Report Cost

The cost of preparing the report elements required in law is approximately $210,000.

Executive Summary

Purpose and Scope of the Report

This report identifies and analyzes the nature of discrepancies in highway construction costs and cost inflation estimates between Minnesota and other federal and national measures as described in the language in the Omnibus Transportation Finance Bill signed into law on May 30, 2017.

Methods of analysis included an evaluation and survey of the practices currently being used at the Minnesota Department of Transportation, a review of MnDOT's Highway Construction Cost Index methodology and trends to evaluate if the HCCI is overinflating the true cost of construction as determined by the marketplace, and a comparison of MnDOT HCCI to the Federal Highway Administration's recent HCCI (2.0) published in July 2017. Results of the data analyzed show that MnDOT's current cost estimating practices and cost indexing is consistent with peer states and that of FHWA.

The report addresses the benchmarking analysis, but has some limitations. Impacts due to varying construction standards and requirements established in law between peer states were not directly researched as part of this study because of the extensive effort that would be needed to fully understand these impacts as they relate to costs differences between states. However, with the analysis of the construction cost indexes, the study draws the conclusion that peer states operate under similar construction standards and requirements in law since their HCCI trends over time are very similar to MnDOT.

MnDOT State of the Practice

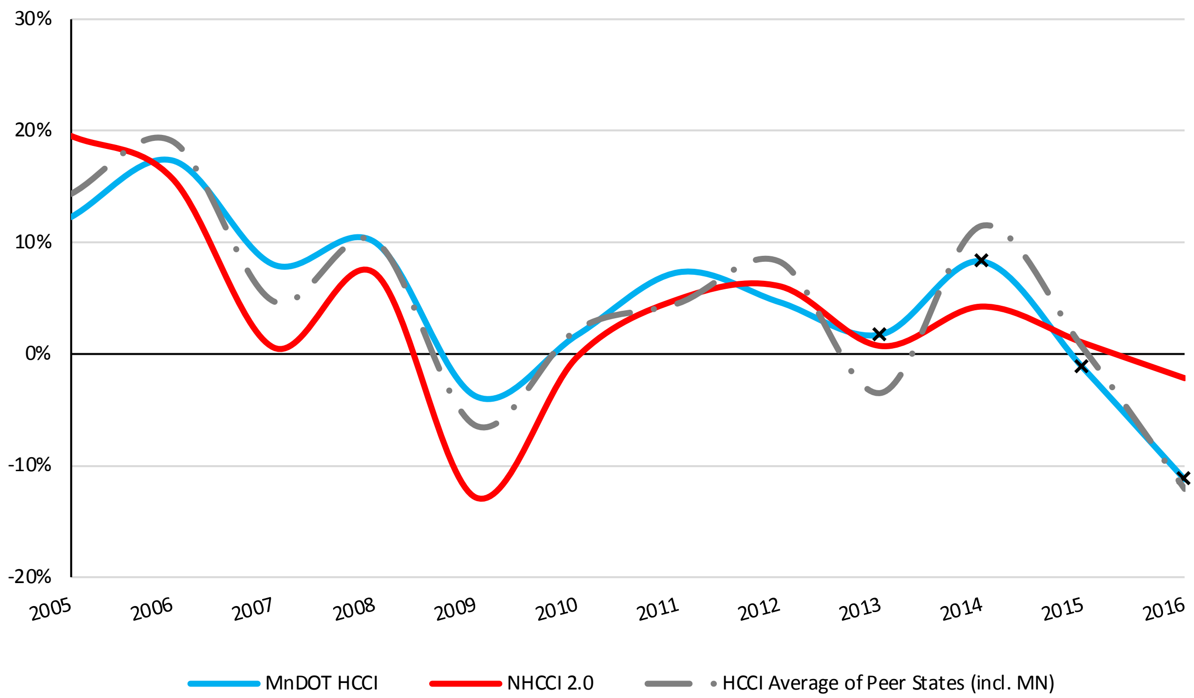
A review of MnDOT's current cost estimation and cost management process was conducted through an examination of publicly available documentation and focused interviews with key management personnel. Overall, the findings show that MnDOT continues to make improvements in cost estimation and cost management as part of its practice. Key findings include:

- Despite approval gates, initial cost estimates do not always account for project scope creep
- Generally, cost estimation techniques often do not improve until final design because of a lack of time and resource availability in earlier stages of the project
- Accounting for the right amount of risk and contingency continues to be challenging
- Historically program balance is achieved using early let, late award and shelf ready projects

MnDOT Benchmarking Analysis

The findings from the benchmarking analysis comparing highway construction cost indexes from 1987 to 2016 from the FHWA and five peer states of Utah, Iowa, Washington, Ohio and Montana demonstrate that MnDOT's tracking of highway construction inflation growth is comparable to that of the peer states. The five peer states were chosen because these states share similar geographies, climate and highway construction programs. As of July 2017, the FHWA released an updated HCCI, the National Highway Construction Cost Index 2.0 beginning in March 2003. The release of NHCCI 2.0 was because the previous index was not representing current trends in highway construction cost inflation at the national level.

Figure 1 demonstrates on an annual basis the variations in year-over-year percent change in the three different index series. The median difference between the growth rates for MnDOT HCCI and the average of the peer states' HCCI from 2005 to 2016 is only -0.3 percentage units. The median difference between the MnDOT HCCI and the NHCCI 2.0 is slightly larger at 2 percentage units. The larger median difference in growth rates in the latter comparison makes sense as the NHCCI 2.0 tracks highway construction projects from all mainland U.S. states and peculiarities found in Minnesota and the other peer states are masked by the weight of data from the remaining states.



Note: MnDOT HCCI values for 2013, 2015 and 2016 are based on imputed values and are denoted by an 'x.' For comparison purposes across multiple agencies, index values were all rebased as of 2004.

Figure 1: Comparing Annual MnDOT HCCI with NHCCI 2.0 and the Average HCCI for Peer States

Of interest is that on a compound annual basis, the growth rate of the MnDOT HCCI and the NHCCI 2.0 between March 2003 and March 2017 is at 4.3 and 3.5 percent, respectively. The compound annual growth rate for the average of the peer states for years 2004 to 2016 is 4.3 percent. The 1 percent difference or less in the compound growth rates across all three indexes indicates how closely MnDOT is tracking highway construction inflation relative to its peer states and the nation.

A statistical correlation analysis, termed Pearson correlation coefficient analysis, was conducted to assess how closely the MnDOT HCCI tracked with that of the peer states' HCCIs and the NHCCI 2.0. The analysis identified that the correlation coefficient between the MnDOT HCCI and each of the following Iowa, Montana, Washington and Ohio HCCIs and the NHCCI 2.0 was high at over a coefficient score of 0.8. A perfect correlation coefficient score is 1.0.

Other construction cost indexes relevant to the MnDOT HCCI can be used to assess the performance of the MnDOT HCCI. Such indexes include the Asphalt and Tar Paving Mixture (Excluding Liquid), Including Bitumen or

Asphalt Concrete, Asphalt Paving Cement producer price index[1] and the Fabricated Structural Metal PPI. Finally, the performance of MnDOT's highway cost estimates, or engineer's estimates, which rely on the MnDOT HCCI to aid in cost escalation, are assessed for their ability to forecast market prices for highway projects.

Using these additional indicators to measure MnDOT HCCI's ability to track highway construction cost of inflation for its highway construction projects resulted in the following conclusions:

- Trends in MnDOT HCCI closely follow trends observed in the Asphalt and Tar Pavement PPI.
    - The higher compound growth rates observed for the MnDOT HCCI over the period 2012 to 2014 of 5 percent relative to the NHCCI 2.0 of 2.5 percent coincide with a steep increase in the cost of asphalt over this time period[2], which impacted MnDOT's projects requiring significant amounts of bitumen product.
- MnDOT's EEs during the period of 2012 to 2016 are at, or are within, 2 percent of FHWA's cost estimating performance guideline of 50 percent of projects within ± 10 percent of award.
    - The median percent differences between the EE, second bidder and third bidder to that of the award over the period 2005 to 2017 are 2, 6 and 13 percent, respectively, indicating MnDOT's ability to accurately forecast the price of the winning bid.

Review of MnDOT Methodology

An investigation and documentation of MnDOT's methodology, along with best practices and a comparison of FHWA methodology was completed as part of this report. MnDOT is one of a few state DOTs that have developed a cost index and made it available to the public. As of July 2017, FHWA adopted new statistical procedures (see **Appendix A**) to:

- more closely reflect or approximate price changes in highway construction costs over time
- allow the use of more input data in the calculation of the index.

For instance, the thresholds used for identifying outlier observations, pay items subject to quantity discounts, and observations with extreme price fluctuations were revised to allow for the inclusion of a wider range of observations, resulting in a better representation of price trends.

The findings indicate that while MnDOT uses a different price index formula method of computing its Cost Construction Index than that of FHWA, the trend analysis shows that they are reflective of each other over a 15-year period, and where there are differences, economic variances provide insight into those differences. With any forecast, the challenge with the direct comparison is the availability of data. With the indicators used by MnDOT, some of the supporting input data in certain periods are not available due to lack of qualified projects to allow for an apples-to-apples comparison.

1 For simplicity, the Asphalt and Tar Paving Mixture (Excluding Liquid), Including Bitumen or Asphalt Concrete, Asphalt Paving Cement PPI (US Bureau of Labor series PCU3241213241210131) will be referred to as the Asphalt and Tar Paving Mixture PPI.
2 "Higher Oil Prices Push Asphalt Up 11.2% from a Year Ago", Engineering News-Record, March 26, 2012, downloaded Nov. 17, 2017

Findings and Recommendations

In summary, through internal interviews, peer state interviews and data collection and analysis, this report shows that MnDOT's cost estimating practices and cost indexing when compared to peer states and FHWA are sound. Noting that each peer state and FHWA do have some differences with respect to their methodologies, MnDOT has strong procedures and practices in place that support the development of their estimates and indexes, providing for consistency from project to project. The study does recommend the following to provide for a more robust estimating and index methodology:

1. Pilot use of the dynamic item basket and multidimensional index methodology
   a) This method reduces index variability since:
      - more item types are tracked
      - stratification of project types controls for index variation
      - leverages both current and previous items

   b) MnDOT can implement the DIB method by tracking which awarded items appear between a current period and the previous period within a category, such as bituminous surfacing or concrete surfacing. These items are then used to produce a current cost per unit. The current cost per unit is divided by the base period's cost per unit to produce an inflation index. For example, a check on the number of bituminous category items awarded between 2015 and 2016 showed that 49 different item codes were common between the two periods. These items covered 80 percent of total awarded bituminous items in 2016. The high coverage rate coupled with the relevancy of the items ensures that the true cost of inflation is being captured over time. Initially, MnDOT should focus on a particular type of project (project size, work type and/or location) to manage the scale of the research. Once a process is established for a given project category and a given item category, the methodology can be expanded to include a wider range of projects and item categories.
2. Pilot use of the Fisher index method so that weights are constantly updated
3. Implement programmable logic to access bid data in real time as input into the HCCI methodology
4. Implement a more systematic and transparent cost data editing/ cleaning process, perhaps similar to what FHWA is doing now
5. Monitor NHCCI and HCCI of peer states on a regular basis and compare with price trends in Minnesota

Part One:
Current State of the Practice

Introduction

As part of the Construction Cost Study commissioned by MnDOT, the consulting firm, HDR, reviewed the cost estimation and cost management process currently in place at MnDOT. The assessment relied on a review of relevant documentation prepared by (or for) MnDOT, including publicly available reports describing policies and procedures in place to develop unit price estimates and project cost estimates. In addition, HDR conducted in-person interviews with MnDOT personnel to obtain additional information and answers to questions arising from the review of documents.

Overview of Cost Estimation and Cost Management Process

MnDOT's CE and CM process is described in great detail in the 2008 *Cost Estimation and Cost Management Technical Reference Manual*. The manual was the outcome of MnDOT's Cost Estimation Process Improvement and Organizational Integration Project. It was developed using guidance from *National Cooperative Highway Research Program Report 574* with a view to improving accuracy, accountability, consistency and credibility.

MnDOT's project delivery process comprises five phases: planning, scoping, design, letting and construction. The process begins with the planning phase where transportation system performance needs are identified and prioritized. The most critical needs are carried forward into the scoping phase. During this phase, stakeholder groups are engaged to identify potential work to be completed during the project. Decisions are made as to what can and cannot be included in the project's definition. These decisions are documented in a scoping report so that they can be conveyed to those that will work on the project. A cost estimate is also developed based on the project's definition. The defined projects are then reviewed during programming; and then the projects are included in the 4-year Statewide Transportation Improvement Program, the 10-year Highway Infrastructure Program or are held for reconsideration the following year. Once the project is programmed in the STIP, the design phase begins and the project is developed. The developed project then goes to the letting phase.

Cost estimating is performed throughout the first four phases of the project development process. (The flow chart of the integration of the CE and CM process within MnDOT's project development process is provided in **Appendix C.**)

The planning phase consists of five processes:

- Determine estimate basis
- Prepare base estimate
- Determine risk and set contingency
- Review and approve estimates
- Determine estimate communication approach

Cost estimates prepared during this phase provide an order of magnitude of the total project cost. They are used to determine the funds required to support the projects in long-range plans. They can also be used in benefit-cost analysis to rank the projects.

The scoping phase also consists of five processes with similar objectives. While a number of cost estimates are often prepared during the scoping phase, the most critical estimate is the estimate that supports programming the project in the STIP. This estimate is based on a preferred alternative and is typically completed in year five from the expected letting date. It will serve as the baseline cost estimate from which project costs will be managed during the design phase.

During the design phase, the CE and CM process focuses on updating the project cost estimate and assessing potential changes resulting from deviations in the baseline project definition and budget. Updating the project cost estimate follows similar processes to those in the scoping phase. The estimate is updated based on an increased level of detailed design information. It is then compared with the Scoping Phase Total Project Cost Estimate. If there are differences, the project change process may be initiated.

As the project advances to the letting phase, the engineer's estimate is prepared. The engineer's estimate reflects the project as defined in the final contract plans and specifications. The final project design forms the major input to the cost estimation and the basis for the engineer's estimate. Unlike the scoping and design phases, contingency is not included as a separate cost element. The preliminary engineer's estimate is compared to the cost estimate prepared by the district and major differences are reconciled prior to finalizing the engineer's estimate.

Cost Estimating and Cost Management Implementation Review

In 2013, the University of Colorado-Boulder and Parsons Brinkerhoff were commissioned by MnDOT to review the implementation and effectiveness of its CE and CM process. The review relied on the examination of available documentation and an extensive outreach effort that included a department-wide survey, a workshop and focus interviews with key management personnel. As part of the review, the following activities were undertaken:

- Investigate tracking and communication systems for total project cost estimate elements
- Review quality of performance measures and associated data
- Verify that CE and CM roles and responsibilities are clear and precise throughout the department
- Review integration of CE and CM system with scoping initiative, enterprise risk management and project management
- Determine department awareness and acceptance of CE and CM system
- Investigate knowledge support systems for CE and CM
- Review current CE and CM tools, risk management tools, and risk management practices

Overall, the reviewers noted that the current CE and CM process represents a vast improvement over past practices and noted that MnDOT is recognized as a national leader in highway cost estimating. The main area for improvement is cost control.

Based on the review findings, a number of recommendations were made with respect to MnDOT personnel, the CE and CM process and performance. These recommendations are summarized in the table below. Note that MnDOT has started implementing some of them since the completion of the 2013 study.

Table 1: Recommendations from 2013 Study on Cost Estimating and Cost Management Implementation Review

Focus Areas	Recommendations
Personnel	1. Refine the dedicated estimator roles and responsibilities to promote consistent understanding and application across the districts. Provide quarterly or semi-annual meetings of district estimators. 2. Update CE and CM training and consider delivering it in short, online courses or videos. 3. Develop new training modules with a focus on CM for project managers and district estimators to improve cost control during scoping and detailed engineering in particular. 4. Increase the sharing of information and lessons learned through the CE and CM department website and email bulletins.
Process	1. Formalize and enforce project and program cost management policies. 2. Invest in a centralized CE and CM data system to improve cost management. 3. Review and refine the scoping process to address smaller, non-complex projects. 4. Investigate the possibility of removing the scope report requirement for small and low-complexity type projects. 5. Review and update CE and CM tools on a regular basis. 6. Refine the Technical Reference Manual for project managers and non-estimating staff and consider creating a complementary guide for project managers.
Performance	1. Increase resources, training, and guidance for risk management and contingency. 2. Promote consistency in the application of cost baselines when projects enter the STIP. 3. Provide additional guidance in development and management of contingency. 4. Revise or introduce additional estimating performance measures to better identify strengths and weaknesses in the CE and CM process. 5. Focus additional performance measures on the quality of project documents.

Interview Findings

To supplement the literature review and obtain up-to-date information on cost estimation, HDR conducted in-person interviews with key MnDOT staff from Oct. 2 to Oct. 5, 2017. The interviews were an opportunity for the staff to comment on improvements made since the 2013 study and discuss any new or lingering issues within their areas of expertise. The following individuals were interviewed:

- Nancy Sannes, Estimates Engineer
- Val Svensson, Project Delivery Manager
- Eric Janssen, Senior Engineering Specialist

- John Wilson, Economic Policy Analyst
- Mike Ginnaty, District 2 Interim Engineer
- Chris Roy, Assistant Division Director for Engineering Services

A summary of the main cost estimation issues raised during these interviews is provided below.

Bid Prices

Certain types of project can impact bid price history. For instance, a very large project might attract an atypical contractor that may want to submit a lower bid to increase the chances of being selected and thereby gaining a market share. With larger pavement projects, alternative bids, where MnDOT prepares both a bituminous option and a concrete option, can also lead to challenges by changing the expected outcome of the bidding process with life-cycle costs factored into the bidding process.

Other factors that influence bid prices include:

- industry concentration (this is especially true in the aftermath of the Great Recession)
- occasional labor shortages because of large projects happening at the same time (e.g., Central Corridor Light Rail Transit Project)
- market/ general economic conditions in neighboring states (e.g., recent downturn in oil industry and construction in North Dakota)
- ownership of material pits (public vs. private)
- a lack of aggregate sources especially in the outstate districts

Scope

MnDOT has a number of processes in place to assist with scoping and cost estimating. With project initiation four to five years in advance of letting, scoping challenges exist with the advance of time. What may have been true in year five may no longer be true in year three or year two. Generally, a project's scope will change after it is first included in the STIP.

Project managers are responsible for assigning risk and contingency with input from functional group managers on projects to account for any scope changes. While the practice is followed for most projects, assigning the right amount of risk and contingency is challenging particularly on larger, more complicated projects. As projects get closer to letting, functional groups continue to refine the scopes. Unforeseen scope creep can be due to external causes, including changes in funding and policy (e.g., guardrail end treatments, new ADA regulations). For instance, an unexpected increase in one-time funding can cause "up-scoping" in large preservation projects, changing from a thin mill and overlay to an unbonded concrete overlay or reclamation project. Scope changes can also be due to internal causes. For example, a project's original scope identified major preservation needs on the roadway but did not identify major upgrades to other systems, such as lighting, overhead signing or median barriers. As the project advances, and because of the significant investment in the roadway, the timing of the replacement of other infrastructure might be advanced to match the roadway fix.

In reality, however, cost estimates do not always account for scope creep, even though MnDOT's project cost estimation process establishes critical points, or "gates," that require a cost estimate approval from the appropriate management staff before a project is allowed to move to the next phase. Accounting for risk and contingency early in the process is often challenging four years in advance of the project being let. Typically a project does not get fully scoped and locked in until design resources are assigned on a full-time basis.

Cost Estimation Technique

MnDOT acknowledges that, as projects advance through the project development process, the cost estimation technique should be refined to reflect a more accurate definition of the project. While the length, width, and depth approach is appropriate in the scoping phase, a more robust technique (e.g., bottom-up approach) is recommended in the final design stage. However, projects often continue to use the higher-level LWD approach because of a lack of time and resource availability.

Risk and Contingency

With a focused effort through the Wildly Important Goal 1.0 on project management, MnDOT placed a lot of emphasis on providing tools to project managers to improve effectiveness. Project scoping and cost estimating were one of many areas reviewed through the WIG 1.0 process. Initial cost estimates of projects entering the STIP still remain a challenge because only a small portion of them are fully scoped, and they often do not adequately account for all risks and associated contingencies, particularly on larger, more complicated projects. It is estimated that, at best, only 15 percent of projects match their original scope four years before letting. That percentage does not improve significantly in year three and year two. MnDOT recognizes this issue and continues to work with project managers and functional group leaders to equip them with better tools and training. Statistical analysis, such as Monte Carlo, which uses simulations to model the probability of something occurring, is particularly useful in developing challenging cost estimates. This, along with risk registers and independent estimates, are just some of the ways MnDOT is working to better account for what it does not know in early phases of project development.

Construction Cost Index

MnDOT's Construction Cost Index currently tracks price trends for six indicator items:

- Roadway excavation
- Concrete pavement
- Bituminous pavement
- Reinforcing steel
- Structural steel
- Structural concrete

Tracking the costs of other items may be beneficial to MnDOT.

Part Two:
Index Benchmarking Analysis

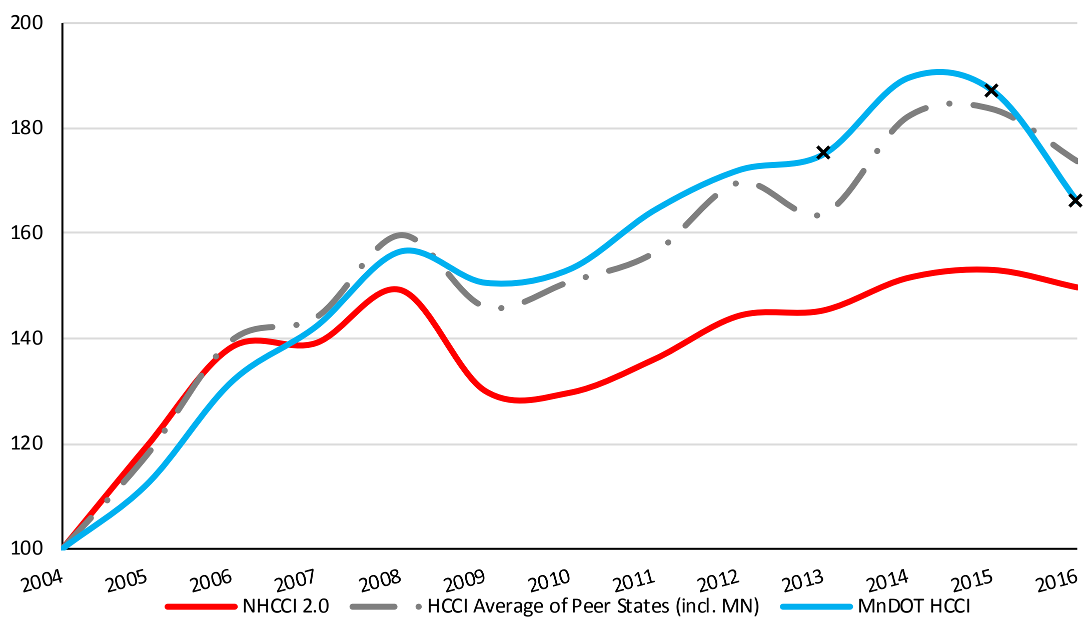
Introduction

This analysis evaluates the performance of the Minnesota Department of Transportation's highway construction cost index in relation to the performance of the Federal Highway Agency's National Highway Construction Index 2.0, and to the performance of five peer states selected for their similarity in terms of geography, environmental conditions and nature of construction program. The five peer states are Utah, Iowa, Washington, Ohio and Montana.

This review of MnDOT's HCCI methodology and trends is to evaluate if the HCCI is overinflating the true cost of construction as determined by the marketplace. The goal of this analysis is to present and evaluate existing metrics used by the peer state DOT's and from the FHWA, to estimate highway construction cost changes over time. The assumption is that if MnDOT is capturing true price escalation rates related to highway construction projects year after year, then its trends should follow, to a reasonable extent, trends observed from the peer states and from the national average.

HCCI Comparison

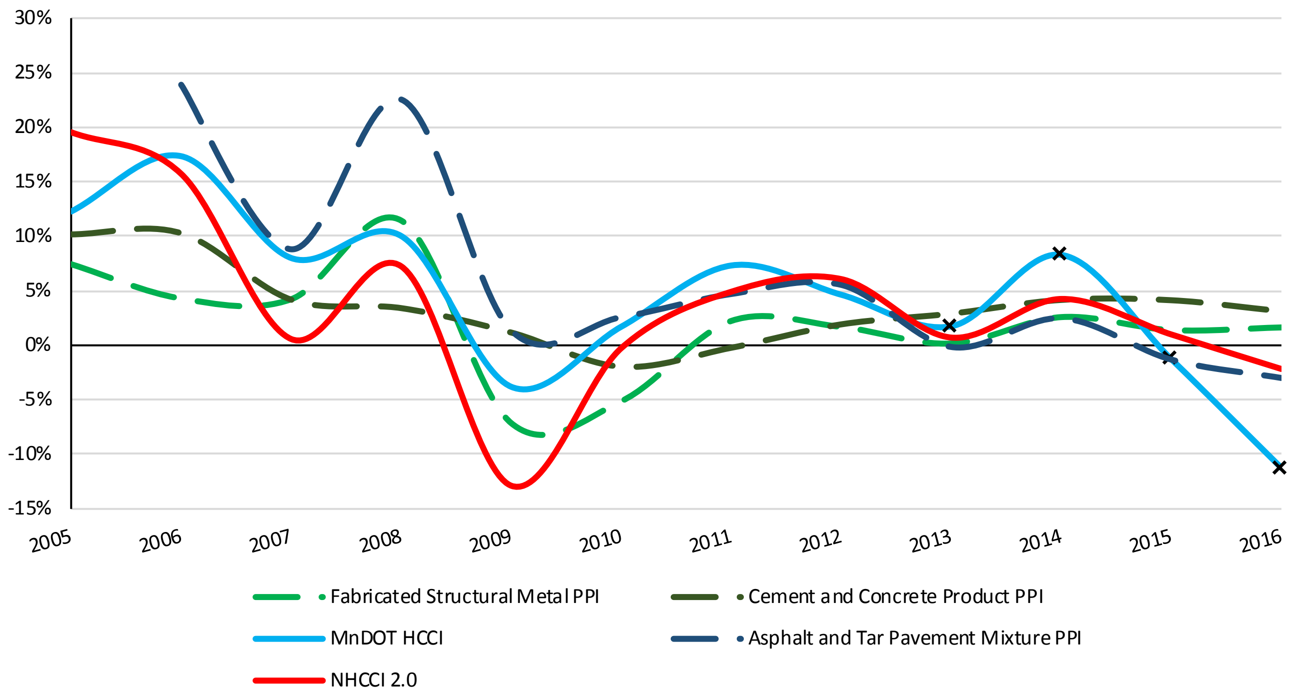
To support the analysis, HCCIs from MnDOT, the five peer states and FHWA were collected from 1987 to 2016. Not all of the agencies had current index values based in 1987. For the comparative analysis, index values were all rebased to start in 2004 and shown in **Figure 2**. An analysis of deviations of the year-over-year percent differences over the study period between the MnDOT HCCI and the peer states' average HCCI and the MnDOT HCCI to that of the NHCCI 2.0 shows that the median differences are -0.3 and 2 percentage units, respectively. If the MnDOT HCCI trended perfectly in step with that of the average of the peer states' HCCI or the NHCCI 2.0, both the median and the mean of all the differences would be 0 percentage units. This is indicative of how close the changes in MnDOT's HCCI year-over-year trends are to those from the trends observed from the peer states' average HCCI and to a marginally lesser extent, to those changes observed in the NHCCI 2.0.



Note: MnDOT HCCI values for 2013, 2015 and 2016 are based on imputed values and are denoted by an 'x.'

Figure 2: Comparing MnDOT HCCI with NHCCI 2.0 and the Average HCCI for Peer States, Rebased to 2004

Other relevant price indicators, such as fabricated steel, concrete and bituminous producer price indexes, are incorporated into the analysis to provide a separate line of evidence as to the strength of MnDOT's HCCI trends. See **Figure 3.**



Note: MnDOT HCCI values for 2013, 2015 and 2016 are based on imputed values and are denoted by an 'x.'

Figure 3: Year-over-Year Percent Change of PPIs and HCCIs

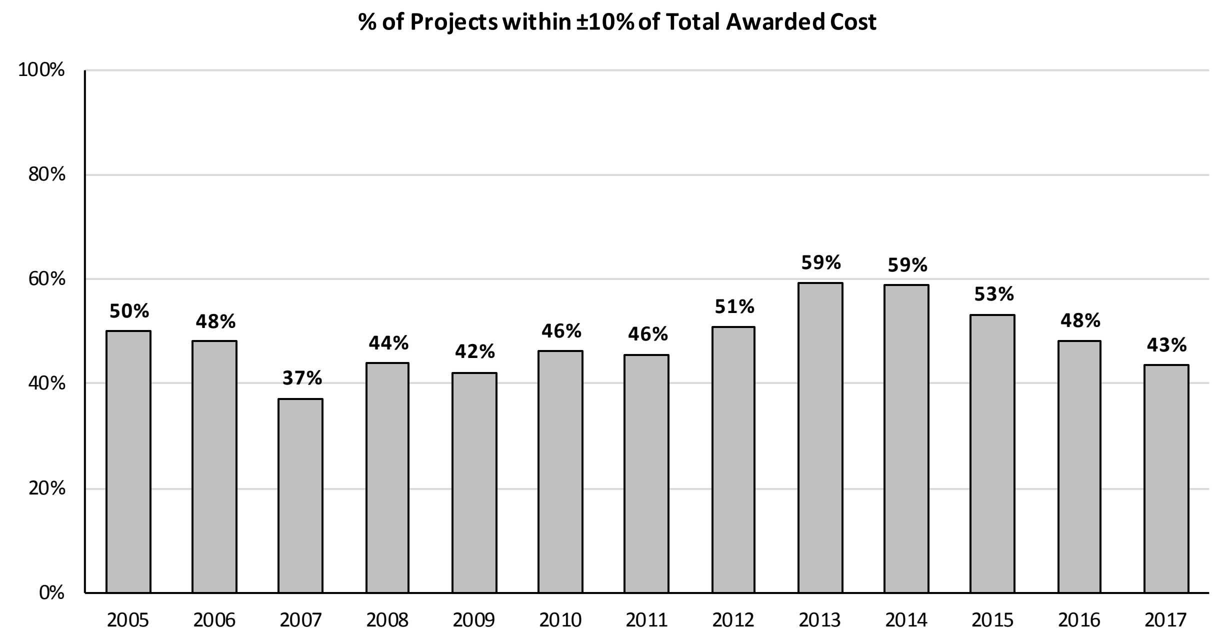
Figure 3 compares year-over-year percent changes across relevant producer price indexes, such as fabricated structural metal and concrete products, as well as asphalt and tar paving mixtures, to that of the MnDOT HCCI and the NHCCI 2.0. The NHCCI 2.0 tends to follow index changes from the structural metals, and cement and concrete PPIs. Between 2009 and 2013, the MnDOT HCCI more closely follows the trends observed from the asphalt and tar pavement PPI. Of interest is that the average annual growth rate in the MnDOT HCCI is 5 percent per year between 2012 and 2014, while the FHWA's NHCCI 2.0 average annual growth rate over the same two year period is only 2.5 percent. This is to be expected since MnDOT's HCCI methodology only applies a weight of 11 percent to structural steel items while bituminous items receive the greatest weight of 43 percent. All indexes appear to converge in terms of rate of change in 2013.

Engineer's Estimates

Actual historical engineer estimates and final awards for 2,648 of MnDOT's design-bid-build projects let between Quarter 1 of 2005 to Quarter 1 of 2017 were used to monitor how accurate the EEs are to that of the award. The FHWA's guidelines on preparing EEs recommend that 50 percent of the EEs of let projects should be within ± 10 percent of the award. Changes in the HCCI over time, the cost estimating process itself and forecasting methods are used to help cost estimators forecast project budgets, so a high level of cost estimate accuracy relative to the award suggests a strong price index methodology.

As shown by the EEs, MnDOT's ability to estimate project costs especially since 2005, is strong and regularly meets or closely approaches FHWA's guidelines in cost estimation performance of EEs. Performance metrics in **Figure 4** show a range from a low of 37 percent of EEs of let projects in 2007 to a high of 59 percent 2013. Years 2012 to 2016 show the best performance period with performance near or significantly exceeding performance guidelines. Year 2017 is a partial year and performance will change as more projects are let and awarded.

The median percent difference between the EEs and the awards from the 2005 to 2017 study period is 2 percent showing a satisfactory level of accuracy. The median percent differences for the second and third bidders to the awards are 6 and 13 percent, respectively. On average, the EEs are closer to the lowest bidders' values compared to what other vendors are submitting.



Results from 2005 to 2017 are year-end and were calculated by HDR using EEs and awarded vendors' bid items from an extract of MnDOT's database.

Note that 2017 only contains projects let in the first quarter.

Figure 4: Percentage of MnDOT Projects with EEs within ± 10% of Award, by Calendar Year

Pearson Correlation Coefficient

The statistical analysis using the Pearson correlation coefficient focused on the similarity in HCCI trends over time for studied peer state DOT HCCIs and FHWA's NHCCI 2.0. The assumption is that if MnDOT's HCCI is well specified and representative of the actual construction cost of inflation, it should be correlated with the HCCI trends observed at the peer state level and the national level. The Pearson correlation coefficient is chosen as the statistical method to test this assumption.

The results of the Pearson correlation coefficient analysis demonstrates high positive correlation in MnDOT's HCCI trends over time with that of other individual peer states and the NHCCI 2.0. Correlation coefficients of 0.8 to 1 denote a high level of correlation and such relationships may be used to forecast future near-term trends for one variable as a function of the other. Correlation statistics ranging from 0.84 (MnDOT compared to ODOT) to a high of 0.99 (MnDOT compared to Iowa DOT) denote highly similar trends across the price indexes under consideration. The correlation metric between the MnDOT HCCI and FHWA's NHCCI 2.0 is 0.88, which infers that, based on the time horizon, it is expected that these two indexes will generally follow a similar directional trend.

Summary

In summary, the findings from this benchmarking analysis are the following:

1. MnDOT's HCCI exhibits similar trends over time to those in the selected peer states, the average of all peer states (including MnDOT), and most importantly, the FHWA's NHCCI 2.0. The median of the differences in the year-over-year percent changes between the MnDOT HCCI and the average of the peer states' HCCIs is only -0.3 percentage units and 2 percentage units when compared to the NHCCI 2.0.
2. Year-over-year percent changes in MnDOT's HCCI is directionally proportional to those observed from the average of the year-over-year peer states' HCCIs and the NHCCI 2.0 based on changes of observed MnDOT HCCI. That is, if either the average of the peer states' HCCIs or the NHCCI 2.0 shows a positive year-over-year growth for a particular two year period, the MnDOT HCCI is also positive, similarly so for negative growth.
3. Recent growth in MnDOT's HCCI between 2012 and 2014 may be attributed to higher costs for bituminous pavement on let projects that required significant amounts of bituminous product.
4. MnDOT's EEs, which rely on changes in the HCCI to escalate costs for highway components, produce project estimates that are within the range of the FHWA's guidelines for highway cost estimation since 2005, although the level of performance declined slightly to 48 percent of projects with EEs within ± 10 percent of award as of year-end 2016, down from a high of 59 percent in 2013 and 2014.
5. MnDOT's EEs are price competitive since an analysis of the percent deviations between each of the EEs, second bidder's estimate, third bidder's estimate and the award show that the median percent difference between the EEs estimate and the award is only 2 percent while the second and third bidders' estimates are 6 and 13 percent, respectively.
6. MnDOT's HCCI shows high positive Pearson correlation coefficient (>0.80) with the NHCCI 2.0 and for peer states Iowa, Montana, Washington and Ohio.

Overall, MnDOT's HCCI is a strong measure of the rate of construction cost inflation. Its trends over time are reflective of trends observed from the peer states and the NHCCI 2.0, and the asphalt and tar pavement mixture and fabricated structural metal PPIs. While MnDOT has its own particularities in terms of project work types and vendor dynamics, which may or may not be shared by all the peer states selected for this study, the changes in its HCCI since 2004 demonstrate sound methodologies for tracking and quantifying cost escalation.

Progress made in tracking changes to highway construction costs over time by the FHWA and other state DOTs such as Montana DOT, encourages improvements. Possible changes to MnDOT's HCCI current methodology are explored in Part Three: "Review of MnDOT's Construction Cost Index."

Objective of the Analysis

The Minnesota Legislature requested a review of the Minnesota Department of Transportation's highway construction cost index methodology and trends to evaluate if the HCCI is overinflating the true cost of construction as determined by the marketplace. The assumption held in this analysis is that if MnDOT is capturing true price escalation rates related to highway construction projects year after year, then its trends should follow, to a reasonable extent, trends observed from the peer states and from the national average.

The goal of this analysis is to present existing metrics, used by the DOT's of various states, to estimate highway construction cost changes over time. In particular, this analysis will focus on the peer states selected based on relevance from a geographical and program management perspective. Moreover, the analysis of HCCIs used by these comparable states may provide insight on their respective management of highway construction costs. MnDOT's and its peer states' HCCIs were also compared to the Federal Highway Administration's recently revised national highway construction cost index, NHCCI 2.0, as a means to benchmark performance relative to the advanced price index methodology discussed by the FHWA.[3]

This analysis also incorporates relevant metrics that track price changes of critical highway input materials, such as bituminous pavement and concrete pavement, as a separate line of evidence to understand the performance of MnDOT's HCCI. Finally, the analysis provides an overview of performance measurements for MnDOT's cost estimation metrics, relative to the FHWA's "Guidelines on Preparing Engineer's Estimate, Bid Reviews and Evaluation"[4]

[3] National Highway Construction Cost Index (NHCCI) 2.0, U.S. Department of Transportation FHWA, July 19 2017.

[4] See Guidelines on Preparing Engineer's Estimate, Bid Reviews and Evaluation, downloaded Nov. 14, 2017.

Overview of Highway Construction Cost Indexes

Highway construction is a complex activity that requires a wide range of inputs in its process and may vary across projects. Construction cost indexes supply insight into the costs of construction materials and services over time, and aid program planners and cost engineers when estimating budgets for proposed projects. CCI's provide a means to understand trends in construction inflation and to forecast near-term cost escalation rates. Both perspectives allow an agency to understand where design and construction efficiencies can be incorporated and whether it is tracking the correct price components for cost escalation when planning for future projects.

This report provides a comparative overview of MnDOT's HCCI's trends relative to that of the trends observed from selected peer state HCCIs. The peer states included in this report are: Utah, Iowa, Washington, Ohio and Montana. These states were selected in a workshop (Oct. 12, 2017) led by MnDOT based on relevance from a geographical and program management perspective. Missouri was also considered; however, this state does not create its own HCCI.[5] In addition to these states' HCCIs, the FHWA's NHCCI 2.0 and Producer Price Index for construction materials, such as fabricated structural metals, cement and concrete products, and asphalt and tar paving mixtures, were included. These PPIs represent a level of quality in terms of methodology and data inputs that was used as a standard to compare the trends in MnDOT's HCCI and those of the peer states' HCCIs to provide a deeper understanding of the MnDOT's HCCI performance.

Highway Construction Cost Indexes Under Consideration

The following sections summarize the key features of MnDOT's and its peer states' HCCIs in terms of data inputs (i.e., bid items) and price indexing methodology. Finally, with the recent release of the FHWA's NHCCI 2.0 in July, 2017, an overview discussion of its methodology and data inputs is provided to gain greater insight into common approaches and differences across MnDOT, the peer states and the FHWA, and how MnDOT compares to other studied state and federal agencies. (**Appendix E** of this report tabulates the following discussion for ease of reference. **Appendix F** provides more detailed information on the main price indexing methodologies of Laspeyres, and Fisher and Young, which are used by some of the peer states.)

Minnesota

The Minnesota Highway Construction Cost Index, referred to as MnDOT HCCI, is developed by MnDOT, is calculated using a Laspeyres methodology and is composed of six indicator items that represent the price trends in highway construction:[6]

- Roadway excavation
- Concrete pavement
- Plant-mixed bituminous pavement
- Reinforcing steel
- Structural steel
- Structural concrete

[5] Appendix D contains a comparative analysis of MoDOT's average prices for asphalt and concrete to that of asphalt and tar PPI and concrete and cement PPI.
[6] Based on: Minnesota Department of Transportation, "Highway Construction Cost Index–3rd Quarter 2016," September 6, 2017, (accessed Sept. 25, 2017).

These items are tracked and indexed separately. The data is then used to compute the Excavation Index, the Surfacing Index, the Structures Index and the composite Construction Cost Index. The Excavation Index is represented by just one aggregate item, roadway excavation. The Surfacing Index is composed of the concrete pavement and plant-mixed bituminous pavement indicators and represents trends for all surface types. The Structures Index is composed of reinforcing steel, structural steel, and structural concrete indicators, and represents the price trends for structures in general. Bituminous pavement makes up 43 percent of the composite index, concrete applications account for a total of 31 percent of the composite HCCI (with a split of one-third for pavements and two-thirds for structures), roadway excavation accounts for 14 percent of the HCCI, and reinforcing and structural steel account for 11 percent.

The MnDOT HCCI uses 1987 as the base year to align with FHWA's previous national highway cost construction index. The MnDOT index is computed quarterly and at year-end based on unit prices from the actual bids for projects (excluding design-build projects) costing more than $100,000 and let during that quarter. The unit prices include the cost of materials, labor, equipment, overhead and profit. If there is no data for certain indicator items in a given period, the corresponding index and the composite construction index is not calculated for that period.[7]

Utah

The Utah Department of Transportation reports a construction cost index derived from the following item categories:

- Roadway excavation
- Hot mix asphalt (HMA)
- P.C.C.P (9"—11" thick)
- Structural concrete
- Reinforced steel (coated)
- Structural steel

The Utah HCCI uses 1987 as its base year with the index value at 100 for 1987. UDOT reports both quarterly and annual index values. The HCCI reported follows a modified Laspeyres methodology, which is a basic index methodology compared to the new methodologies currently being used by various states, including those used in this analysis and the FHWA's NHCCI 2.0.

Iowa

The Iowa Department of Transportation develops a highway construction cost index, called, "Price Trend Index for Iowa Highway Construction," and is based on the following item categories:[8]

- Class 10 roadway and borrow, and embankment-in-place
- Hot-mix asphalt pavement and shoulder mixes
- Class 'A,' class 'B,' and class 'C' PCC pavement
- Reinforcing steel
- Structural steel
- Structural concrete

[7] Table 7: Minnesota DOT Highway Construction Cost Index 1987–2016, Base Year 19871, Appendix G.
[8] Based on: Iowa DOT Office of Contracts "Price Trend Index for Iowa Highway Construction," (accessed Sept. 22, 2017). This document provides information for the CCI for the period from 1987 to 2017.

These items are tracked and broken into separate construction categories: roadway excavation, surfacing and structures. These separate construction categories are sub-indexes that are used to create the composite price index. The Iowa HCCI uses 1987 as a base figure calculated through weighted averages of the six indicator items on awarded contracts let through the Iowa DOT's Office of Contracts, for calendar years 1986, 1987 and 1988. The weight of each item in the composite index is calculated using the share of the respective item in total project costs.[9] Beyond the construction cost index, the Iowa DOT also tracks the annual price trends, which had been previously compared to the discontinued "Price Trends for Federal-Aid Highway Construction," published by the U.S. Department of Transportation, Federal Highway Administration.[10]

Washington

The Washington HCCI is derived from the following item categories:[11]

- Roadway excavation
- Crushed surfacing
- Hot asphalt mix
- Concrete pavement
- Structural steel
- Reinforcing steel bar
- Structural concrete

The above items are used to calculate the composite index, using bid data collected from construction projects.[12] While the index is calculated annually and uses 1990 as the base,[13] information regarding the specific methodology used for the calculation of the composite index is not publically available. Moreover, the time series of the construction cost indexes on WSDOT's website ends as of July 15, 2016.[14]

Ohio

The construction cost index developed by the Ohio Department of Transportation follows a Chained Fisher index[15] methodology and is based on the follow 20 item categories:[16]

- Aggregate Base
- Asphalt
- Barriers
- Bridge Painting
- Curbing
- Drainage
- Earthwork
- Erosion Control
- Guardrail
- Landscaping
- Lighting
- Maintenance of Traffic
- Pavement Markings
- Pavement Repair
- PCC Pavement
- Removal
- Signalization
- Structures
- Traffic Control
- Unclassified Construction (Other)

[9] Based on: Iowa DOT Office of Contracts "Price Trend Index for Iowa Highway Construction," (accessed Sept. 22, 2017). This document provides information for the CCI for the period from 1987 to 2017.
[10] Ibid.
[11] WSDOT Highway Construction Cost Index – June 2016, Washington State Department of Transportation, July 2016, (accessed Nov. 2017)
[12] Construction Cost Trends, Washington State Department of Transportation, 2017 (accessed Nov. 2017)
[13] Jeong, David H., Douglas D. Gransberg, and K. Joseph Shrestha, "Advanced Methodology to Determine Highway Construction Cost Index (HCCI)," prepared for The State of Montana Department Of Transportation, June 2017; (accessed Oct. 5, 2017)
[14] Construction Cost Trends, Washington State Department of Transportation, 2017.
[15] See Appendix F
[16] Ohio Department of Transportation, "The Chained Fisher ODOT Construction Cost Index," November 8, 2013; (accessed Oct. 6, 2017)

The ODOT replaces outlier prices, defined as prices greater than two median absolute deviations from the median, with the median price. It also groups related item classes but excludes non-standard item classes and item types. For barriers, earthwork and landscaping, ODOT uses weighted-average prices smoothed by a two-year moving average. These are some of the adjustments made by the ODOT to improve its data quality. The index uses quarter 1 of 2012 as its base year and reports the index on a quarterly basis.

Beyond its HCCI, ODOT's quarterly Construction Cost Outlook and Forecast presents information and insights on key construction input trends. In particular, factors such as labor, contractor and supplier margins, oil diesel and natural gas, liquid asphalt, aggregate, steel and ready-to-mix concrete are reviewed.[17]

Montana

The Montana Department of Transportation is proposing an update to its HCCI, changing the old methodology that followed a Young index.[18] The new index methodology will follow a Chained Fisher Index, covering items that account for more than 70 percent of the total construction costs, and uses eight times more bid items (approximately 650 bid items annually).[19] The proposed index breaks down the item-based characteristics into 31 item classes, 10 items types and 6 item divisions, where the item divisions are:

- general provisions
- earthwork
- aggregate surfacing and base courses
- bituminous pavements
- rigid pavements and structures
- miscellaneous construction

The proposed index, which is planned to be operational by mid-2018, will include a dynamic item basket and create a multidimensional index to overcome the limitations of the current MDT index. In its DIB, the items in the basket and corresponding cost and quantity information are updated automatically based on current purchasing behavior of the department. The DIB captures item data used in the current and previous periods providing a larger sampling size than the item baskets used in other DOT indexes. By increasing the overall sample size of items, the sampling error of the estimates is reduced, improving the accuracy and reliability of the HCCI. After selecting the items which define the DIB, multidimensional indexes can be calculated. In particular, the methodology creates costs indexes for highway construction sectors defined by factors such as project size, type and location, because those factors are known to affect the cost of construction. This allows for adjustments to economies of scale, specialization, project variations and geographic-related conditions.[20]

Currently, MDT's HCCI is calculated following a modified Young's Index, with a base year set to 1987, and reports two different indexes, a regular HCCI and a Modified HCCI. The difference between the two reported HCCIs is

[17] ODOT Chained- Fisher Construction Cost Index for Selected Highway Construction Cost Items, Ohio Department of Transportation, October 2017, (accessed Nov. 2017)
[18] See Appendix F
[19] Jeong, David H., Gransberg, Doug, Shrestha, K. Joseph, "Implementation Meeting: Advanced Methodology to Determine Highway Construction Cost Index (HCCI)," Prepared for the State of Montana Department of Transportation, June 6, 2017; (accessed Oct. 6, 2017)
[20] Jeong et al., "Advanced Methodology to Determine Highway Construction Cost Index (HCCI)," prepared for The State of Montana Department Of Transportation, June 2017

related to differences in weighting methodologies. In particular, the regular HCCI considers item weights from the current year, whereas the Modified HCCI uses constant weights throughout the years.[21]

Federal Highway Administration

The National Highway Construction Cost Index 2.0, developed by the FHWA, measures the average changes in the prices of highway construction costs over time. It also converts current-dollar highway construction expenditures to real dollar expenditures. The index values are derived from data extracted from state web-postings of the winning bids submitted on highway construction contracts. By using such a large quantity of data, the NHCCI covers all of the nation's highway projects and arrives at an average cost index for all highway construction.

This national index is calculated from a Chained Fisher index[22] methodology, which allows for the market basket to be updated throughout the index, removing the inherent bias that would otherwise occur if the mix of goods changed over time.[23] The NHCCI requires relevant information such as state, bid price, unit of measure, general expenditure category and date the contract was awarded. Although this index uses state level data, it produces a national average and does not compare state prices, allowing it to overcome variations in "pay-item" definition across different states.[24]

The FHWA recently updated the NHCCI in July 2017. The update adjusts items with inconsistent units, non-standard items and items whose identification codes or pay items have a numbering change at the state level, which could not be accounted for in the original version. The updated NHCCI can also better identify outlier observations, items subject to discount and observations with extreme price fluctuations. While the adjustments made to the NHCCI use more data, it allows for the price trends to better reflect trends from other national price indexes and provide more consistent estimates over time.[25]

HCCI Best Practices

A best practice is using that methodology or procedure considered the most correct or most effective. A caveat to this statement is that effectiveness needs to be tempered with the level of effort required to reach such a practice. The economic methodologies used by the peer states and the FHWA for price indexing such as Laspeyres, Fisher or Young are all types of *best practices* for price indexing. Recent trends by peer states and the FHWA to implement the chained Fisher price index reflects changing methodologies aimed at addressing the higher volatility market prices seen in all sectors, not just the construction sector, since 2001. The chained Fisher index approach is better at mitigating the impacts from shifting focus from one class of projects to another type (e.g., focus on mega-projects or bridge projects for a few years, and then change to other project work types) as basket items may change over time. From a state perspective, the changing of state-level price indexing

[21] Ibid
[22] See Appendix F
[23] White, Karen, and Erickson, Ralph, "New Cost Estimating Tool," U.S. Department of Transportation, July/August 2011; (accessed Oct. 5, 2017)
[24] White, Karen, and Erickson, Ralph, "New Cost Estimating Tool," U.S. Department of Transportation, July/August 2011; (accessed Oct. 5, 2017)
[25] U.S. Department of Transportation, "National Highway Construction Cost Index (NHCCI) 2.0"

methodologies from the traditional Laspeyres method to that of the chained Fisher index indicates a desire by some of the peer states to follow the lead taken at the national level.

A review of FHWA's website found that FHWA identified Ohio and Wisconsin as having 'notable' practices in cost estimating and the development of HCCIs.[26] Ohio is tracking 20 different item categories, has implemented an algorithm to flag outlier prices and uses a two year moving average to smooth out prices. Wisconsin was noted for its ability to draw on bid data from construction projects to produce its HCCIs. However, as of 2016, Wisconsin is not publishing its HCCI. It currently is using a proprietary, national HCCI based on the NHCCI 2.0 to estimate its projects costs.

Montana has conducted extensive research and is piloting a revised HCCI that follows the chained Fisher index approach. Like the NHCCI 2.0, it draws on a larger set of bid item categories. However, it takes the process a step further by creating a multi-dimensional HCCI that varies by project work type, project size and location, among other factors. The revised methodology provides improved accuracy in price escalation rates, but based on the length of time between research in early 2015 and planned implementation in 2018, a significant level of effort and financial investment has been expended. Though, through automation of the new HCCI methodology, this investment will have a good return on investment over the long run.

The chained Fisher index method is trending as the best practice at this point in time. For agencies with access to extensive databases of project bid items and resources to manage and parse through the database to track changing baskets of bid items, the chained Fisher index method is appropriate. Nonetheless, the particularities of long term budgeting and planning of highway construction projects mean that price changes may not always be captured on a timely basis, no matter what type of indexing methodology is used. At the state level, each agency needs to evaluate the best method given the types and numbers of projects it plans on a yearly basis, and the resources available from which to build and maintain price indexes.

[26] See FHWA's web page on Major Projects Cost Estimating Resources, accessed Oct. 5, 2017

Benchmarking Analysis

Methodology and Assumptions

Benchmarks are a point of reference from which measurements may be made and serve as a standard by which others may be measured. Given the sophisticated sampling and calculation methodologies used in FHWA's current NHCCI, it will serve as the benchmark from which to compare MnDOT's and its peer states' HCCIs. Drawing on the principles of meta-analysis, the average of the studied states' HCCI values per time period (e.g., annually) tracked over time can also serve as a benchmark. The basic philosophy behind meta-analyses is that there is a common truth behind all conceptually similar scientific studies, but which has been measured with a certain error within individual studies. By taking the average of such estimates, the error in the estimates is reduced.

State HCCI data was obtained from the respective DOTs. Adjustments were made to the state HCCI data due to a variation in the reporting (i.e. annual or quarterly reported values) and the difference in captured time horizons. To better gauge the indexes' change over time, all studied indexes were normalized by rebasing each series to coincide to the first time value in the study period. For the NHCCI 2.0 and for states' HCCIs that are reported on a quarterly basis , the average of the quarterly reported values was used as an estimate of the annual index values.

Starting in 1998, MnDOT provided detailed information on its HCCI for its sub-indexes and its composite index, and index data dating back to 1987 was obtained through the most recently reported highway cost index. However, the annual composite HCCI was missing years 2013, 2015 and 2016 because no projects were let in those years with qualifying price estimates for structural steel and concrete sub-components. Imputation methods using ordinary least squares regression and time series trend analysis were used to substitute a value for the missing annual composite HCCIs.[27] Data used to support the analyses in this report is found in **Appendix G**. The data points used in the report's figures can be found in **Appendix H**.

Montana DOT reports two annual HCCIs and both are considered in this analysis. The difference between the original MDT HCCI and the modified MDT HCCI lies in item category weighing methods. In particular, the original MDT HCCI uses item category weights from the current year, while the modified MDT HCCI uses constant weights throughout time.

The HCCI index data provided by Ohio presents index values from first quarter 2001 to third quarter 2017 using two different methodologies for calculating quarterly price changes – one for values prior to 2007 Q1 and another for values from 2007 Q1 onwards. The methodology used to calculate the quarterly relative change before 2007 Q1 follows a Laspeyres methodology, while values from 2007 Q1 onwards follow a chained Fisher methodology. The overall index is calculated based on the quarterly values dating back to 2001 Q1 (including values from both methodologies), and is rebased to 2012 Q1.

Product Price Index data was gathered from the Bureau of Labor Statistics.[28] The PPI data used in the analysis includes major highway construction inputs such as fabricated structural metal, concrete products, and asphalt and tar paving mixtures. The extracted monthly PPI data is then transformed to both quarterly and annual index

[27] **Table 7**: Minnesota DOT Highway Construction Cost Index 1987–2016, Base Year 19871, Appendix G.
[28] Data obtained through using the Bureau of Labor Statistics' Inflation and Price Database https://www.bls.gov/data/#prices

values. The transformation was done by taking averages over the appropriate time horizon, which for quarterly index values, cycled every 3 months.

For annually reported index values, the time horizon of 2004 to 2016 was used. These years were selected as there were minimal missing data during this period for a span of at least 10 years. For the quarterly reported index values, the time horizon 2003 Q1 to 2016 Q4 was explored. However, the quarterly index analysis only compares the trends between Minnesota's HCCI, the NHCCI and selected construction material PPIs.

For the completed annual data set, comparable state HCCIs with the same base year as Minnesota's HCCI are first graphed visually to identify trends, similarities and potential deviations. Minnesota's HCCI is then visually compared between the time horizon of 2004–2016 with all peer state HCCIs, the average of all peer state HCCIs (including MnDOT's HCCI), the NHCCI 2.0, and relevant construction material PPI. The year-over-year percent change of the Minnesota HCCI is compared to that of the peer states' average HCCI and the NHCCI 2.0. This provides insight on the performance of the Minnesota HCCI. In particular, it helps identify if the HCCI follows similar trends or if there is a significant deviation from the construction costs of the peer states, the national average or price trends of major construction materials.

HCCI Comparisons

Annual HCCI

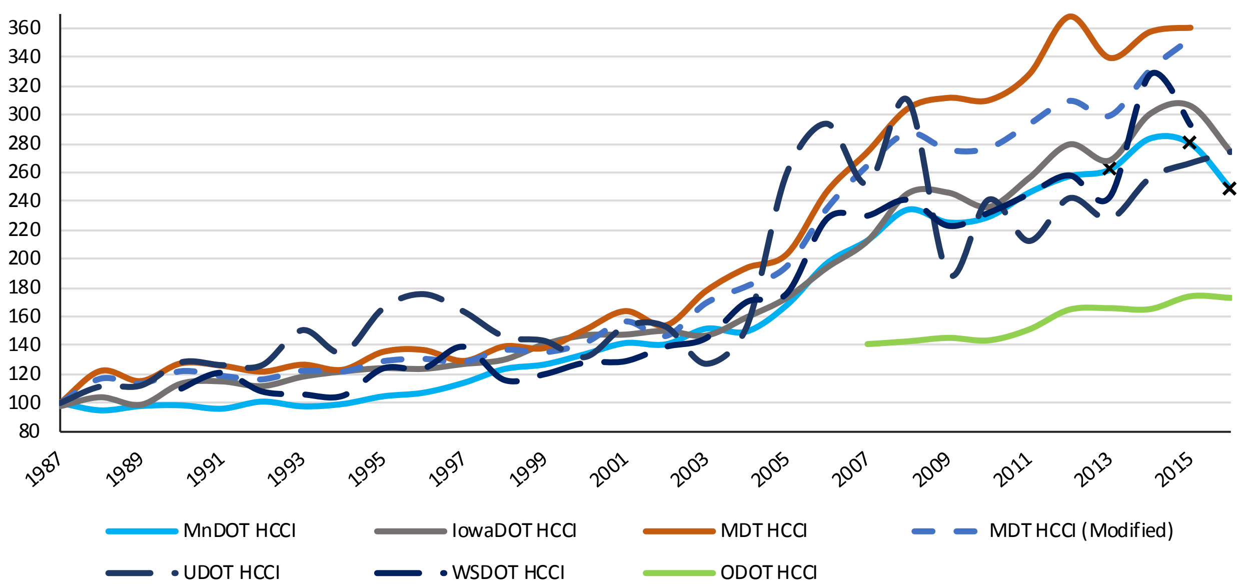


Figure 5: Construction Cost Index, Base Year 1987[29]

Figure 5 provides a comparison of the HCCIs from MnDOT and the peer states that share the same base year of 1987. It should be noted that for years 2013, 2015 and 2016, MnDOT's HCCI values were imputed using ordinary

[29] ODOT HCCI values were obtained from ODOT and based from 2007 Q1 to correspond with ODOT's introduction of the Chained Fisher index methodology.

least squares regression analysis and time series trends and are flagged by the symbol 'x'.[30] Analysis of the plots should focus on the rate of change over time and not the absolute values among the different indexes since each state has its own particular "market basket" of quantities and costs during the base period. A state with higher index values does not imply that construction costs are higher in that state.

Consider a recent 2017 study by the Midwest Economic Policy Institute, "A Comparison of Highway Construction Costs in the Midwest and Nationally"[31] The study shows Minnesota ranking as the 8eighth lowest cost state in terms of average annual highway construction costs (averaged over years 1984-2014) per lane mile. While the rankings do not incorporate costs of new lane construction, their tracking of total maintenance and rehabilitation costs related to existing road infrastructure are indicative of Minnesota having effective highway cost management policies. Given that Minnesota was compared to the southern states in this study, its lower average costs in light of the adverse impacts related to more expensive winter road maintenance is evidence of its ability to manage highway costs.

With the exception of the large deviation from UDOT's HCCI, it is evident that MnDOT's HCCI follows a similar trend to that of Montana (modified) and Iowa. With respect to UDOT's HCCI, the type of projects and materials used between 2004 and 2009 may have driven the observed large fluctuations between 2003 and 2009. For instance, if there had been a big push to build mega-projects for its highway network until 2009, the need for structural steel would significantly drop afterwards, impacting its HCCI. It is noted that national steel production significantly dropped around 2009.[32] UDOT's HCCI would vary significantly based on these particular projects and materials.

[30] The relationship of the three main sub-index values to that of the composite index values over the years from 1988 to 2016 was leveraged to impute the three missing year-end composite indexes. First, a time series trend methodology was used to impute the missing structures sub-index values for 2013, 2015, and 2016. This approach was also used to impute the missing roadway excavation index value for 1995. Then an ordinary least squares model was developed to quantify the annual trends of the composite index as a function of the trends in the three sub-indexes for years will full data (1988–1994, 1996–2012, 2014).The resulting equation then output an estimated composite index value for 2013, 2015, and 2016 using the sub-index and item category values for those years as inputs. Imputed values are contained in **Table 7** of Appendix G.

[31] Mary Craighead, AICP "A Comparison of Highway Construction Costs in the Midwest and Nationally", Midwest Economic Policy Institute May 3 2017, downloaded, Oct. 9, 2017.

[32] Steel production down to 56 million metric tons in 2009 from 91.9 million metric tons in 2008. Data and information from: Mineral Commodity Summaries, U.S. Geological Survey, January 2010.

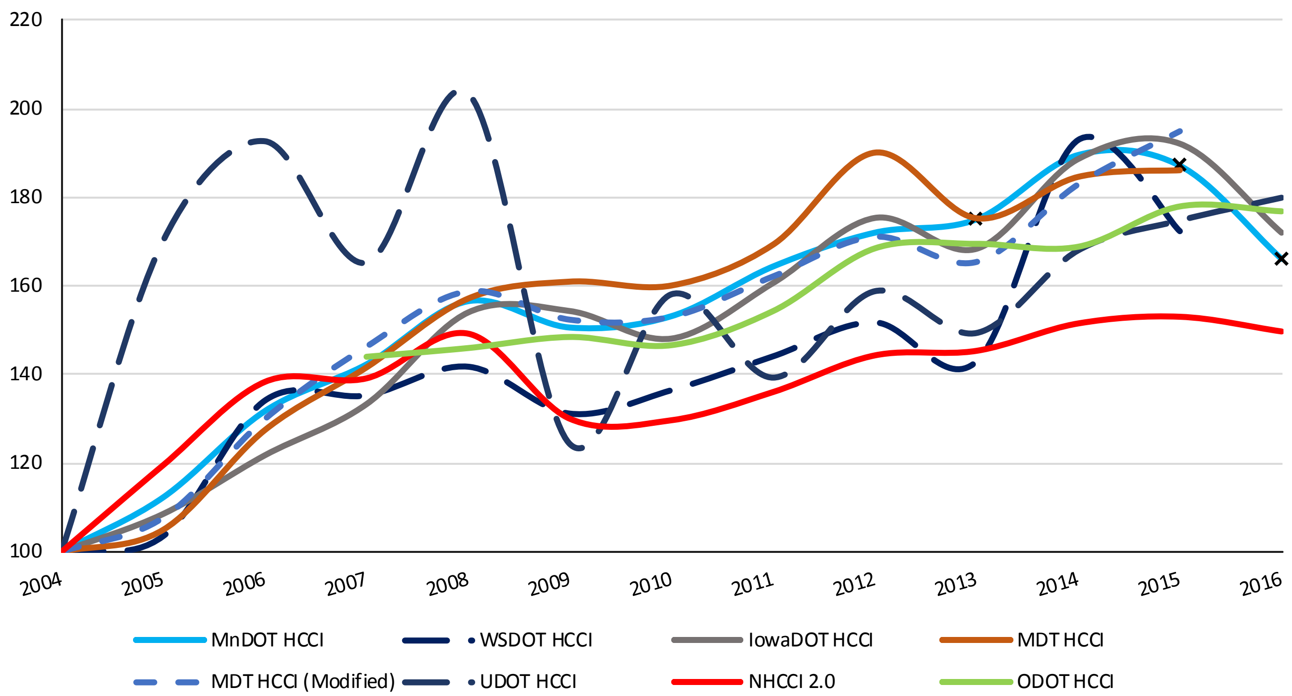


Figure 6: Highway Construction Cost Indexes (2004–2016), Rebased to 2004

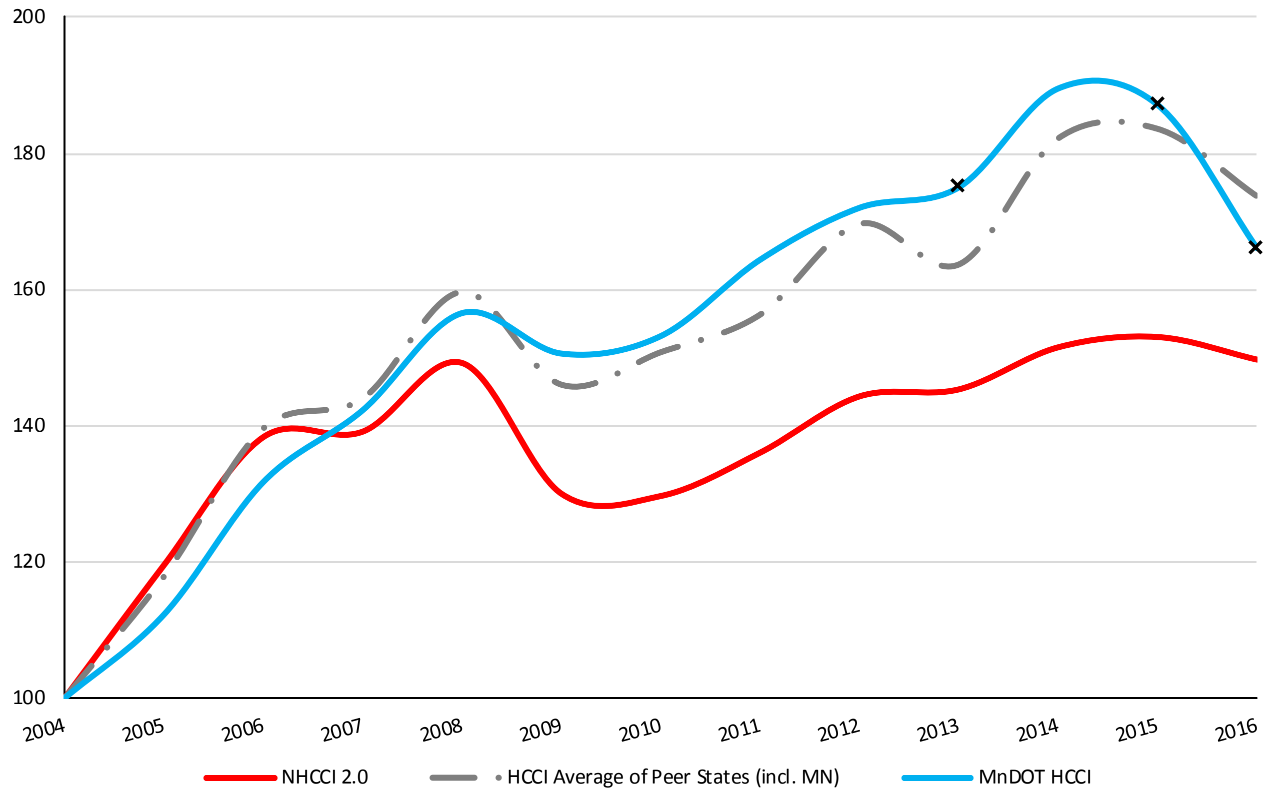


Figure 7: Comparing MnDOT HCCI with NHCCI 2.0 and the Average HCCI for Peer States, Rebased to 2004

Figure 6 compares the MnDOT HCCI with HCCIs of the peer states and the NHCCI 2.0, rebased to year 2004 when the NHCCI 2.0 series begins. **Figure 7** compares the MnDOT HCCI with the NHCCI 2.0 and the average HCCI of all studied peer states, rebased to year 2004. Rebasing the peer states' HCCIs to 2004 is type of normalization of the data to better compare changes over time.

Figure 6 highlights that Minnesota's highway cost escalation trends are fairly comparable to Iowa, which is the closest peer state to Minnesota geographically. Moreover, the deviation between the average of the peer states and Minnesota in **Figure 7** may be attributed by Washington and Utah, which may face different conditions (e.g., environment).

If there are major differences in how an agency weights the sub-components of a HCCI and what pay-items are selected for analysis by sub-component, these are then reflected in varying fluctuations over time. For example, the similar patterns across the less volatile changes in the MnDOT HCCI, the Modified MDT HCCI, and the Iowa DOT HCCI may be due to their similar weighting and data sampling methodologies. If a state has differing weights for groups of items or the relative quantities of those items in a given year are notably different from that observed in other states, large variances may be observed in the HCCI trends as observed for UDOT's HCCI.

As mentioned previously, MDT reports two annual HCCI values based on different item category weighting methodology. Both **Figure 5** and **Figure 6** demonstrate that the trend and index values are fairly similar throughout both time horizons. However, between 2009 and 2015 there is a large deviation between the two where the constant weighting (modified index) reports index values lower than that of the dynamic weighting (original index). This highlights the issue where the constant weighting does not consider changes in the overall item basket when certain materials may be used more extensively as a result of the different nature of projects or costs. The divergence in the two indexes from MDT demonstrates the impact of how methodologies can impact trends and year-over-year estimates in cost escalation.

Actual index values are transformed to track year-over-year percent changes in **Figure 8** and **Figure 9** below. A visual inspection of **Figure 8** indicates that MnDOT's annual HCCI trend follows closely with the peer states' average HCCI and NHCCI annual trends. It is noted that the rate of decline in the NHCCI 2.0 between 2008 and 2010 is not as steep as that observed for MnDOT's HCCI and the peer states average HCCI. Between 2009 and 2008, the NHCCI 2.0 drops by 13 percent, while MnDOT's HCCI and the peer states' average HCCI drops only by 4 and 6 percent, respectively.

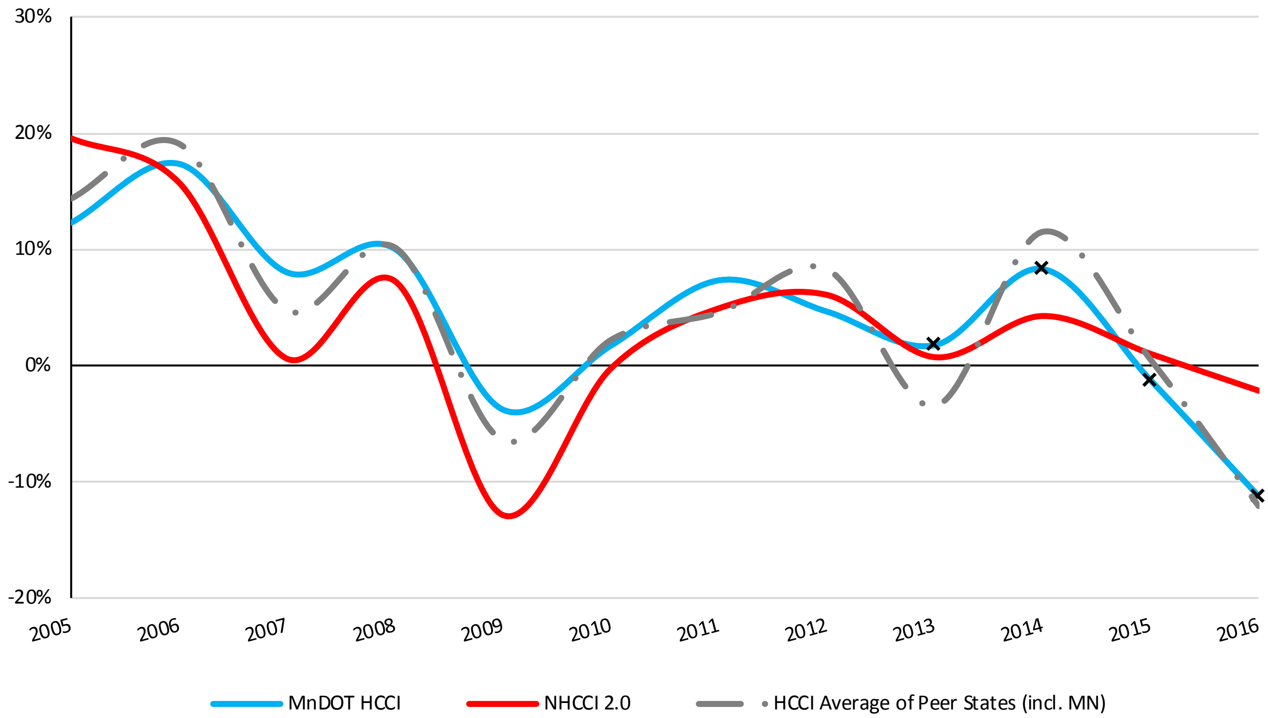


Figure 8: Year-over-Year Percent Change for MnDOT HCCI, Peer States' Average HCCI, and NHCCI 2.0

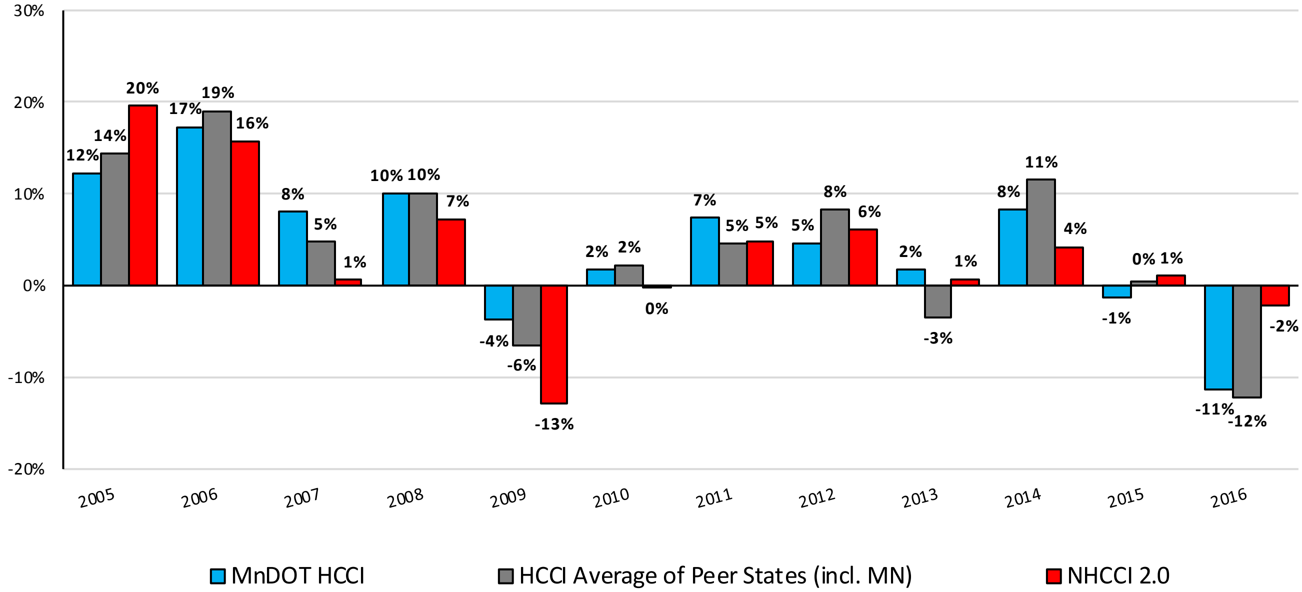


Figure 9: Year-over-Year Change for MnDOT HCCI, NHCCI 2.0, and the Average HCCI of All States

Overall, the year-over-year changes to the MnDOT HCCI, as shown in **Figure 8** and **Figure 9**, follow closely to that of the NHCCI 2.0 from 2005 to 2016. For some years, MnDOT's highway construction rate of inflation is within 1 percent or less than the year-over-year percent change in the NHCCI during years 2005 and 2012. In **Figure 9**, 2006 is shown as within 1 percent or less due to rounding; however, without rounding, the difference is 1.6 percent for 2006.[33] The values are within 1 percent or less in 2013, 2015 and 2016 as well; however, since MnDOT's 2013, 2015 and 2016 HCCIs are imputed, year-over-year percent changes for these years should be interpreted as indicative of trends. Of note is that the average annual growth rate between MnDOT's 2012 and 2014 reported indexes is at 5 percent while it is only 2.5 percent for the NHCCI 2.0. When compared to the peer states' year-over-year change in the average HCCIs, MnDOT is within 1 percent or lower during years 2005, 2006, 2008, 2010, 2012, 2014 (imputed), 2015 (imputed), and 2016 (imputed). Years where MnDOT's annual percent changes in their construction price index are notably larger as observed in 2007, 2009 and 2011 are to be expected given differing project priorities at the state level.

Interestingly, both the MnDOT HCCI and average of the peer states' HCCIs drop significantly from 2015 to 2016 relative to that of the NHCCI 2.0, at 11 and 12 percent respectively compared to 2 percent as the effects of deflation catch up to prices in the peer state region. Since the NHCCI 2.0 draws on all states' bid items with the exception of Alaska and Hawaii,[34] and produces a national weighted average, a particular state (or group of states) will deviate at times from the national average.

An analysis of deviations of the year-over-year percent differences over the study period between the MnDOT HCCI and the peer states' average HCCI and the MnDOT HCCI to that of the NHCCI 2.0 shows that the median

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[33] Correction needed to this sentence and another sentence on page 48; In the Highway Construction Costs and Cost Inflation Study released on Feb. 22, 2018, the report indicated that in 2006, the highway construction rate of inflation was within 1 percent or less; however, this was due to rounding. The actual difference was 1.6 percent. The changes clarify and/or correct the sentence and references to these statements.
[34] FHWA web page Public Roads: New Cost Estimating Tool

differences are -0.3 and 2 percentage units, respectively.[35] If the MnDOT HCCI trended perfectly in step with the average of the peer states' HCCI or the NHCCI 2.0, both the median and the mean of all the differences would be 0 percentage units. Fifty percent of the differences between year-over-year trends of the MnDOT HCCI and the peer states' average HCCI and between the MnDOT HCCI and the NHCCI 2.0 are between -2 to 3 percentage units and -2 to 4 percentage units, respectively. This is indicative of how close the changes in MnDOT's HCCI year-over-year trends are to those from the trends observed from the peer states' average HCCI and to a marginally lesser extent, to those changes observed in the NHCCI 2.0.

Figure 10 highlights all the HCCIs over the time period of reported ODOT HCCI data (i.e. 2007 to 2016). Throughout this time frame, the MnDOT HCCI and the Iowa DOT HCCI follow very similar trends, with slight differences between 2009 and 2010, where MnDOT HCCI was increasing while Iowa DOT HCCI was decreasing. ODOT's HCCI also follows a similar trend to the MnDOT HCCI, though as MnDOT HCCI begins to drop 2014 onwards, ODOT HCCI remains fairly constant from 2014 onwards.

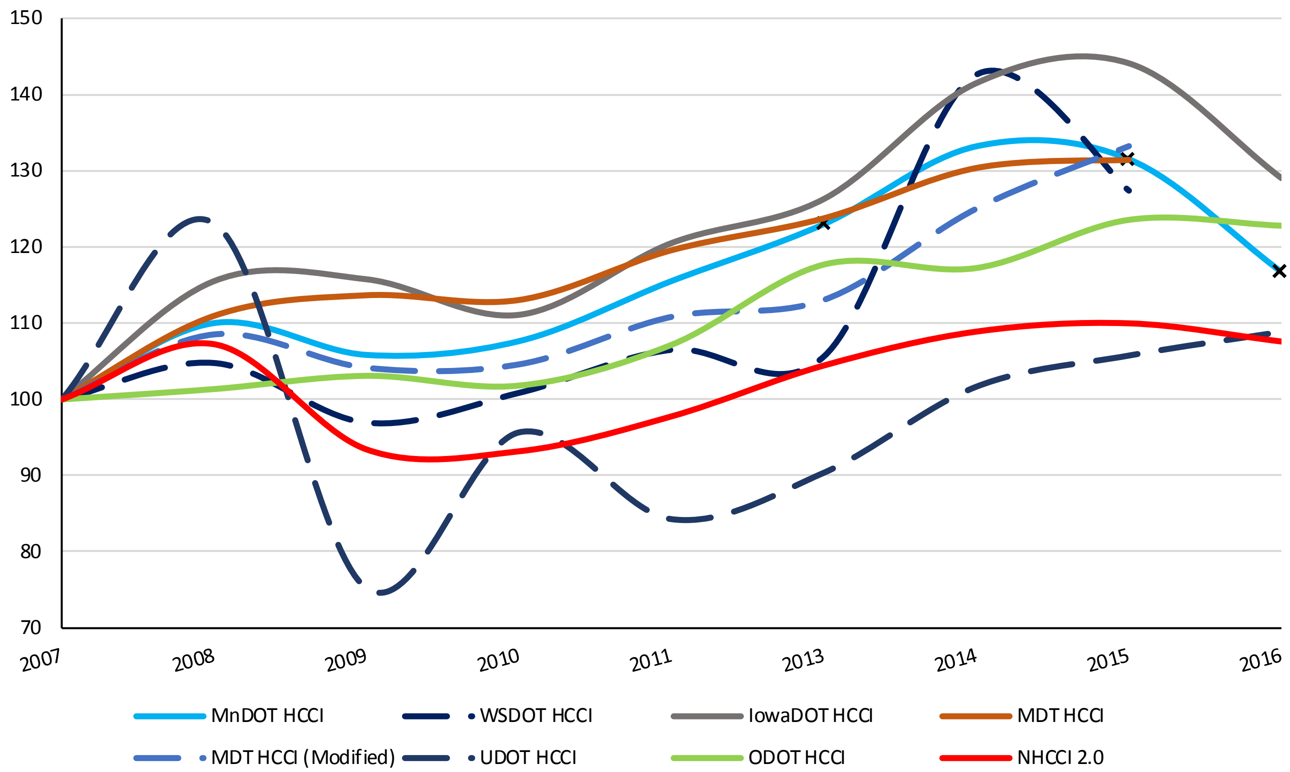


Figure 10: All HCCIs used in Benchmarking Analysis over Ohio Data Horizon, Rebased 2007

[35] **Table 23**: Percentile Analysis of Differences between MnDOT HCCI Year-over-Year Percent Changes to those of Peer States' Average HCCI and the NHCCI 2.0, Appendix J.

Quarterly HCCI

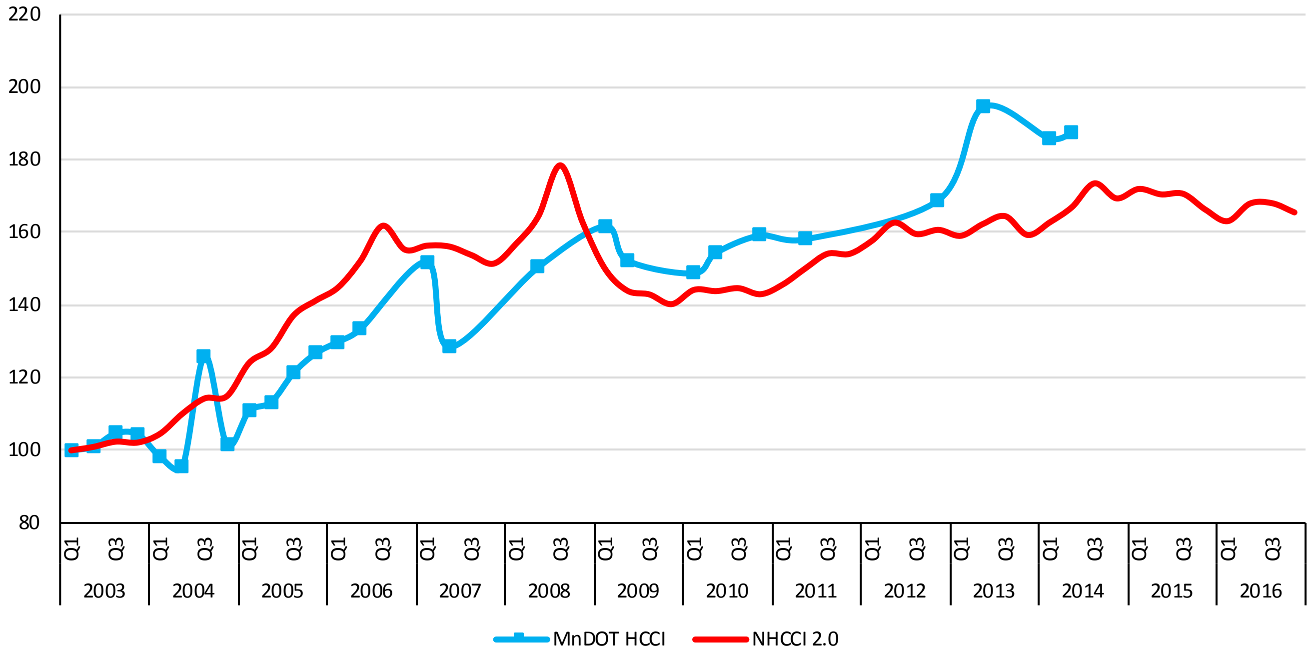


Figure 11: MnDOT HCCI vs NHCCI 2.0, Rebased to Q1 2003

Figure 11 highlights the trends from the MnDOT HCCI and the NHCCI 2.0 on a quarterly basis from Q1 of 2003 to Q4 of 2016. MnDOT does not have HCCIs for quarters after 2014 Q2. Since 2003, the trends in both quarterly series are comparable; however, there is a divergence after 2011 Q2. MnDOT's quarterly HCCI increases by 23 percent between 2011 Q2 and 2013 Q2, then drops by 3.5 percent at 2014 Q2. The NHCCI 2.0 quarterly series is relatively stable over the period 2012 Q2 (HCCI=162.71) to 2016 Q24 (HCCI=165.52). MnDOT does have values for 2017 Q1 and 2017 Q2 of 180.42 and 192.92 (rebased to 2003 Q1) respectively, which are slightly lower than the 2013 Q2 to 2014 Q2 index values of 194.49 to 187.49, suggestive of a de-inflationary period for MnDOT. The annual series shown in **Figure 7** supports this finding at the quarterly level with that of the annual trend dropping 14 percent from 2014 to 2016.

Other Price Indexes

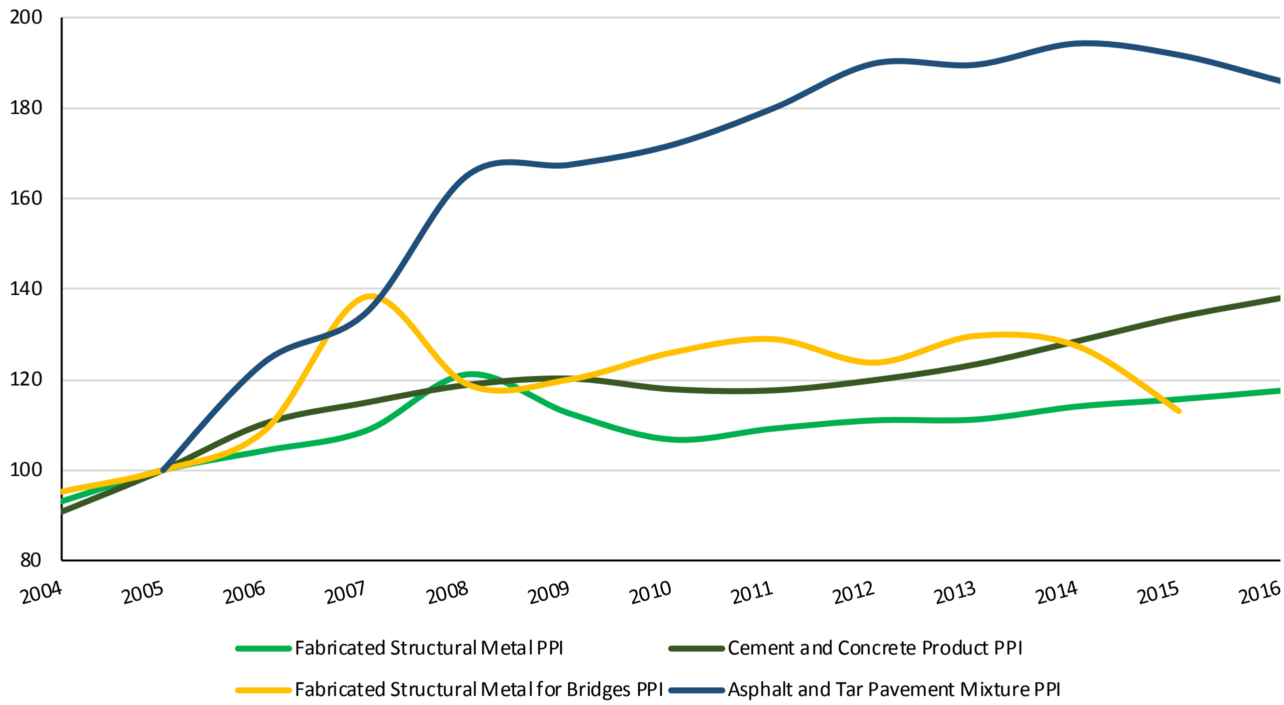


Figure 12: Construction Material PPI (2004–2016), Rebased to 2005

Generally, the two metal based PPIs reflect the downturn in the economy between 2008 and 2009, dropping by 7.1 percent for fabricated structural metal. Fabricated structural metal bridges PPI is a sub-component of the fabricated structural metal PPI as shown in **Figure 12**. While the PPI for bridges saw a slight increase of 0.9 percent from 2008 to 2009, from 2007 to 2008 it dropped by 14 percent. The cement and concrete product PPI exhibits a gradual increase since 2004, on average by 3.3 percent annually. On the other hand, the asphalt and tar pavement mixture PPI rapidly rises between 2005 and 2008, on average by 13.4 percent annually, then the rate of increase slows down towards 2016.

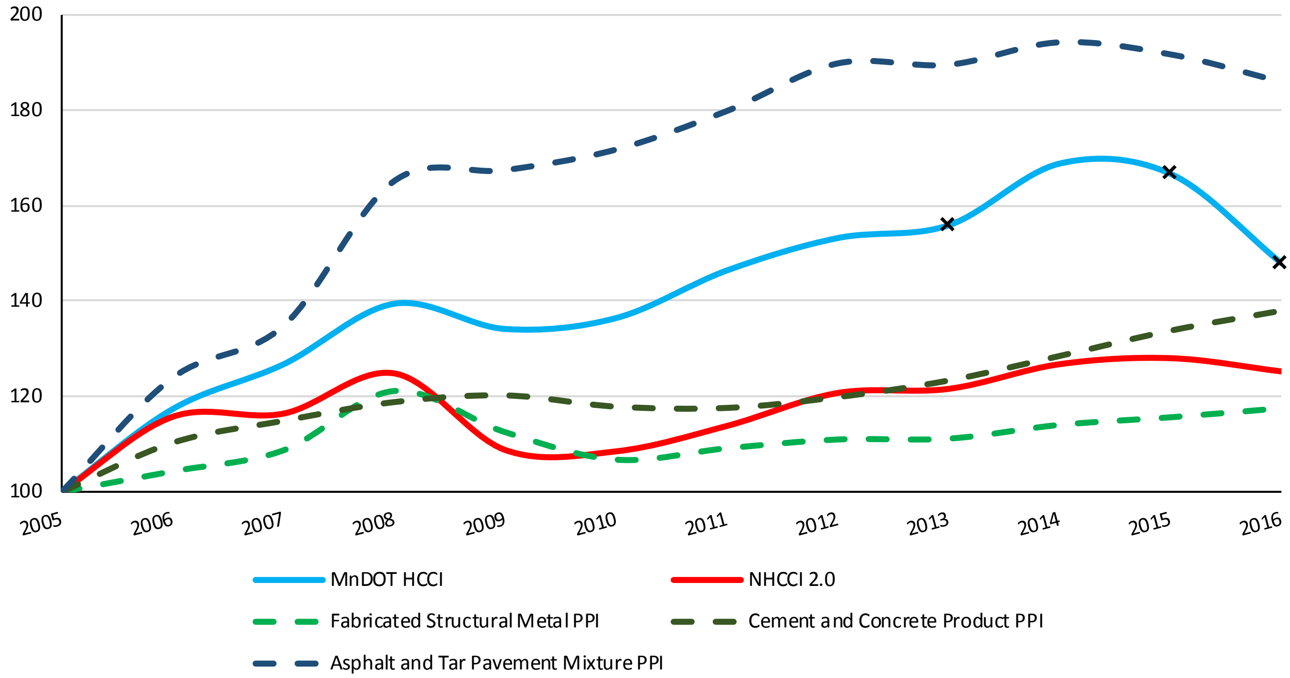


Figure 13: Comparing HCCI with Construction Material PPI, Annual, Rebased to 2005[36]

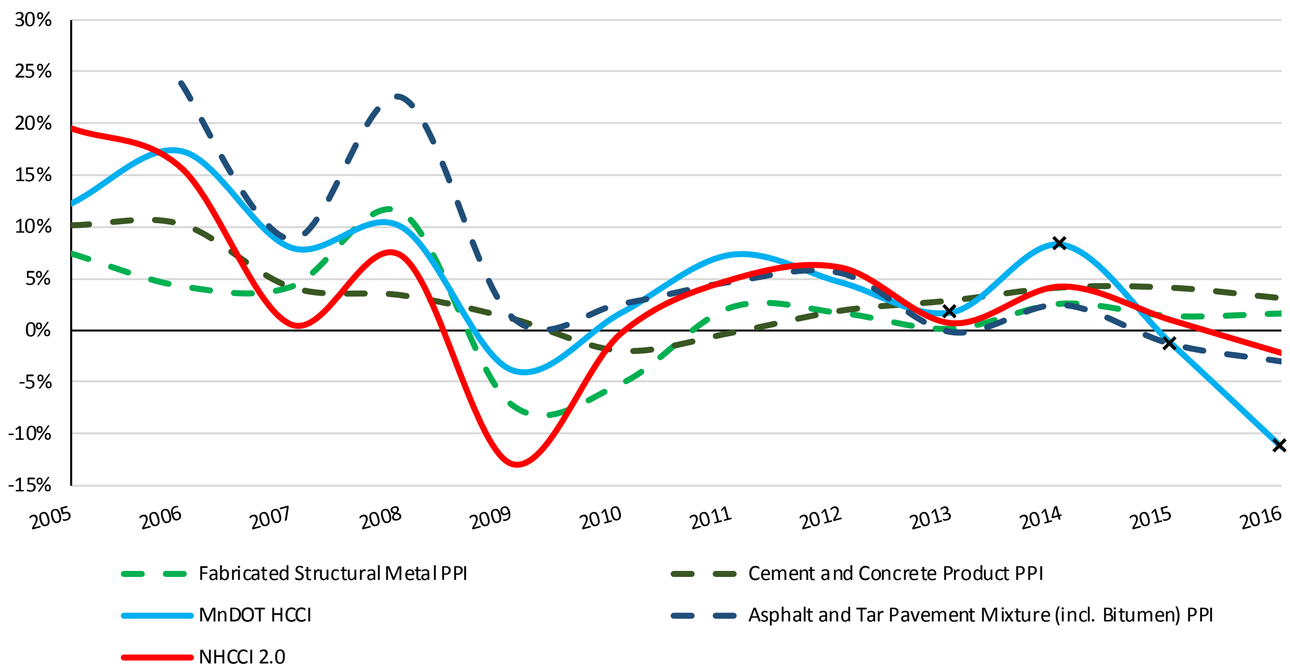


Figure 14: Year-over-Year Percent Change of PPIs and HCCIs

[36] PPI for Fabricated Structural Metal for Bridges is not included as it is a subset of the Fabricated Structural Metal PPI

Figure 13 and **Figure 14** compare annual and year-over-year percent change of PPIs to the trends observed from the MnDOT HCCIs and NHCCIs 2.0. The NHCCI 2.0 tends to follow index changes from the structural metals and cement and concrete PPIs. During the time period between 2009 and 2013, the MnDOT HCCI more closely follows the increasing trends observed from the asphalt and tar pavement PPI. Prices for asphalt jumped to 11.2 percent nationally between 2011 and 2012.[37] For states that planned major highway construction projects with significant amounts of asphalt during these times, the price increases certainly impacted their budgets. Given that MnDOT's HCCI methodology only applies a weight of 11 percent to structural steel items while bituminous items receive the greatest weight of 43 percent, it is expected that MnDOT's HCCI trends would more closely follow the trends observed in the asphalt and tar PPI. All indexes appear to converge in terms of rate of change in 2013.

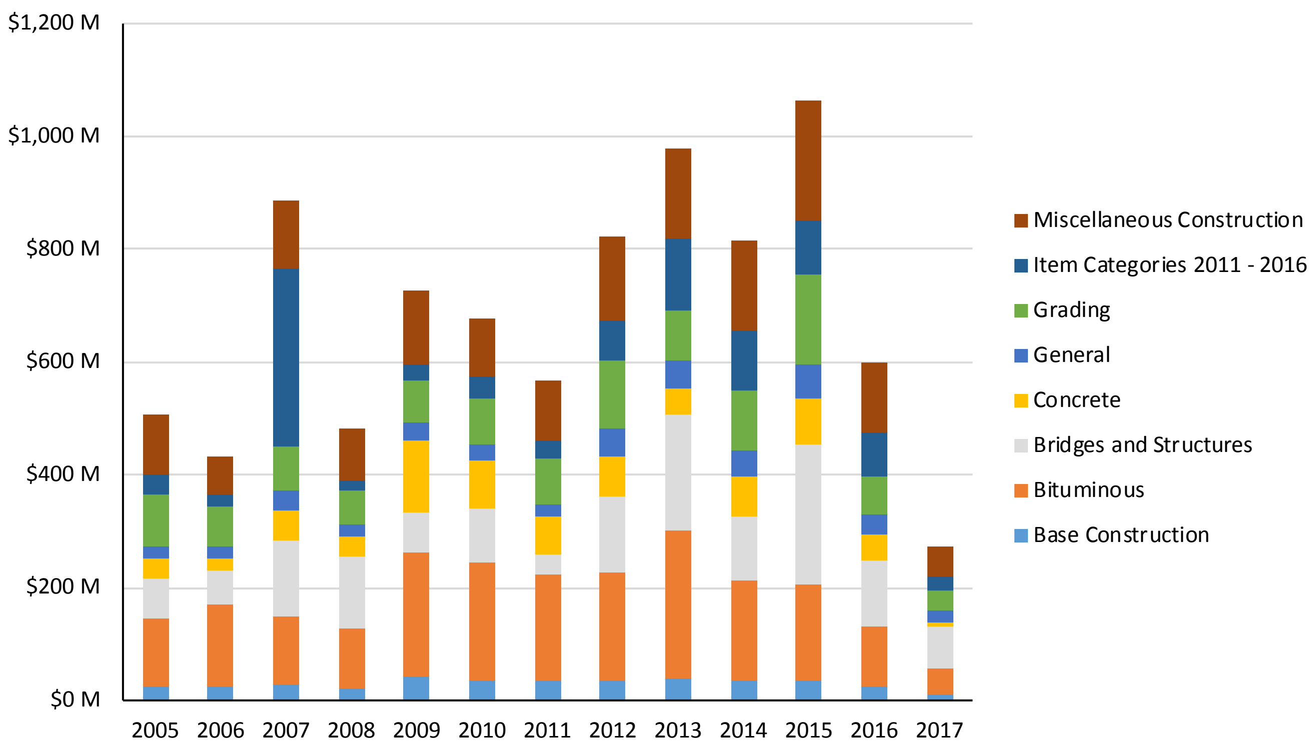


Figure 15: 2016 Dollar Breakdown of MnDOT Total Award Project Costs by Item Category, Annual

[37] "Higher Oil Prices Push Asphalt Up 11.2% from a Year Ago", Engineering News-Record, March 26, 2012, downloaded Nov. 17, 2017

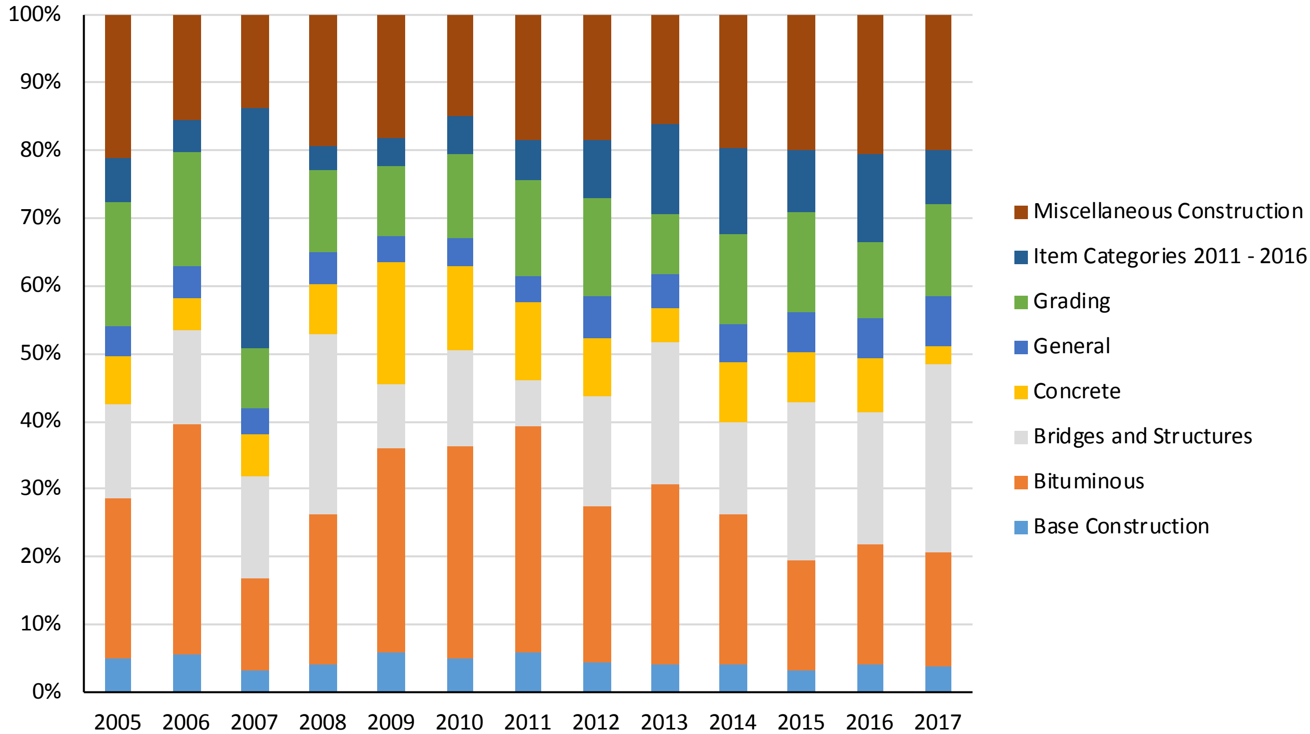


Figure 16: Percent Breakdown of MnDOT Total Award Project Costs by Item Category, Annual

Recent data from MnDOT's design-bid-build projects let between 2005 and 2017 Q1 in **Figure 15** and **Figure 16** demonstrate about 10 to 35 percent of the projects' costs can be attributed to bituminous items. [38] On an annual basis, 2013 had the highest total annual costs for bituminous items at $260 million in 2016 dollars. Total costs for bituminous in 2011 were less at $189 million in 2016 dollars; however, the bituminous costs amounted to over a third of total costs in that year. MnDOT's let projects since 2009 contained significant amounts of bituminous pavement bid items. These years coincide with times of higher growth rates such as between 2012 and 2014 in MnDOT's HCCI relative to that of the NHCCI 2.0 and are attributed to the use of this product and its heavier weighting as part of MnDOT's HCCI methodology.

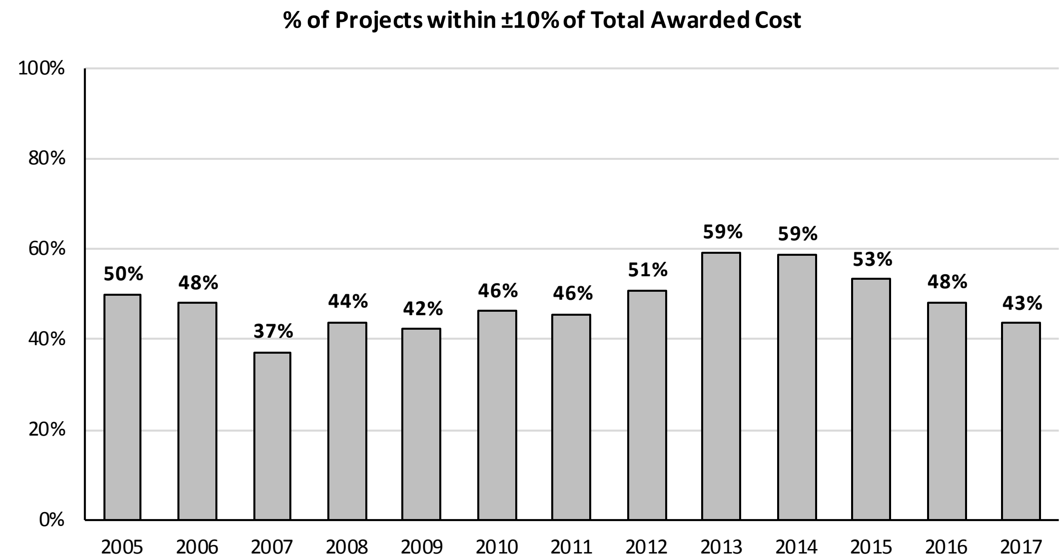
Performance of MnDOT HCCI

The HCCI is a valuable tool used to forecast cost escalation as part of program planning and budgeting. If the index is well specified, then estimates such as the engineer's estimates should be within ± 10 percent of the awarded price for the plurality of the projects. The FHWA offers performance guidelines to help DOTs gauge their cost estimating methodologies. [39] Currently, FHWA's technical guidance for final EE states that the estimates should be within ± 10 percent of award value 50 percent of the time.

MnDOT's previous study "MnDOT Cost Estimate Performance from FY 2010 to FY 2013" revealed that MnDOT's EEs were meeting FHWA guidelines, ranging from a low of 51 percent in FY2010 to a high of 69 percent in FY2012. Actual historical engineer estimates and final awards for 2,648 of MnDOT's design-bid-build projects let between Q1 of 2005 to Q1 of 2017 shown in **Figure 17** were used to monitor how accurate the EEs are to that of

[38] Quarterly breakdown of costs and percentages are in Appendix K of this report.
[39] See Guidelines on Preparing Engineer's Estimate, Bid Reviews and Evaluation, downloaded Nov. 14, 2017.

the award over this period. The data show that between 2005 Q1 to 2017 Q2 the EEs are within range for each year on an annual basis, though EEs in 2007 fell short of the 50 percent target and since 2015, performance has dropped below the 50 percent target.



Note that 2017 only contains projects let in the first quarter.

Figure 17: Percentage of MnDOT Projects with EEs within ± 10% of Award, by Year

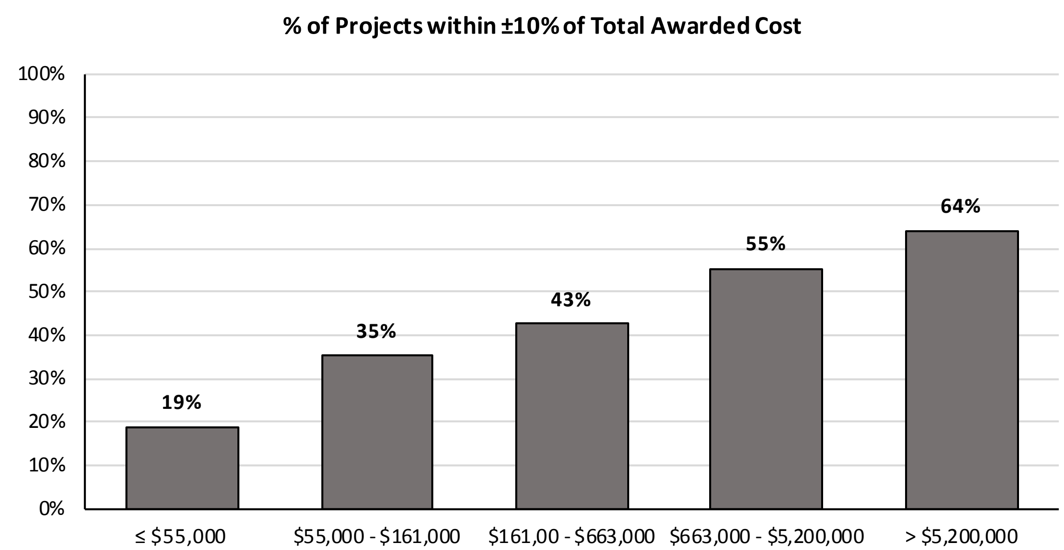


Figure 18: Percentage of MnDOT Projects with EEs within ± 10% of Award, by Total Awarded Value, 2015 Q1 to 2017 Q1

The same set of recently awarded 2,648 projects broken down by project cost ranges in **Figure 18** show that the largest projects are more likely to be within FHWA's guidelines.

Table 2 looks at the distribution of the percent differences between the engineers', the second bidders' and the third bidders' estimates to those of the respective awards over the 2005 to 2017 period. The fact that the median percent difference between the EE and the award is at 2 percent while the median percent differences for the second and third bidders are 6 and 13 percent, respectively, shows that for the majority of bids, MnDOT's cost estimates are competitive. One project awarded in 2012 Q2 with only two vendors bidding was awarded to the vendor who provided an extremely low bid, resulting in a maximum percent difference over 1,000 percent. A few projects were awarded to the vendor whose bid was higher than either the second or third bidder resulting in some instances of negative percent deviations when the second and third bidders' estimates were compared to those of the awarded bidders.

The continued performance levels by MnDOT on its ability to be within FHWA's guidelines with respect to its EEs since 2005 is evidence of the robustness inherent in the MnDOT HCCI, and its relevance to help program planners and cost estimating engineers forecast and estimate project costs to a realistic level of reliability.

Table 2: Percent Deviations from Award

	Engineer's Estimate	Second Bidder	Third Bidder
Number of Projects	2,648	2,251	1,812
Minimum	-94%	-85%	-55%
25^{th} Percentile	-7%	3%	7%
Median	2%	6%	13%
75^{th} Percentile	14%	14%	23%
Maximum	1169%	1169%	305%

Statistical Analysis of HCCIs

The statistical analysis focused on the similarity in HCCI trends over time for studied state level HCCIs, the NHCCI 2.0 and various indicators of highway construction cost escalations, such as various PPI metrics. The assumption is that if MnDOT's HCCI is well specified and representative of the actual construction cost of inflation, it should be correlated with the HCCI trends observed at the peer state level and the national level, and at levels observed for selected PPIs. The Pearson correlation coefficient is chosen as the statistical method to test this assumption.

The Pearson correlation coefficient statistic is a measure of strength of a linear association between two variables. If both variables increase at the same rate over the observations, the correlation is 1. If one increases in a direction and the other variable decreases in the other direction, both at the same rate, then the correlation is -1. Rates of change which are not identical between the two variables will result in values between -1 to 1. Correlation coefficients of 0.8 to 1 denote a high level of correlation and such relationships may be used to forecast future near-term trends for one variable as a function of the other.

Table 3 reports the Pearson correlation coefficients among the various HCCIs and the PPIs for relevant construction materials over the time horizon of 2004 to 2016. All correlations were calculated using annual index values. While it is expected to observe strong positive correlations between the HCCIs of states of close proximity to Minnesota with values ranging from 0.97 to 0.99 for Montana and Iowa, respectively, WSDOT's HCCI and ODOT's HCCI are also reported as being highly positively correlated with MnDOT's HCCI with a value of 0.90 and 0.84 respectively.

Although all HCCIs are positively correlated with one another, the correlation matrix presented displays a low positive correlation between UDOT's HCCI with other HCCIs. This may be driven by the volatile changes for UDOT's HCCI values from 2004 to 2009, with a 38.9 percent decrease from 2008 to 2009.

Finally, the correlation analysis presents a strong positive correlation between the NHCCI 2.0 and MnDOT HCCI with the correlation coefficient of 0.88. This infers that, based on the time horizon, it is expected that MnDOT's HCCI and NHCCI 2.0 will generally follow a similar directional trend, as historically demonstrated in **Figure 7** and **Figure 8**.

Table 3: Pearson (Bivariate) Correlation Coefficient Matrix, 2004–2016

	MnDOT HCCI	WSDOT HCCI	Iowa DOT HCCI	MDT HCCI	MDT HCCI (Modified)	UDOT HCCI	ODOT HCCI	NHCCI 2.0	Fabricated Structural Metal PPI	Cement and Concrete Product PPI	Fabricated Structural Metal for Bridges PPI	Asphalt and Tar Pavement Mixture PPI
MnDOT HCCI	-	0.92	0.99	0.97	0.99	0.32	0.84	0.88	0.81	0.90	0.66	0.95
WSDOT HCCI	0.92	-	0.91	0.86	0.92	0.38	0.73	0.85	0.73	0.89	0.55	0.77
Iowa DOT HCCI	0.99	0.91	-	0.98	0.98	0.26	0.89	0.84	0.81	0.91	0.58	0.96
MDT HCCI	0.97	0.86	0.98	-	0.97	0.19	0.91	0.81	0.79	0.93	0.68	0.98
MDT HCCI (Modified)	0.99	0.92	0.98	0.97	-	0.31	0.91	0.88	0.84	0.97	0.64	0.93
UDOT HCCI	0.32	0.38	0.26	0.19	0.31	-	0.16	0.69	0.56	0.43	0.15	-0.26
ODOT HCCI	0.84	0.73	0.89	0.91	0.91	0.16	-	0.71	0.31	0.85	-0.35	0.82
NHCCI 2.0	0.88	0.85	0.84	0.81	0.88	0.69	0.71	-	0.89	0.89	0.62	0.69
Fabricated Structural Metal PPI	0.81	0.73	0.81	0.79	0.84	0.56	0.31	0.89	-	0.88	0.59	0.70
Cement and Concrete Product PPI	0.90	0.89	0.91	0.93	0.97	0.43	0.85	0.89	0.88	-	0.65	0.84
Fabricated Structural Metal for Bridges PPI	0.66	0.55	0.58	0.68	0.64	0.15	-0.35	0.62	0.59	0.65	-	0.52
Asphalt and Tar Pavement Mixture PPI	0.95	0.77	0.96	0.98	0.93	-0.26	0.82	0.69	0.70	0.84	0.52	-

Findings

The findings from this benchmarking analysis are the following:

1. The MnDOT HCCIs visually exhibits similar trends over time to those observed for the selected peer states, the average of all peer states (including MnDOT), and most importantly, the NHCCI 2.0. The median of the differences in the year-over-year percent changes between the MnDOT HCCI and the average of the peer states' HCCIs is only -.3 percentage units and 2 percentage units when compared to the NHCCI 2.0.
2. Year-over-year changes in MnDOT's HCCIs are directionally proportional to those observed from the average of the peer states' HCCIs and the NHCCI 2.0 based on changes of observed MnDOT HCCIs. That is, if either the average of the peer states' HCCIs or the NHCCI 2.0 shows a positive year-over-year growth for a particular two-year period, the MnDOT HCCI is also positive, similarly so for negative growth. Year-over-year changes starting in 2013 have to be taken with caution as MnDOT's HCCI values are based on imputed values.
3. More often than not (five out of the eight years with observed data between 2005 and 2012, data later than 2012 is imputed for MnDOT HCCI),[40] the MnDOT's year-over-year percent increase in the HCCI is within 1 percent or less than that for either the average of the peer states' HCCIs or the NHCCI.
4. Recent growth in MnDOT's HCCI between 2012 and 2014 may be attributed to higher costs for bituminous pavement for let projects requiring significant amounts of bituminous product.
5. MnDOT's EEs, which rely on changes in the HCCI to escalate costs for highway components, produce project estimates that are within the range of the FHWA's guidelines for highway cost estimation since 2005, though the level of performance has declined slightly to 48 percent of projects with EEs within ± 10 percent of award as of year-end 2016, down from a high of 59 percent in 2013 and 2014.
6. MnDOT's EEs are price competitive since an analysis of the percent deviations between each of the EEs, second bidder's estimate and third bidder's estimate and the award show that the median percent difference between the EEs estimate and the award is only 2 percent while the second and third bidders' estimates are 6 and 13 percent, respectively.
7. MnDOT's HCCI shows high positive Pearson correlation coefficient (>0.80) with the NHCCI 2.0 and for peer states Iowa, Montana and Washington.

Overall, the MnDOT HCCI is a robust measure of the rate of construction cost inflation. Its trends over time are well reflective of trends observed from the peer states and the NHCCI 2.0, and the asphalt and tar pavement mixture and fabricated structural metal PPIs. While MnDOT has its own peculiarities in terms of project work types and vendor dynamics, which may or may not be shared by all the peer states selected for this study, the changes in its HCCI since 2003 demonstrate sound methodologies for tracking and quantifying cost escalation. Improvements can be made to avoid some of the weaknesses in the current methodology related to missing sub-component indexes or the lack of flexibility to change sub-component weighting to mitigate the impact of spurious price changes. Possible changes to MnDOT's HCCI current methodology are explored in Part Three - "Cost Calculation and Indexing Technical Memorandum."

[40] Correction needed to this sentence and another sentence on page 37; In the Highway Construction Costs and Cost Inflation Study released on Feb. 22, 2018, the report indicated that since 2004, in five of eight years the highway construction rate of inflation was within 1 percent or less; however, the years this is accurate are between 2005 and 2012. Data in later years is imputed with MnDOT HCCI. The changes clarify and/or correct the sentence and references to these statements.

Part Three:

Review of MnDOT’s Construction Cost Index

Introduction

As part of the Minnesota Department of Transportation's Highway Construction Cost Study, the consulting firm, HDR, examined the agency's highway construction cost index. The assessment included a literature review of practices and phone interviews with a selected sample of state DOTs -Ohio, Missouri, Iowa, Montana and Washington-similar in program size and/or geography to MnDOT. In addition, MnDOT's highway construction cost index was compared to FHWA's National Highway Construction Cost Index 2.0. The comparative analysis included a re-casting of MnDOT's HCCI using FHWA's methodology applied to MnDOT's cost data. The results of the comparative analysis were compared to the current MnDOT HCCI.

Overview of State DOT Practices on Construction Cost Indexes

It should be noted that, although all state DOTs track certain construction costs (e.g., asphalt price) over time, a majority of them do not have a HCCI (e.g., Missouri DOT). And not all state DOTs that have a HCCI, publish it.

A recent study conducted by Iowa State University (2017) and sponsored by Montana DOT, showed that state DOTs use base years ranging from 1987 (the original base year for FHWA's Bid Price Index) to 2012. Generally, a base value of 100 or 1.00 is used. Also, most state DOTs calculate their index quarterly and/or annually.

The most popular price indexes are the Laspeyres and chained Fisher indexes. A number of state DOTs (e.g., Ohio DOT) have switched to the chained Fisher index since FHWA first published the NHCCI in 2009. And it is expected that some state DOTs will also update their cost index methodology in light of the recent improvements made by FHWA (NHCCI 2.0).[41] Besides the Laspeyres and Fisher indexes, the Lowe and Young indexes are also in use. The Montana DOT has been using the Young index but is in the process of implementing a new multidimensional HCCI with dynamic item basket.[42]

Typically, state DOTs sort bid items into several item categories. A majority of them use 10 or fewer cost item categories. Overall, the most common item categories are:

- Earthwork
- Asphalt
- Concrete pavement
- Structural concrete
- Reinforcing steel
- Structural steel
- Aggregates

Sub-indexes, such as the asphalt pavement index and the excavation index, can be calculated for these item categories. Those sub-indexes are then aggregated to arrive at a composite HCCI.

[41] A summary of improvements is available on FHWA's website.

[42] Jeong, David H., Douglas D. Gransberg, and K. Joseph Shrestha, "Advanced Methodology to Determine Highway Construction Cost Index (HCCI)," prepared for The State of Montana Department Of Transportation, June 2017; (accessed Oct. 5, 2017)

Some state DOTs, including those that use fixed weight indexes, such as the Laspeyres index, are using an outdated item basket. Colorado DOT had not changed their base year since 1987, until 2012, when it switched from the Laspeyres index to the Fisher index.

Data cleaning is a standard procedure before calculating the HCCI. Data from projects delivered through alternate project delivery methods other than the design-bid-build method are typically removed as they can introduce bias in the index. For instance, MnDOT removes data from projects delivered through Construction Manager General Contractor, design-build, Indefinite Delivery Indefinite Quantity, emergency relief, urgent and negotiated contracts.

In the same way, outliers are removed from the dataset. For instance, Minnesota, California and Wisconsin DOTs do not include data from projects smaller than $100,000 in value. Iowa DOT removes concrete items with quantities of less than 125 cubic yards.

Comparison of FHWA and MnDOT Construction Cost Index Methodologies

MnDOT's Highway Construction Cost Index is calculated using the Laspeyres price index formula; weights are calculated with quantities for the base period only, and is comprised of the following six indicator items:

- Roadway excavation
- Reinforcing steel
- Structural steel
- Structural concrete
- Concrete pavement
- Bituminous pavement

By contrast, FHWA's National Highway Construction Cost Index is calculated using the chained Fisher price index formula. Weights of both the base period and the current period are taken into account and relies on price data for 31 predefined work categories, as shown in Table 4 below.

Table 4: Item Categories Used for National Highway Construction Cost Index 2.0

Item Categories		
1. Grading/Excavation	12. Grassing	23. Lighting
2. Bridge	13. Clearing	24. Buildings/Miscellaneous Structures
3. Asphalt	14. Erosion Control	25. Mobilization
4. Base Stone	15. Retaining Wall	26. Concrete Pavement
5. Drainage-Pipe	16. Signalization	27. Misc. Stone/Riprap
6. Drainage-Inlets/Catch Basins	17. Signs-Permanent	28. Roadway Lighting/Electrical
7. Concrete-Culverts	18. Striping/Pavement Marking	29. Underdrain
8. Concrete-Miscellaneous	19. Painting Structures	30. Equipment/Labor
9. Traffic Control	20. Utility-Water	31. Alternates/Bonus/Time
10. Guard Rail	21. Utility-Gas	
11. Fencing	22. Utility-Sewer	

A quick comparison of the two indexes' main features is provided in **Table 5** below.

Table 5: Main Features of MnDOT's Highway Construction Cost Index and FHWA's National Highway Construction Cost Index 2.0

Feature	Minnesota HCCI	National HCCI 2.0
Base Value	100	1.00
Base Period	1987	March 2003
Frequency	Quarterly	Quarterly
Index Formula	Laspeyres	Chained Fisher
Sub-Indexes	Yes (6)	No

Another critical difference between the two indexes is the methodology employed to clean the input data. In 2017, the FHWA made a series of major changes to the NHCCI methodology. In particular, new statistical procedures were applied to more closely reflect or approximate price changes in highway construction costs over time and allow the use of more input data in the calculation of the index.

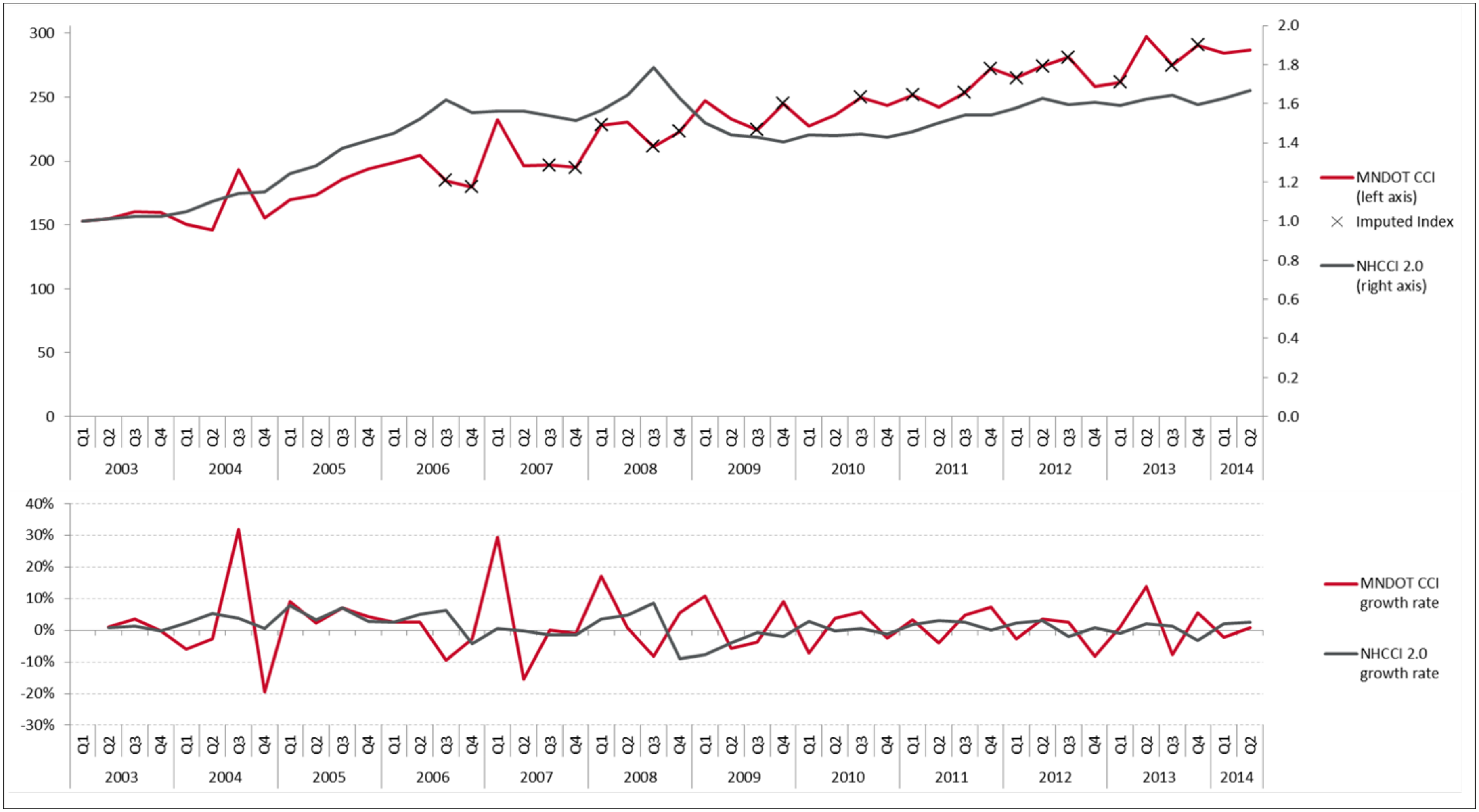
The methodology changed in several ways:

- **Unit of measure and non-standard pay item issues** – The enhancement establishes crosswalk applications that translate inconsistent units and non-standard pay items into consistent units and standard pay items so that more observations can be included in the index calculation.
- **Changes in statistical exclusion procedure** – The thresholds used for identifying outlier observations, pay items subject to quantity discounts, and observations with extreme price fluctuations were revised to allow the inclusion of a wider range of observations, resulting in a better representation of price trends.
- **Changes in data reporting by states** – States occasionally introduce changes to their pay item numbering system for organizing and reporting construction bid data. Such changes create a break in the time series of goods included in the calculation of the index. The revised methodology addresses this issue, enabling the use of more data and more consistent estimates over time.

A detailed description of the FHWA's new data cleaning procedure for the NHCCI 2.0 that reflects the changes described above is available in **Appendix L**.

Figure 19 on the following page shows MnDOT's HCCI and FHWA's NHCCI 2.0 from 2003 Q1 to 2014 Q2, both in absolute value and percent difference. Overall, the two indexes follow a similar trend, starting with an acceleration in growth from 2004 until mid-2008, followed by a decline during the first half of the Great Recession (through 2009) and a sluggish increase afterwards. It is noteworthy that while the Minnesota HCCI trended lower than the NHCCI 2.0 up until the onset of the Great Recession, it consistently trended higher afterwards – an indication, perhaps, that the state economy (and the construction sector in particular) was not affected by the downturn as much as the national economy. In addition, as evidenced by the quarterly percent change, the Minnesota HCCI is more prone to large fluctuations (e.g., 2004 Q4 and 2007 Q2) than the NHCCI 2.0. This is expected, however, since the NHCCI 2.0 has a larger base, thereby leveling regional differences.

Figure 19: Comparison of MnDOT's Highway Construction Index with FHWA's National Highway Construction Cost Index 2.0 (2003 Q1 – 2014 Q2)



Note: In many quarters, MnDOT's HCCI values were imputed using ordinary least squares regression analysis and time series trends and are flagged by the symbol 'x'.

To better illustrate the differences between the two indexes, the chained Fisher price index formula used for the NHCCI 2.0 was applied to the input data used by MnDOT to calculate the highway construction composite cost index. Quarterly data on costs and quantities from 2003 to 2017 were obtained from MnDOT at the project level and for each of the six indicator items. Unit cost estimates were then calculated by simply dividing total cost by total quantity. When no data was available on an indicator item in a given quarter, an approximation was computed by means of linear trend regression in Tableau Software. While there are other methodologies that could be used to develop proxies for the missing observations, a linear trend regression was used because the amount of data to adequately compare them was missing and some of the other methods (e.g., use another index closely correlated to MnDOT's HCCI and for which the data are available) would require substantially more effort with little to no improvement in the final results. Next, the chained Fisher price index formula was applied:[43]

$$F(p) = \sqrt{\frac{\sum_{j=1}^{N} p_{j,t} q_{j,t-1}}{\sum_{j=1}^{N} p_{j,t-1} q_{j,t-1}} \times \frac{\sum_{j=1}^{N} p_{j,t} q_{j,t}}{\sum_{j=1}^{N} p_{j,t-1} q_{j,t}}}$$

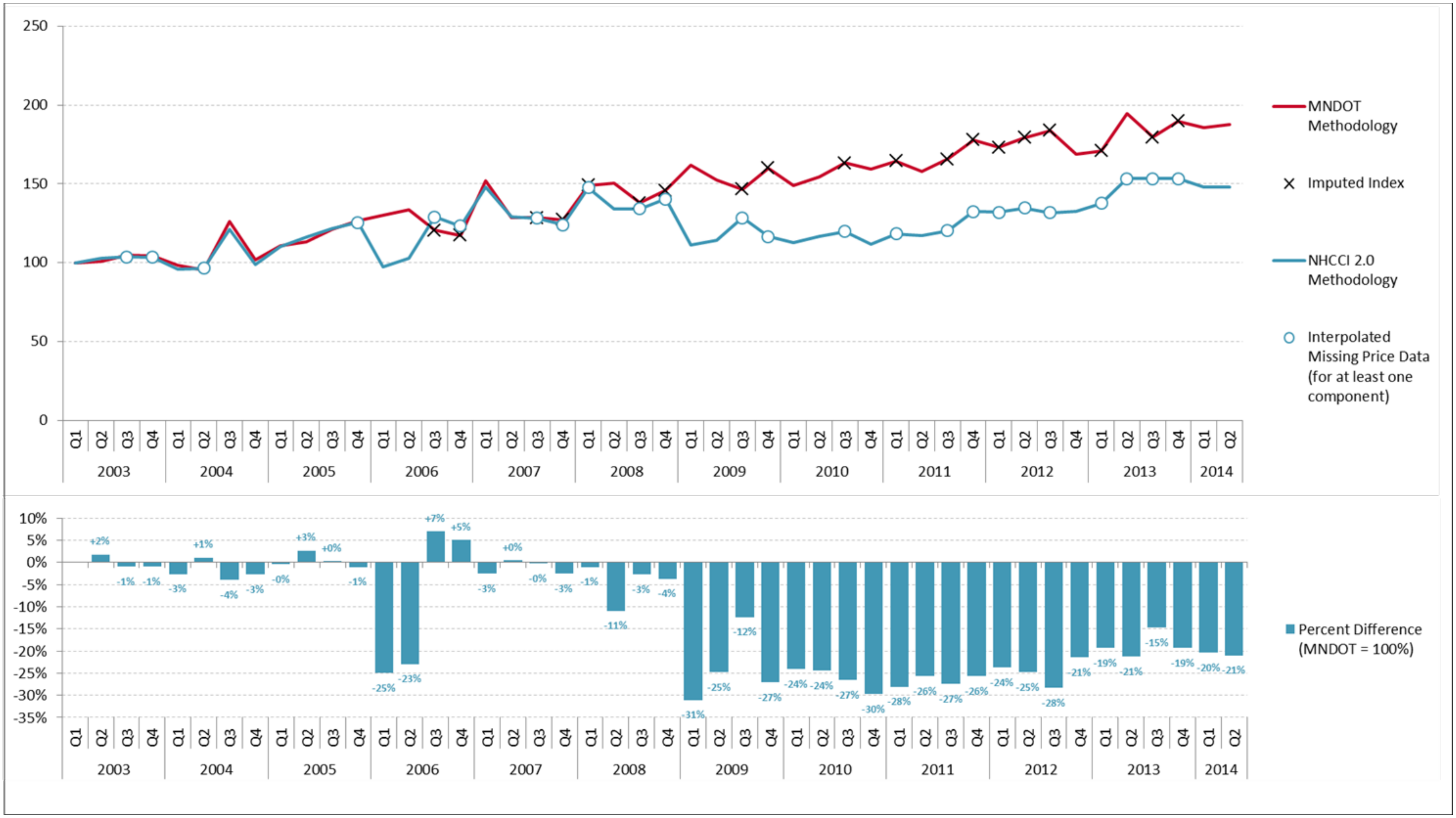
Finally, to compare the new composite index with the current one, their respective values were adjusted so that they both share the same base value of 100 in 2003 Q1 (March 2013). **Figure 20** on the following page shows the Minnesota highway construction composite cost index using MnDOT's current methodology (Laspeyres index formula) and FHWA's methodology (chained Fisher index formula). From 2003 to 2008, the two series track each other rather well. From 2009 Q1 onwards, however, they diverge significantly and the Laspeyres-based index remains significantly higher than the chained Fisher-based index; the difference between the two series reaches a maximum of 31 percent in 2009 Q1 and a minimum of 12 percent in 2009 Q3.

It should be noted that the composite index could not be calculated by MnDOT in more than half of the quarters from 2008 Q1 to 2014 Q2, due to data limitations (i.e., absence of bid price data for one or several indicator item[s]). It was last measured more than three years ago, in 2014 Q2. Therefore, it is difficult to draw any definitive conclusions as to the respective trends of the two series and the reasons for the gap between the series over that period. Although, one may speculate that, over time, as quantities in the base period became outdated, the two indexes were bound to diverge. Also, the fact that the two indexes started diverging during the Great Recession may not be a coincidence. In other words, structural changes in highway construction (number of potential bidders, project size, construction methods, availability of local materials, etc.) prompted by a new economic environment may be responsible for the growing gap between the two indexes.

The annual compound growth rate between 2003 Q1 and 2014 Q2 for the unchained Fisher-based index (5.5 percent) is very similar to that for the Laspeyres-based index (5.7 percent). The unchained Fisher index formula was preferred to the chained Fisher index formula to estimate the long-term growth because the large number of missing data between 2003 Q1 and 2014 Q2 add uncertainty to the trend of the chained Fisher-based index.

[43] A detailed description of the formula is available on the NHCCI web page.

Figure 20: Comparison of Methodologies for Minnesota Highway Construction Composite Cost Index (2003 Q1 – 2014 Q2)



Notes: The graph only shows the composite index up until the last time it was calculated by MnDOT (2014 Q2). In many quarters, MnDOT's HCCI values were imputed using ordinary least squares regression analysis and time series trends and are flagged by the symbol 'x'.

Historical Accuracy of MnDOT's Construction Cost Index

While the calculation of a construction cost index is functionally based on actual bids, in an effort to respond to the legislative request to provide an analysis of the historical accuracy of MnDOT's construction cost index to actual costs, an assessment was done comparing the sub-indexes produced by MnDOT with their respective underlying bid price data. This was accomplished to confirm that the sub-indexes are a reliable representation of the bid price data (i.e., the procedures applied to edit and clean the bid price data, when developing the sub-indexes, do not alter the actual price levels). If they are indeed reliable, then similar historical trends should be exhibited.

Historical bid price data (by pay item and by project) were obtained from MnDOT for the period extending from 2005 Q1 to 2017 Q1. The data was sorted by quarter and by item description, processed (in accordance with MnDOT practices summarized in **Appendix C**, to the extent feasible),[44] and combined into individual bid price data series corresponding to the six indicator items. Note again, however, that due to data limitations (i.e., absence of bid price data) it was difficult to develop reliable bid price data series for reinforcing steel, structural steel and structural concrete. To make the comparison easier, each one of the six bid price data series was converted to an index with a base value of 100 in 2005 Q1 and MnDOT's indexes were also rebased to the same period.

Figure 21 through **Figure 23** on the following pages represent the bituminous pavement index, the roadway excavation index, the reinforcing steel index[45] and their associated bid price data series from 2005 Q1 to 2016 Q3. Each figure represents the index and the associated bid price data series both in absolute value and percent difference. In general, and as expected, the bid price trend is more erratic than the index trend because it is not as refined. In particular, it includes data for projects under $100,000, which often display high unit costs because of low quantities.

For bituminous pavement, the index and bid price trends are similar, overall. The average quarterly difference over the analysis period is 10.4 percent and the mean absolute deviation is 18.1 percent. For roadway excavation, the trends are similar but only at times (e.g., 2014 Q4 to 2015 Q3). On several instances, the quarterly difference is above 100 percent. The average quarterly difference over the analysis period is 26.9 percent and the mean absolute deviation is 55.1 percent. Similarly, the percentage difference between the index and the bid price series can be very large (up to 397 percent) for reinforcing steel. The average quarterly difference over the analysis period is 26.3 percent and the mean absolute deviation is 36.2 percent.

---

[44] In particular, quantities were converted where necessary (e.g., square yards were converted to tons for bituminous surface) so as to arrive at a single unit (e.g., ton) for each bid price data series.

[45] These three indicator items represented 67.7 percent of the composite index in 2016. The relative weight of the bituminous pavement index alone was 45.9 percent.

Figure 21: Historical Accuracy of Bituminous Pavement Index (2005 Q1 – 2016 Q3)

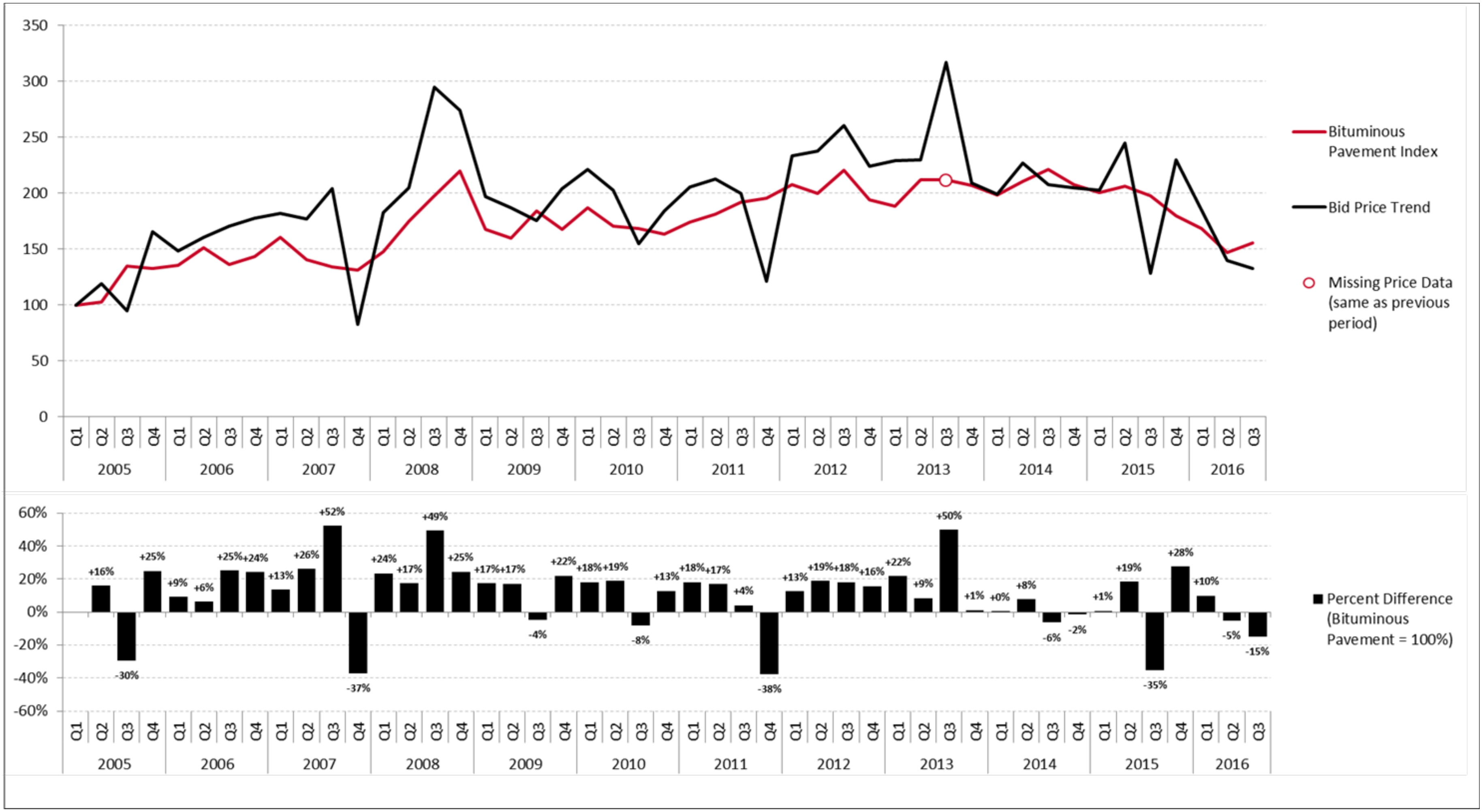


Figure 22: Historical Accuracy of Roadway Excavation Index (2005 Q1 – 2016 Q3)

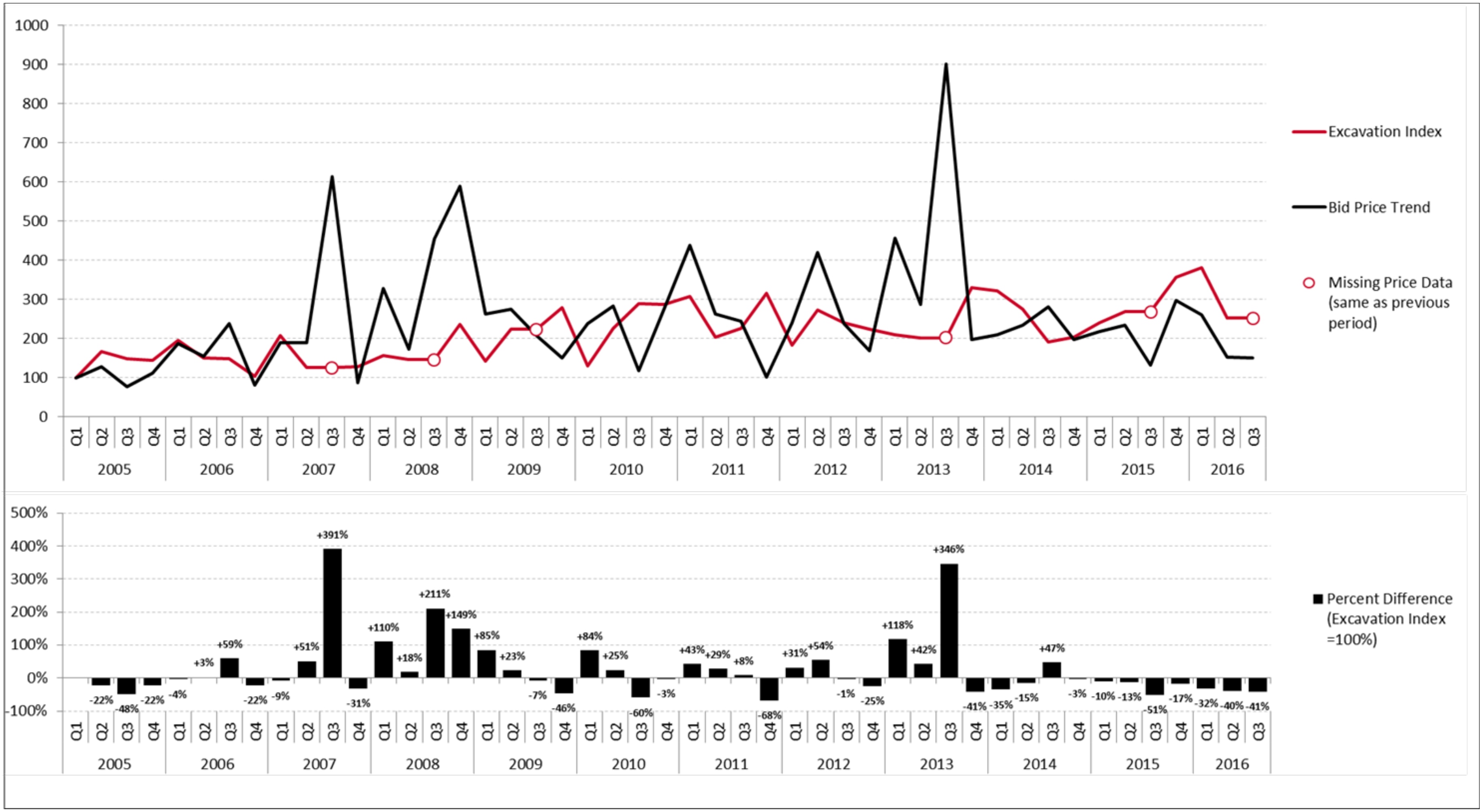
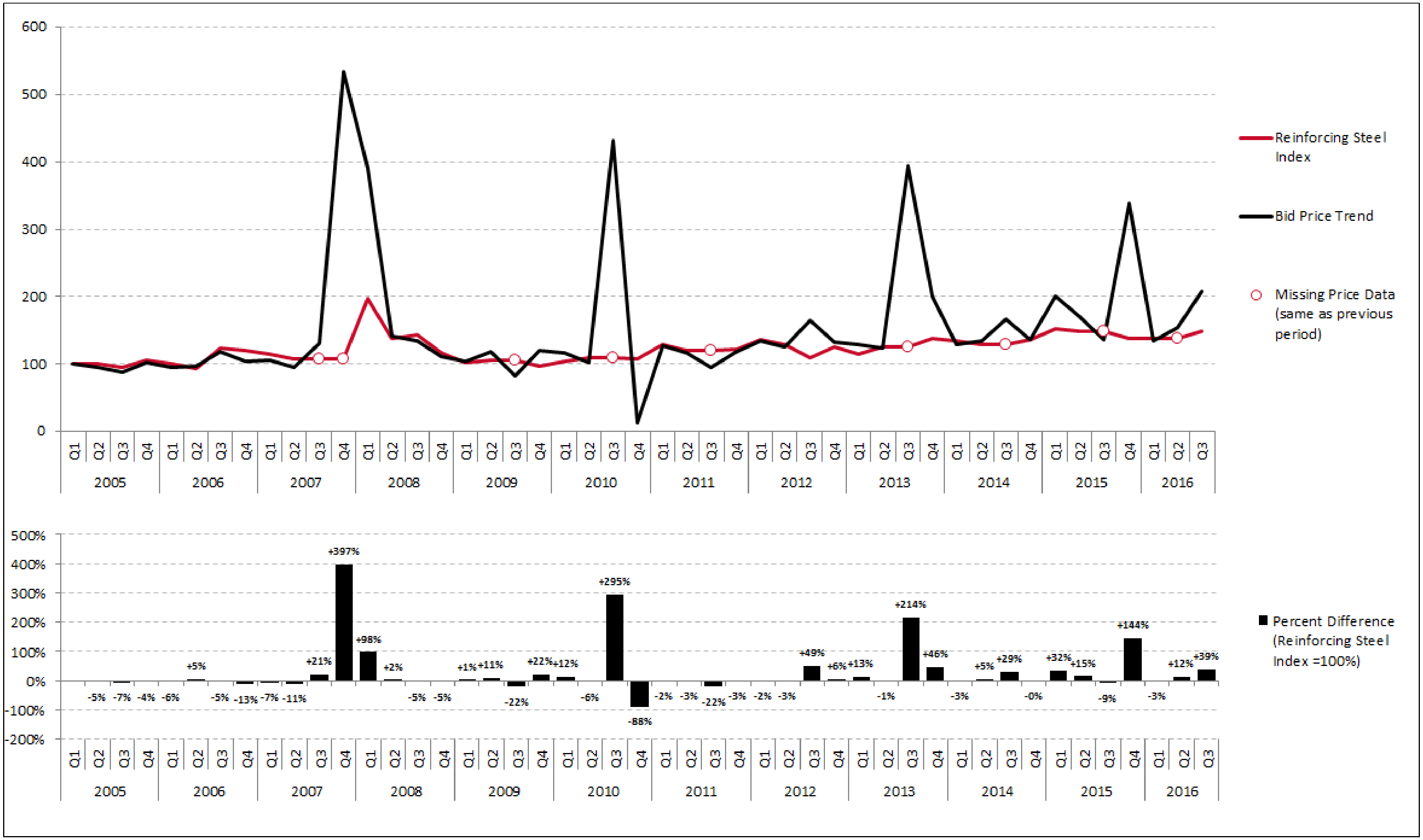


Figure 23: Historical Accuracy of Reinforcing Steel Index (2005 Q1 – 2016 Q3)



Appendices

Appendix A: Nov. 2017 FHWA Cost Index Memorandum

Federal Highway Administration

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News

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Contact: Doug Hecox
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FHWA Releases Latest National Highway Construction Cost Index Figures

WASHINGTON – The FHWA today released its latest National Highway Construction Cost Index, a quarterly estimate of the rising cost of domestic highway construction and maintenance over time. It is the first time the Index – now called "NHCCI 2.0" – has been published since the agency made major methodological revisions to improve its accuracy.

NHCCI 2.0 is the first major revision since FHWA created this index in 2007, and reflects steadily rising costs of highway construction and repair. Though the data fluctuate slightly each quarter due to a variety of factors, including market conditions, labor supply, materials costs and inflation, the latest figures show that highway construction costs today have climbed by 67 percent compared to similar costs in 2003.

Such information is of critical importance to national transportation decision makers, who rely on forecasts and cost-estimates to ensure sufficient financial support for the nation's growing transportation needs.

According to the Index, highway construction costs nationwide grew by an estimated 68 percent over the last 13 years. Key highway components, as measured by the Bureau of Labor Statistics, like asphalt, concrete and metal, grew at 107 percent, 61 percent and 45 percent, respectively between 2003 and 2016.

Many states track their own construction costs, with some experiencing much higher inflation than others. For example, California's composite cost index increased by 143 percent between 2003 to 2016, while Texas' increased by only 122 percent over the same period.

To review the entire NHCCI 2.0, visit

https://www.fhwa.dot.gov/policyinformation/nhcci/pt1.cfm

# # #

FHWA Press Releases

Page posted on July 19, 2017.

Appendix B: References

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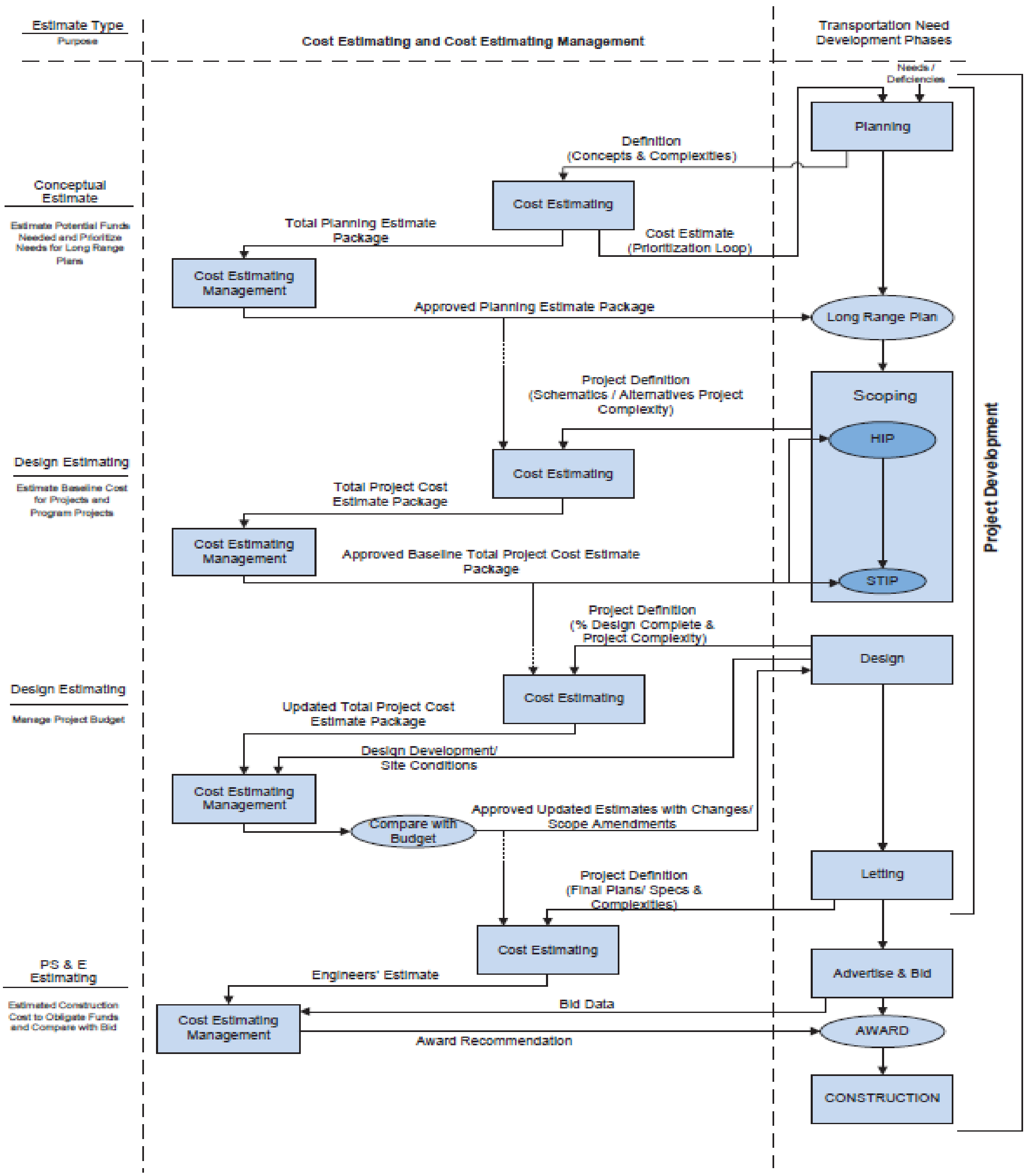
Appendix C: Integration of Project Development Process, Cost Estimation, and Cost Management

Figure 24: Integration of Project Development Process, Cost Estimation, and Cost Management flow chart



Appendix D: Analysis of Missouri DOT

The Missouri Department of Transportation, or MoDOT, currently does not produce a highway construction cost index, but it does track the cost of two main construction materials, concrete and asphalt. The construction materials are tracked in terms of price-price per cubic yard for concrete and price per ton for asphalt-and are derived from the total quantities and the average prices awarded for MoDOT projects. The time horizon spans from 1992 to 2016 bid openings. Given the different methodology of tracking costs for highway construction, direct comparisons between other state highway construction cost indexes should not be done as the other indexes incorporate much more than the pavement process, as well as the uncertain weighting of pavement costs within the composite indexes. However, MoDOT's average prices can be compared to the related national PPIs for construction materials, such as asphalt and tar pavement mixtures, and cement and concrete products. The data on asphalt and cement prices obtained from MoDOT were in nominal terms and were transformed to 2016 dollars.

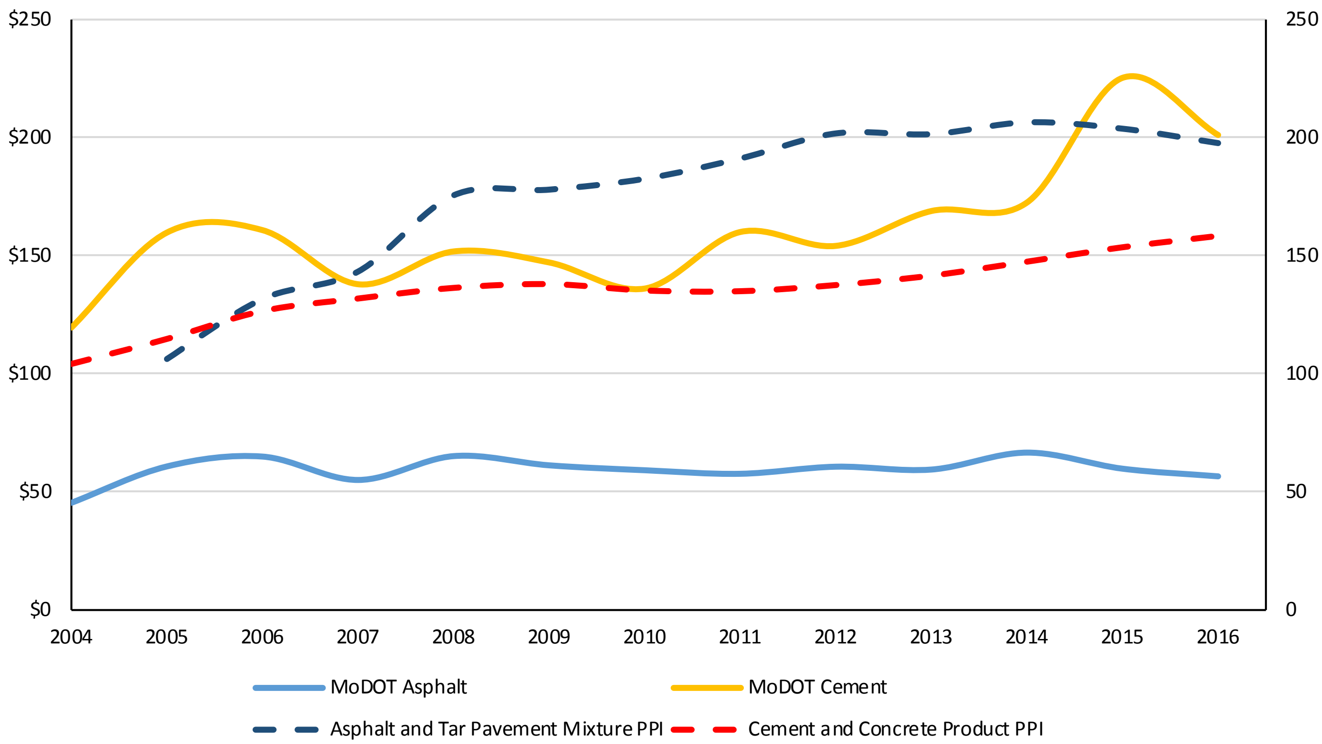


Figure 25: Comparing MoDOT Construction Material Prices (2016$) with Relevant PPI (2004-2016)

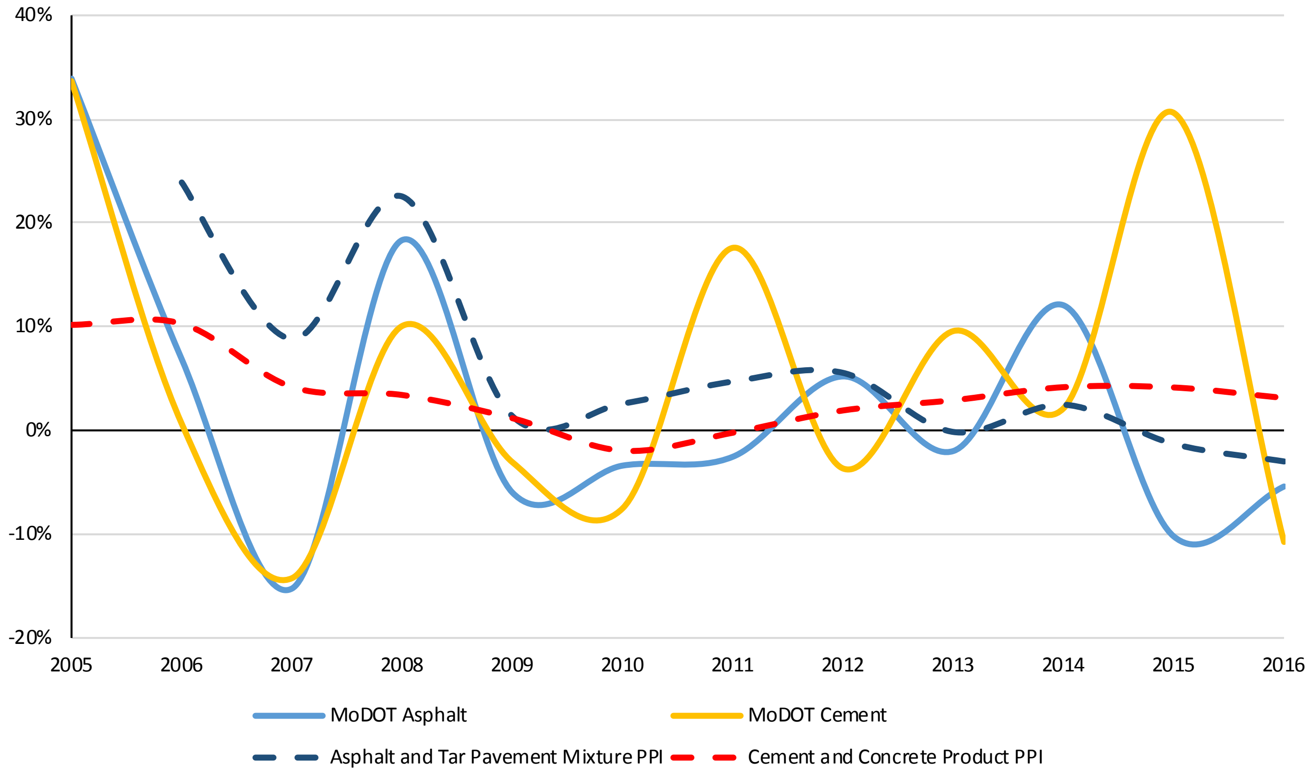


Figure 26: Year-over-Year Percent Change of MoDOT Construction Material Prices and Relevant PPI (2005 – 2016)

As is shown in the figures above, trends and shifts for both the asphalt and tar and cement and concrete PPIs are relatively smooth over the 2009 to 2016 period while MoDOT's average unit price percent changes year-over-year for asphalt and concrete products are highly variable, especially for concrete. This suggests issues with supply and demand at the state level, because this fluctuation was not experienced on a national average basis. MoDOT's asphalt unit price changes, at times, do approximate changes in the asphalt and tar PPI between 2008 and 2014, although changes in MoDOT's asphalt prices tend to be larger in magnitude.

Appendix E: Summary Comparison of State HCCI's

Table 6: Summary Table of State Construction Cost Index[46]

State	Washington[47]	Montana	Minnesota[48]	Iowa[49]	Ohio	Utah[50]
Index		*Young Index*	*Laspeyres*	*Laspeyres*	*Chained Fisher Index*	*Modified Laspeyres Index*
Frequency	*Quarterly*	*Annually*	*Quarterly, Annually*	*Quarterly, Annually*	*Quarterly*	*Quarterly*
Base Year	*1990*	*1987*	*1987*	*1987*	*2012 Q1*	*2003*
Categories	*7*	*9*	*6*	*6*	*19*	*6*
Item Category	• roadway • excavation • crushed • surfacing • hot asphalt mix • concrete pavement • structural concrete • steel reinforcing bar • structural steel	• excavation • aggregate base • surfacing • drainage • concrete • reinforcing steel • bridge • traffic • misc. item	• excavation • reinforcing steel • structural steel • structural concrete • concrete pavement • plant-mix bituminous pavement	• class 10 roadway and borrow, and embankment-in-place • HMA pavement and shoulder mixes • class 'A', class 'B' class 'C' pavements • reinforcing steel • structural steel • structural concrete	• asphalt • aggregate base • barrier • bridge painting • curbing • drainage • earthwork • erosion control • guardrail • landscaping • lighting • maintenance of traffic • pavement marking • pavement repair • PCC pavement • removal • signalization • structures • traffic control unclassified construction items	• roadway excavation • hot mix asphalt (HMA) • P.C.C.P (9" – 11" thick) • reinforcing steel (coated) • structural steel • structural concrete

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[46] Jeong, David H., Douglas D. Gransberg, and K. Joseph Shrestha, "Advanced Methodology to Determine Highway Construction Cost Index (HCCI)," prepared for The State of Montana Department Of Transportation, June 2017; (accessed Sept. 22, 2017).

[47] Item Category obtained from: WSDOT Highway Construction Costs, Washington Department of Transportation, June 2016, (accessed Nov. 2017)

[48] Item Category obtained from Minnesota Department of Transportation

[49] Item Category obtained from: Price Trend Index for Iowa Highway Construction, Iowa Department of Transportation, Office of Contracts, October 2017, (accessed Nov. 2017).

[50] Item Category obtained from: UDOT Construction Cost Indices, Utah Department of Transportation, August 2017, (accessed Nov. 2017)

Appendix F: Cost Index Types and Definitions

Definitions for Cost Index Types

Laspeyres Index

The Laspeyres Index is calculated using both quantity and price of individual cost items in calculating the aggregate price index. Like other price indexes, it uses the quantities of individual cost items as weights to their respective prices. For the Laspeyres Index, the weight used is the quantity in the base period.

One limitation of the Laspeyres Index is that it tends to overstate the impact of price increases and understates the impact of price decreases. This limitation becomes more noticeable as the difference between the observed time period and the base period increases (i.e. as you move further away from the base period). This is a direct result of using quantities from an earlier period as weight, which systematically biases the aggregate price index upward from the real change in aggregate prices.

Another limitation of the Laspeyres Index is that as time goes on, the fixed base year becomes less relevant to the current year(s) of concern. One method to correct this is to shift the base year forward in time. However, shifting the index forward will change the entire index series and history will be rewritten every time the base year is changed.[51]

Fisher Ideal Index

The Fisher Ideal Index (or Fisher Index) takes the weights of both the base period and the current period into account. By doing so, it accommodates the effects of substitution, which is something the Laspeyres Index does not do.[52] Effectively, the Fisher Index is an average of two indexes, one of them being the Laspeyres Index.

A major advantage of the Fisher Ideal Index is its "dual" property, which refers to the idea that a Fisher Ideal price index implies a Fisher Ideal quantity index and vice versa. The two components define the total change in value (measured in current dollars) between two given periods. However, in order to build an index that accurately tracks price changes from one period to the next requires the calculation of an index number for every pair of adjacent periods of the entire time period for which an index is built.[53]

Chained Price Index

The basic methodology for the two price indexes mentioned above tend to be calculated between two time periods and, over time, the quantities from the base period become progressively out-of-date. One solution to this issue is to use a chained price index, where price indexes are calculated for two consecutive periods only (i.e. only prices and quantities from current and previous periods are used to calculate the current index). This method also accounts for the addition and removal of items over time from the item basket. The overall index between two periods is then calculated through the product of consecutive price indexes between the periods.

[51] Jeong, David H., Douglas D. Gransberg, and K. Joseph Shrestha, "Advanced Methodology To Determine Highway Construction Cost Index (HCCI)"
[52] U.S. Department of Transportation, "National Highway Construction Cost Index (NHCCI): The Mathematics of the National Highway Construction Cost Index," November 7, 2014; (accessed Oct. 10, 2017)
[53] U.S. Department of Transportation, "National Highway Construction Cost Index (NHCCI): The Mathematics of the National Highway Construction Cost Index"

If there are significant fluctuations in the prices and quantities, the spread between the Laspeyres and Fisher indexes will be large and it will distort the measure of an overall price change between the first and last periods. Thus, if the prices and quantities of items fluctuate significantly, then a longer period (i.e. year or annual) index should be preferred as they would fluctuate less than chained price indexes calculated over shorter periods of time (i.e. monthly or quarterly).

While it is ideal for the value of the chained price index to return to one when the price and quantities of items in the basket return to their corresponding base year values, in reality this does not happen. In particular, the value of the index will be close to one but not exact due to varying market condition fluctuations. This bias is known as "chain drift." Shorter interval and seasonal fluctuations tend to contribute to a higher chain drift, which makes an annual chained price index the preferred time interval.[54]

Young Index

The Young Index is an alternative to the commonly used indexes, such as Laspeyres and Fisher Ideal index. The Young Index uses the average price of the current period, the average price of the previous period of a given item, and a weight of the item. Specifically, it measures the current average price to the average price of the last period, weighted by the shares of expenditure of the item in an arbitrary period. This arbitrary period is limited to any periods from base period to the current period. If the weights were to be taken from some base period, then the Young Index becomes the Laspeyres Index.[55]

One disadvantage of the Young Index is that it does not price update or revalue the expenditure shares and rather keeps the expenditure shares constant to the arbitrary period. Another issue is that the Young Index fails in the time reversal test (i.e. reversing the direction of comparison does not yield the inverse of the original) and lacks transitive properties.[56]

[54] Jeong, David H., Douglas D. Gransberg, and K. Joseph Shrestha, "Advanced Methodology To Determine Highway Construction Cost Index (HCCI)"
[55] Ibid
[56] International Labor Organization. "Consumer Price Index Manual: Theory and Practice," 2004; (accessed Oct. 10, 2017)

Appendix G: Reported Highway Construction Index

Minnesota

Table 7: Minnesota DOT Highway Construction Cost Index 1987–2016, Base Year 1987[57]

Year	Composite Index	Roadway Excavation	Bituminous Surfacing	Concrete Surfacing	Surfacing Index	Reinforce Steel	Structural Steel	Structural Concrete	Structures Index
1987	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1988	94.90	84.08	95.68	85.55	93.59	109.73	109.34	97.90	102.26
1989	97.90	103.72	92.01	94.50	93.23	115.99	111.15	97.29	103.45
1990	98.41	78.30	100.58	97.24	98.89	117.48	112.81	99.09	105.17
1991	96.04	67.31	97.72	109.11	100.07	111.54	121.31	93.98	102.28
1992	100.98	90.60	99.05	97.07	98.64	106.37	105.54	112.38	109.98
1993	97.70	80.75	101.91	96.30	100.75	108.13	127.30	90.07	100.21
1994	99.32	75.38	102.48	104.96	102.99	105.52	110.88	101.55	103.98
1995	104.63	72.20	99.81	113.94	102.73	121.47	126.83	116.53	119.32
1996	107.13	97.01	97.12	117.89	101.40	120.85	178.06	106.59	121.98
1997	114.03	108.51	109.84	125.63	113.10	122.08	99.44	122.32	118.25
1998	123.58	106.99	124.06	132.22	125.95	127.70	146.08	121.58	127.10
1999	126.75	95.07	135.87	142.46	137.23	124.73	114.64	124.72	122.95
2000	133.91	105.38	138.87	157.19	142.65	139.49	137.59	127.59	131.71
2001	141.61	123.17	137.25	153.92	140.69	142.53	171.70	149.25	151.85
2002	140.73	115.64	150.27	142.16	148.60	159.74	157.32	126.43	138.49
2003	151.60	129.12	163.83	156.17	162.25	166.37	116.91	143.23	143.23
2004	149.61	103.48	159.35	141.15	155.60	191.19	162.96	150.02	160.50
2005	167.97	130.43	169.66	183.55	172.53	202.26	201.13	162.78	177.39
2006	197.10	127.80	228.04	173.91	216.88	204.99	183.53	193.74	204.80
2007	212.88	147.02	232.91	198.59	225.84	233.69	262.24	204.79	220.64
2008	234.22	136.85	282.00	175.62	260.06	349.63	239.92	195.24	233.87
2009	225.32	147.46	265.08	184.33	248.43	213.94	252.12	214.03	220.70
2010	229.17	151.35	277.15	167.66	254.58	222.32	197.81	226.24	220.47
2011	245.95	212.74	289.32	145.22	259.61	254.49	216.82	237.48	237.25
2012	257.36	207.23	322.38	182.48	293.54	261.73	221.19	201.04	216.68
2013	261.85*	201.96	320.88	197.83	295.51	277.52	232.54*	285.73	230.29*
2014	283.58	236.40	329.72	199.71	302.92	274.37	247.88	276.96	271.34
2015	279.95*	253.63	314.25	268.68	304.86	307.10	245.11*	327.03	247.23*
2016	248.49*	231.36	250.05	250.81	250.21	270.74	250.77*	345.79	253.45*

[57] Composite Index values for 2013, 2015, and 2016 are imputed using regression analysis. Structural Steel and Structures Index for 2013, 2015, and 2016 are imputed following time series trends. Similar method was done for Roadway Excavation values in 1995. Imputed values denoted with *. Data from: Highway Construction Cost Index – 3rd Quarter 2016, Minnesota Department of Transportation, Sept. 2017; (accessed Nov. 2017)

Table 8: Minnesota DOT Highway Construction Cost Index 1998 Q3–2017 Q2, Base Year 1987[58]

Quarter	Year	Composite Index	Roadway Excavation	Bituminous Surfacing	Concrete Surfacing	Surfacing Index	Reinforce Steel	Structural Steel	Structural Concrete	Structures Index
Q3	1998	139.4	135.95	150.01	129.84	145.85	133.21	--	126.04	127.51
Q4	1998	140.22	--	155.16	--	155.16	146.08	110.58	119.22	--
Q1	1999	133.51	90.59	130.95	210.3	147.31	133.64	--	126.39	128.14
Q2	1999	126.58	92.34	137.5	139.09	137.83	121.34	--	121.92	121.78
Q3	1999	125.78	85.22	135.66	--	135.66	125.58	168.87	121.78	130.81
Q4	1999	160.66	182.25	143.08	202.56	155.34	132.1	107.12	183.75	160
Q1	2000	133.77	96.35	141.29	153.08	143.73	142.36	151.96	125.61	133.57
Q2	2000	133.33	111.93	138.88	158.17	142.86	137.49	136.03	120.21	126.43
Q3	2000	127.13	102.18	128.03	--	128.03	137.29	--	140.48	139.71
Q4	2000	148.21	115.61	136.47	170.73	143.53	149.27	--	185.41	176.66
Q1	2001	141.28	91.27	131.58	133.42	131.96	166.65	--	196.86	189.55
Q2	2001	140.36	116.05	135.28	149.2	138.15	135.53	219.62	144.03	155.6
Q3	2001	134.11	109.17	130.04	154.51	135.09	140.67	166.76	138.68	144.01
Q4	2001	158.06	157.83	160.9	185.56	165.98	149.31	86.82	158.62	144.16
Q1	2002	135.49	123.44	147.14	119.78	141.5	151.68	143.03	120.19	130.48
Q2	2002	136.82	148.48	149.69	140.07	147.71	150.31	165.23	85.03	112.13
Q3	2002	132.77	--	132.77	--	132.77	--	--	--	--
Q4	2002	149.61	95.26	157.12	161.93	158.12	167.64	154.74	158.85	159.88
Q1	2003	153.05	119.16	168.38	149.65	164.51	165.32	124.83	149.85	148.55
Q2	2003	154.57	149.11	166.29	171.88	167.44	168.38	109.25	130.53	134.34
Q3	2003	160.21	126.34	162.12	190.96	168.07	166.04	--	161.37	162.5
Q4	2003	159.77	142.18	144.11	--	144.11	162.08	139.53	213.05	189.98
Q1	2004	150.36	89.34	157.99	145.67	155.45	184.4	166.06	166.16	169.78
Q2	2004	146.23	101.93	156.99	153.21	156.21	193.4	--	135.92	149.83
Q3	2004	192.95	156.87	173.66	220.06	183.23	231.7	126.15	253.8	226.99
Q4	2004	155.53	171.37	153.88	126.7	148.28	175.45	195.43	146.69	160.98
Q1	2005	169.57	91.95	159.35	221.3	172.12	206.72	281.37	176.99	201.24
Q2	2005	173.44	152.75	163.52	230.4	177.31	206.89	201.87	159.27	176.24
Q3	2005	185.71	135.85	214.4	173.97	206.06	195.34	199.9	158.17	172.91
Q4	2005	193.94	131.93	211.41	--	211.41	219.49	--	192.75	199.22
Q1	2006	198.82	179.64	216.37	168.4	206.48	209.17	167.23	196.99	194.19
Q2	2006	204.11	137.7	241	191.38	230.77	192.21	194.21	184.52	187.87
Q3	2006	--	137	217.53	*	**	257.26	*	230.67	**
Q4	2006	--	95.01	228.13	*	**	247.81	*	212	**
Q1	2007	232.47	190.17	255.61	222.49	248.78	236.81	283.08	202.21	223.31
Q2	2007	196.6	114.76	224.06	155.14	209.85	221.84	187.19	214.66	211.27
Q3	2007	--	*/**	213.4	*	**	*	*	*	**

[58]Data provided by Minnesota Department of Transportation

Quarter	Year	Composite Index	Roadway Excavation	Bituminous Surfacing	Concrete Surfacing	Surfacing Index	Reinforce Steel	Structural Steel	Structural Concrete	Structures Index
Q4	2007	--	117.03	209.36	*	**	*	*	*	**
Q1	2008	--	143.43	235.23	361.9	261.34	409.19	*	189.7	**
Q2	2008	230.2	134.37	278.48	170.51	256.22	286.47	267.39	199.61	228.83
Q3	2008	--	*	314.6	*	**	295.44	215.32	196.42	219.48
Q4	2008	--	217.71	350.82	*	**	242.71	*	187.2	**
Q1	2009	247.42	130.35	267.53	179.27	249.34	212.65	703.64	212.26	298.6
Q2	2009	233.08	205.07	254.33	210.92	245.38	220.7	249.11	218.6	224.37
Q3	2009	--	*/**	293.2	*	**	*	*	*	**
Q4	2009	--	255.96	266.65	174.42	247.63	202.59	*	211.65	**
Q1	2010	227.65	118.81	297.94	155.03	268.47	215.46	171.69	212.82	206.13
Q2	2010	236.32	207.89	271.58	181.95	253.1	226.17	253.31	208.48	219.88
Q3	2010	--	266.22	268.87	*	**	*	*	*	**
Q4	2010	243.64	263.08	260.16	186.16	244.9	222.91	197.32	245.2	232.35
Q1	2011	--	282.29	277.18	138.12	248.51	267.6	*	233.93	**
Q2	2011	241.97	187.26	289.19	147.37	259.95	249.7	216.82	236.44	235.64
Q3	2011	--	206.87	306.2	130.31	269.94	*	*	*	**
Q4	2011	--	290.62	311.17	161.76	280.36	253.69	*	261.73	**
Q1	2012	--	171.16	331.9	164.11	297.3	285.15	*	272.55	**
Q2	2012	--	251.04	318.01	191.58	291.94	267.4	*	218.35	**
Q3	2012	--	220.88	351.69	154.88	311.11	228.22	*	*	**
Q4	2012	258.54	206.53	308.84	260.42	298.86	260.22	221.19	193.13	211.43
Q1	2013	--	192.74	299.93	211.51	281.7	237.57	*	236.42	**
Q2	2013	297.66	185.76	337.29	208.92	310.83	260.31	492.55	301.01	326.52
Q3	2013	--	*	*	*	**	*	*	*	**
Q4	2013	--	304.08	329.32	181.06	298.75	284.22	*	304.71	**
Q1	2014	284.46	296.52	316.42	211.06	294.7	276.99	210.59	269.59	260.71
Q2	2014	286.95	252.8	335.14	191.32	305.49	266.37	307.37	260.77	270.06
Q3	2014	--	175.49	353.17	195.49	320.66	*	*	*	**
Q4	2014	--	186.9185626	331.0165708	219.2291339	307.9686857	280.5022365	*	353.970313	**
Q1	2015	--	220.03	320.13	278.25	311.49	321.17	*	365.47	**
Q2	2015	--	246.97	329.07	290.48	321.12	327.53	*	347.71	**
Q3	2015	--	*	315.16	*	**	*	*	*	**
Q4	2015	--	328.75	287.05	252.29	279.88	286.55	*	283.49	**
Q1	2016	--	350.11	267.82	248.95	263.93	287.15	*	311.2	**
Q2	2016	--	231.37	234.73	*	**	*	*	*	**
Q3	2016	--	*	247.55	*	**	307.96	*	*	**
Q4	2016	--	178.34	243.09	555.46	307.49	241.99	*	406.69	**
Q1	2017	276.14	214.3	287.42	262.73	282.33	269.81	202.59	327.42	294.02
Q2	2017	293.74	417.5	278.25	252.26	272.89	276.4	267.39	273.41	272.95

[56] Data provided by Minnesota Department of Transportation

Utah

Table 9: Utah DOT Highway Construction Cost Index 1972–2016, Base Year 1987[59]

Year	Composite Index
1972	35.9
1973	40.8
1974	57.4
1975	54.8
1976	61.5
1977	67.0
1978	78.2
1979	100.8
1980	109.4
1981	101.2
1982	93.0
1983	96.9
1984	123.3
1985	110.0
1986	110.1
1987	100.0
1988	111.5
1989	112.2
1990	128.3
1991	126.3
1992	126.2
1993	150.6
1994	134.9
1995	165.6
1996	175.6
1997	163.4
1998	146.1
1999	143.1
2000	131.9
2001	153.1
2002	153.0
2003	127.2
2004	152.5
2005	259.5
2006	293.8
2007	252.0
2008	310.2
2009	189.6
2010	241.1
2011	212.4
2012	242.2
2013	227.8
2014	256.2
2015	266.5
2016	274.4

[59] UDOT Construction Cost Index, Utah Department of Transportation, August 2017, (accessed Nov. 2017)

Iowa

Table 10: Iowa DOT Highway Construction Cost Index 1986–2016, Base Year 1987[60]

Year	Composite Index	Roadway Excavation Index	HMA Pavement Index	PCC Pavement Index	Reinforcing Steel Index	Structural Steel Index	Structural Concrete Index	Structures Index
1986	98.1	90.8	100.1	97.7	98.9	105.4	99.7	99.9
1987	97.8	104.1	94.8	98.0	96.9	94.4	98.7	98.1
1988	104.0	105.2	105.0	102.1	108.5	111.0	103.3	104.9
1989	98.8	83.9	96.5	99.3	114.6	128.8	107.8	110.6
1990	113.5	94.7	109.5	105.1	119.3	231.4	143.8	144.4
1991	115.0	108.4	104.1	123.3	117.9	128.0	122.8	122.1
1992	111.7	121.3	99.4	113.0	118.0	131.7	122.8	122.4
1993	118.2	131.1	108.9	118.5	121.0	113.9	126.3	124.4
1994	121.9	127.9	103.4	131.8	128.7	127.8	131.2	130.5
1995	124.2	125.4	108.6	128.9	135.0	145.9	140.4	139.6
1996	123.7	110.6	112.5	130.0	131.5	153.0	139.2	138.5
1997	127.1	116.0	112.7	135.0	135.4	147.9	144.3	142.7
1998	130.1	114.1	115.3	137.5	140.3	163.5	151.8	150.2
1999	140.9	127.1	129.0	150.2	144.9	171.2	152.8	152.4
2000	147.0	128.2	141.9	149.0	150.0	162.5	166.2	162.6
2001	147.5	142.8	130.1	152.9	153.6	161.1	173.1	168.3
2002	150.1	124.5	138.3	151.8	165.5	165.5	186.3	180.7
2003	146.8	111.9	136.2	146.9	162.4	151.0	193.1	184.1
2004	159.4	127.6	143.1	164.8	201.1	194.5	193.0	194.7
2005	173.0	155.9	164.9	165.1	208.3	219.5	207.5	208.4
2006	194.1	192.9	195.6	184.0	213.1	196.0	206.4	207.1
2007	212.5	211.6	225.0	185.8	232.7	347.4	228.5	237.0
2008	245.5	235.2	257.0	227.4	292.1	275.9	254.4	263.5
2009	246.0	190.9	305.0	214.6	232.4	176.5	247.8	240.1
2010	236.1	185.1	290.4	194.1	229.5	353.1	248.9	251.6
2011	256.1	283.7	293.6	199.7	262.7	613.4	246.1	273.2
2012	279.5	488.5	302.7	204.0	254.1	196.8	240.3	240.4
2013	268.4	334.2	294.8	219.0	260.8	324.8	265.4	268.3
2014	300.7	348.2	308.5	255.0	277.7	575.8	306.6	318.0
2015	306.2	346.2	315.5	261.4	302.3	345.8	350.7	340.4
2016	274.2	240.6	271.6	249.3	295.2	192.2	364.2	338.9
2017	283.9	216.4	273.2	292.5	323.9	209.5	338.4	327.1

[60] Price Trend Index for Iowa Highway Construction, Iowa Department of Transportation Office of Contract, October 2017, (accessed Nov. 2017)

Washington

Table 11: Washington DOT Highway Construction Cost Index 1990–2016, Base Year 1990[61]

Year	Composite Index
1990	110.00
1991	121.00
1992	108.00
1993	106.00
1994	105.00
1995	124.00
1996	124.00
1997	139.00
1998	116.00
1999	120.00
2000	128.00
2001	129.00
2002	139.00
2003	145.00
2004	170.00
2005	176.00
2006	228.00
2007	230.00
2008	241.00
2009	223.00
2010	232.00
2011	245.00
2012	258.00
2013	243.00
2014	328.00
2015	293.00
2016	--

[61] WSDOT Highway Construction Cost June 2016, Washington Department of Transportation, July 2016. (accessed Nov. 2017)

Ohio

Table 12: Ohio DOT Highway Construction Cost Index 2007 Q1–2017 Q3, Base Year 2012 Q1[62]

Quarter	Year	Composite Index
Q1	2007	87.0
Q2	2007	88.1
Q3	2007	88.6
Q4	2007	87.7
Q1	2008	87.2
Q2	2008	88.2
Q3	2008	89.8
Q4	2008	91.0
Q1	2009	92.9
Q2	2009	91.7
Q3	2009	89.2
Q4	2009	88.5
Q1	2010	87.8
Q2	2010	88.9
Q3	2010	90.4
Q4	2010	90.7
Q1	2011	91.5
Q2	2011	92.9
Q3	2011	94.7
Q4	2011	97.5
Q1	2012	100.0
Q2	2012	103.8
Q3	2012	102.7
Q4	2012	104.6
Q1	2013	104.2
Q2	2013	104.0
Q3	2013	104.4
Q4	2013	101.0
Q1	2014	101.9
Q2	2014	101.9
Q3	2014	102.9
Q4	2014	105.3
Q1	2015	106.4
Q2	2015	109.9
Q3	2015	109.2
Q4	2015	108.7
Q1	2016	108.6
Q2	2016	107.3
Q3	2016	108.2
Q4	2016	107.4
Q1	2017	106.0
Q2	2017	106.8
Q3	2017	106.8

[62] Cost index provided by ODOT, November 15, 2017

Montana

Table 13: Montana DOT Highway Construction Cost Index 1987–2016, Base Year 1987[63]

Year	Composite Index	Modified HCCI
1987	100.0	100.0
1988	122.3	116.9
1989	115.2	113.5
1990	127.6	122.1
1991	125.9	118.9
1992	121.8	116.4
1993	126.6	122.4
1994	123.1	121.8
1995	135.5	129.0
1996	136.8	130.6
1997	129.2	128.6
1998	139.3	136.8
1999	138.2	135.2
2000	150.8	141.8
2001	163.8	156.6
2002	153.9	146.5
2003	177.8	169.4
2004	193.7	181.0
2005	203.3	194.9
2006	246.9	235.2
2007	274.3	264.8
2008	304.4	287.4
2009	311.8	275.8
2010	310.1	277.0
2011	328.0	293.5
2012	368.2	309.7
2013	339.5	299.4
2014	357.6	331.1
2015	360.5	352.8

[63] Data obtained from the Montana Department of Transportation

Federal Highway Administration NHCCI 2.0

Table 14: FHWA NHCCI 2.0 2003 Q1–2016 Q4, Base Year 2003 Q1[64]

Quarter	Year	Composite Index
Q1	2003	1.00
Q2	2003	1.01
Q3	2003	1.02
Q4	2003	1.02
Q1	2004	1.05
Q2	2004	1.10
Q3	2004	1.14
Q4	2004	1.15
Q1	2005	1.24
Q2	2005	1.28
Q3	2005	1.37
Q4	2005	1.41
Q1	2006	1.45
Q2	2006	1.52
Q3	2006	1.62
Q4	2006	1.55
Q1	2007	1.56
Q2	2007	1.56
Q3	2007	1.54
Q4	2007	1.51
Q1	2008	1.57
Q2	2008	1.64
Q3	2008	1.78
Q4	2008	1.63
Q1	2009	1.50
Q2	2009	1.44
Q3	2009	1.43
Q4	2009	1.40
Q1	2010	1.44
Q2	2010	1.44
Q3	2010	1.45
Q4	2010	1.43
Q1	2011	1.46
Q2	2011	1.50
Q3	2011	1.54
Q4	2011	1.54
Q1	2012	1.58
Q2	2012	1.63
Q3	2012	1.60
Q4	2012	1.61
Q1	2013	1.59
Q2	2013	1.62
Q3	2013	1.64
Q4	2013	1.59
Q1	2014	1.63
Q2	2014	1.67
Q3	2014	1.74
Q4	2014	1.69
Q1	2015	1.72
Q2	2015	1.70
Q3	2015	1.71
Q4	2015	1.66
Q1	2016	1.63
Q2	2016	1.68
Q3	2016	1.68
Q4	2016	1.66

[64] National Highway Construction Cost Index (NHCCI) 2.0, U.S Department of Transportation Federal Highway Administration, July 2017, (Accessed Nov. 2017)

Appendix H: Data Tables used for Figures in Report

Table 15: Highway Construction Cost Index (2004—2016)

Year	MnDOT HCCI	WSDOT HCCI	IA DOT HCCI	MDT HCCI	MDT HCCI (Modified)	UDOT HCCI	ODOT HCCI	NHCCI 2.0
2004	149.6	170.0	159.4	193.7	181.0	152.5	--	111.0
2005	168.0	176.0	173.0	203.3	194.9	259.5	--	132.7
2006	197.1	228.0	194.1	246.9	235.2	293.8	--	153.5
2007	212.9	230.0	212.5	274.3	264.8	252.0	--	154.4
2008	234.2	241.0	245.5	304.4	287.4	310.2	--	165.6
2009	225.3	223.0	246.0	311.8	275.8	189.6	--	144.3
2010	229.2	232.0	236.1	310.1	277.0	241.1	--	143.9
2011	246.0	245.0	256.1	328.0	293.5	212.4	--	151.0
2012	257.4	258.0	279.5	368.2	309.7	242.2	102.8	160.2
2013	261.9	243.0	268.4	339.5	299.4	227.8	103.2	161.3
2014	283.6	328.0	300.7	357.6	331.1	256.2	103.0	168.2
2015	279.9	293.0	306.2	360.5	352.8	266.5	108.6	169.8
2016	248.5	--	274.2	--	--	274.4	107.9	166.2

Table 16: Highway Construction Cost Index (Rebased to 2004)

Year	MnDOT HCCI	WSDOT HCCI	IA DOT HCCI	MDT HCCI	MDT HCCI (Modified)	UDOT HCCI	ODOT HCCI	NHCCI 2.0
2004	100.0	100.0	100.0	100.0	100.0	100.0	--	100.0
2005	112.3	103.5	108.5	105.0	107.7	170.2	--	119.5
2006	131.7	134.1	121.8	127.5	129.9	192.7	--	138.3
2007	142.3	135.3	133.3	141.6	146.3	165.2	144.0	139.1
2008	156.6	141.8	154.0	157.2	158.8	203.4	146.0	149.2
2009	150.6	131.2	154.3	161.0	152.4	124.3	148.5	130.0
2010	153.2	136.5	148.1	160.1	153.0	158.1	146.6	129.7
2011	164.4	144.1	160.7	169.3	162.2	139.3	154.3	136.1
2012	172.0	151.8	175.3	190.1	171.1	158.8	168.5	144.3
2013	175.0	142.9	168.4	175.3	165.4	149.4	169.5	145.3
2014	189.5	192.9	188.6	184.6	182.9	168.0	168.8	151.5
2015	187.1	172.4	192.1	186.1	194.9	174.8	177.9	153.0
2016	166.1	--	172.0	--	--	179.9	176.8	149.7

Table 17: Highway Construction Cost Indexes, Base Year 1987

Year	MnDOT HCCI	IA DOT HCCI	MDT HCCI	MDT HCCI (Modified)	UDOT HCCI	WSDOT HCCI	ODOT HCCI
1987	100.0	97.8	100.0	100.0	100.0	--	--
1988	94.9	104.0	122.3	116.9	111.5	--	--
1989	97.9	98.8	115.2	113.5	112.2	--	--
1990	98.4	113.5	127.6	122.1	128.3	110.0	--
1991	96.0	115.0	125.9	118.9	126.3	121.0	--
1992	101.0	111.7	121.8	116.4	126.2	108.0	--
1993	97.7	118.2	126.6	122.4	150.6	106.0	--
1994	99.3	121.9	123.1	121.8	134.9	105.0	--
1995	104.6	124.2	135.5	129.0	165.6	124.0	--
1996	107.1	123.7	136.8	130.6	175.6	124.0	--
1997	114.0	127.1	129.2	128.6	163.4	139.0	--
1998	123.6	130.1	139.3	136.8	146.1	116.0	--
1999	126.8	140.9	138.2	135.2	143.1	120.0	--
2000	133.9	147.0	150.8	141.8	131.9	128.0	--
2001	141.6	147.5	163.8	156.6	153.1	129.0	--
2002	140.7	150.1	153.9	146.5	153.0	139.0	--
2003	151.6	146.8	177.8	169.4	127.2	145.0	--
2004	149.6	159.4	193.7	181.0	152.5	170.0	--
2005	168.0	173.0	203.3	194.9	259.5	176.0	--
2006	197.1	194.1	246.9	235.2	293.8	228.0	--
2007	212.9	212.5	274.3	264.8	252.0	230.0	140.9
2008	234.2	245.5	304.4	287.4	310.2	241.0	142.8
2009	225.3	246.0	311.8	275.8	189.6	223.0	145.2
2010	229.2	236.1	310.1	277.0	241.1	232.0	143.5
2011	246.0	256.1	328.0	293.5	212.4	245.0	151.0
2012	257.4	279.5	368.2	309.7	242.2	258.0	164.8
2013	261.9	268.4	339.5	299.4	227.8	243.0	165.8
2014	283.6	300.7	357.6	331.1	256.2	328.0	165.2
2015	280.0	306.2	360.5	352.8	266.5	293.0	174.1
2016	248.5	274.2	--	--	274.4	--	173.0

Table 18: Highway Construction Cost Index Comparison, Base Year 2004

Year	MnDOT HCCI	NHCCI 2.0	HCCI Average of Peer States	HCCI Average of Peer States (incl. MN)
2004	100.0	100.0	100.0	100.0
2005	112.3	119.5	119.0	117.9
2006	131.7	138.3	141.2	139.6
2007	142.3	139.1	144.3	144.0
2008	156.6	149.2	160.2	159.7
2009	150.6	130.0	145.3	146.0
2010	153.2	129.7	150.4	150.8
2011	164.4	136.1	155.0	156.3
2012	172.0	144.3	169.3	169.7
2013	175.0	145.3	161.8	163.7
2014	189.5	151.5	181.0	182.2
2015	187.1	153.0	183.0	183.6
2016	166.1	149.7	176.3	173.7

Table 19: Highway Construction Cost Index–Year-over-Year Percent Change

Year	MnDOT HCCI	WSDOT HCCI	IA DOT HCCI	MDT HCCI	MDT HCCI (Modified)	UDOT HCCI	ODOT HCCI	NHCCI 2.0	HCCI Average of Peer States	HCCI Average of Peer States (incl. MN)
2004	--	--	--	--	--	--	--	--	--	--
2005	12.3%	3.5%	8.5%	5.0%	7.7%	70.2%	--	19.5%	14.8%	14.4%
2006	17.3%	29.5%	12.2%	21.4%	20.7%	13.2%	--	15.7%	19.4%	19.1%
2007	8.0%	0.9%	9.5%	11.1%	12.6%	-14.2%	--	0.6%	4.1%	4.7%
2008	10.0%	4.8%	15.5%	11.0%	8.5%	23.1%	1.4%	7.2%	10.2%	10.1%
2009	-3.8%	-7.5%	0.2%	2.4%	-4.0%	-38.9%	1.7%	-12.9%	-6.9%	-6.4%
2010	1.7%	4.0%	-4.0%	-0.5%	0.4%	27.2%	-1.2%	-0.3%	2.3%	2.2%
2011	7.3%	5.6%	8.5%	5.8%	6.0%	-11.9%	5.3%	4.9%	4.1%	4.5%
2012	4.6%	5.3%	9.1%	12.3%	5.5%	14.0%	9.2%	6.1%	8.9%	8.3%
2013	1.7%	-5.8%	-4.0%	-7.8%	-3.3%	-5.9%	0.6%	0.7%	-4.4%	-3.5%
2014	8.3%	35.0%	12.0%	5.3%	10.6%	12.5%	-0.4%	4.3%	12.1%	11.5%
2015	-1.3%	-10.7%	1.8%	0.8%	6.6%	4.0%	5.4%	1.0%	0.8%	0.5%
2016	-11.2%	--	-10.5%	--	--	2.9%	-0.6%	-2.2%	-12.9%	-12.1%

Table 20: Construction Material Index, Rebased to 2005

Year	Fabricated Structural Metal PPI	Cement and Concrete Product PPI	Fabricated Structural Metal for Bridges PPI	Asphalt and Tar Pavement Mixture PPI
2004	93.1	90.8	95.2	--
2005	100.0	100.0	100.0	100.0
2006	104.3	110.3	108.7	123.9
2007	108.7	114.9	138.3	134.8
2008	121.1	118.8	118.9	165.2
2009	112.5	120.2	120.0	167.5
2010	106.7	117.9	125.9	171.8
2011	109.1	117.6	128.9	179.9
2012	111.0	119.9	123.7	189.8
2013	111.2	123.3	129.6	189.6
2014	114.0	128.5	127.4	194.3
2015	115.6	133.8	113.0	191.7
2016	117.5	138.0	--	186.0

Table 21: Construction Material Index–Year-over-Year Percent Change

Year	Fabricated Structural Metal PPI	Cement and Concrete Product PPI	Fabricated Structural Metal for Bridges PPI	Asphalt and Tar Pavement Mixture PPI
2004	--	--	--	--
2005	7.4%	10.2%	5.0%	--
2006	4.3%	10.3%	8.7%	23.9%
2007	4.2%	4.2%	27.2%	8.8%
2008	11.4%	3.4%	-14.0%	22.5%
2009	-7.1%	1.2%	0.9%	1.4%
2010	-5.1%	-2.0%	4.9%	2.6%
2011	2.2%	-0.2%	2.4%	4.7%
2012	1.7%	1.9%	-4.0%	5.5%
2013	0.2%	2.9%	4.8%	-0.1%
2014	2.6%	4.2%	-1.7%	2.5%
2015	1.4%	4.1%	-11.3%	-1.3%
2016	1.6%	3.1%	--	-3.0%

Appendix I: Imputation of Missing Index Values

Imputation is the concept of replacing missing values that can be done following a variety of methodologies. In the case of MnDOT's HCCI, there were missing values for the composite index in 2013, 2015 and 2016 as a result of missing structural steel sub-index values for those years. However, the other item categories for roadway excavation, bituminous surfacing and concrete surfacing were available from1987 to 2014. If values for the years with missing structural steel sub-index values could be imputed, then a relationship between the composite index and its three main components of roadway excavation, surfacing (bituminous and concrete) and structures (reinforcing steel, structural steel, structural concrete) could be quantified using ordinary least squares regression. In this manner, the information contained in the existing data could be leveraged to obtain representative estimates for the composite index values for the years 2013, 2015 and 2016. Two methods were used to impute the missing values reported in the MnDOT's HCCI.

For the sub-index values and the item categories, the missing values were imputed following a trend, using the TREND function in Microsoft Excel. Each imputed valued from the TREND function[1] is a function of the previous values from that given sub-index or item category and their corresponding years. In particular, this was done for the missing values for Structural Steel and the Structures Index for 2013, 2015 and 2016 and for the missing Roadway Excavation value in 1995. The previous index values are inputted as the known y's, while their corresponding years are inputted as the known x's. The new x is inputted as the year for which the value is missing. An example of this is highlighted in the figure below. The known y's are highlighted in blue, the known x's are highlighted in red. The new x, which is the year with the missing observation, is generated and is highlighted in purple.

Year	Structures Index
1987	100.00
1988	102.26
1989	103.45
1990	105.17
1991	102.28
1992	109.98
1993	100.21
1994	103.98
1995	119.32
1996	121.98
1997	118.25
1998	127.10
1999	122.95
2000	131.71
2001	151.85
2002	138.49
2003	143.23
2004	160.50
2005	177.39
2006	204.80
2007	220.64
2008	233.87
2009	220.70
2010	220.47
2011	237.25
2012	216.68
2013	=TREND(J9:J34,$A$9:$A$34,$A35)
2014	271.34
2015	247.23
2016	253.45

[1] Syntax: TREND=(known y's,[known_x's],[new_x's],[const])

Figure 27: Example of Trend Function Used for Imputation

For the composite index, the values are imputed following the results of an ordinary least squares regression. In particular, for years with non-missing data, the composite index values were regressed on the major sub-indexes used to calculate the composite index (i.e. roadway excavation, surfacing index and structures index). The regression used annual data from 1988 to 1994, 1996 to 2012, and 2014, because those were the years where there were no missing values for both the composite and sub-indexes, including the imputed sub-index values. The results are reported in the table below. The missing composite index values are then computed using the observed and imputed sub-index values, multiplied by their respective coefficients from the regression analysis, and then summed with the reported intercept value.

Table 22: Ordinary Least Squares Regression Analysis

Variable	Coefficients
Intercept	0.23
Roadway Excavation	0.15
Surfacing Index	0.55
Structures Index	0.30

Appendix J: Percentile Analysis of Growth Differences

Table 23: Percentile Analysis of Differences between MnDOT HCCI Year-over-Year Percent Changes to those of Peer States' Average HCCI and the NHCCI 2.0

	Difference MnDOT and Average Peer State	Difference MnDOT and NHCCI 2.0
Min	-3.6%	-9.1%
25th percentile	-2.0%	-2.1%
Median	-0.3%	1.8%
75th percentile	2.7%	3.7%
Max	5.2%	9.1%

Appendix K: Breakdown of Total Awarded Project Costs by Item Category

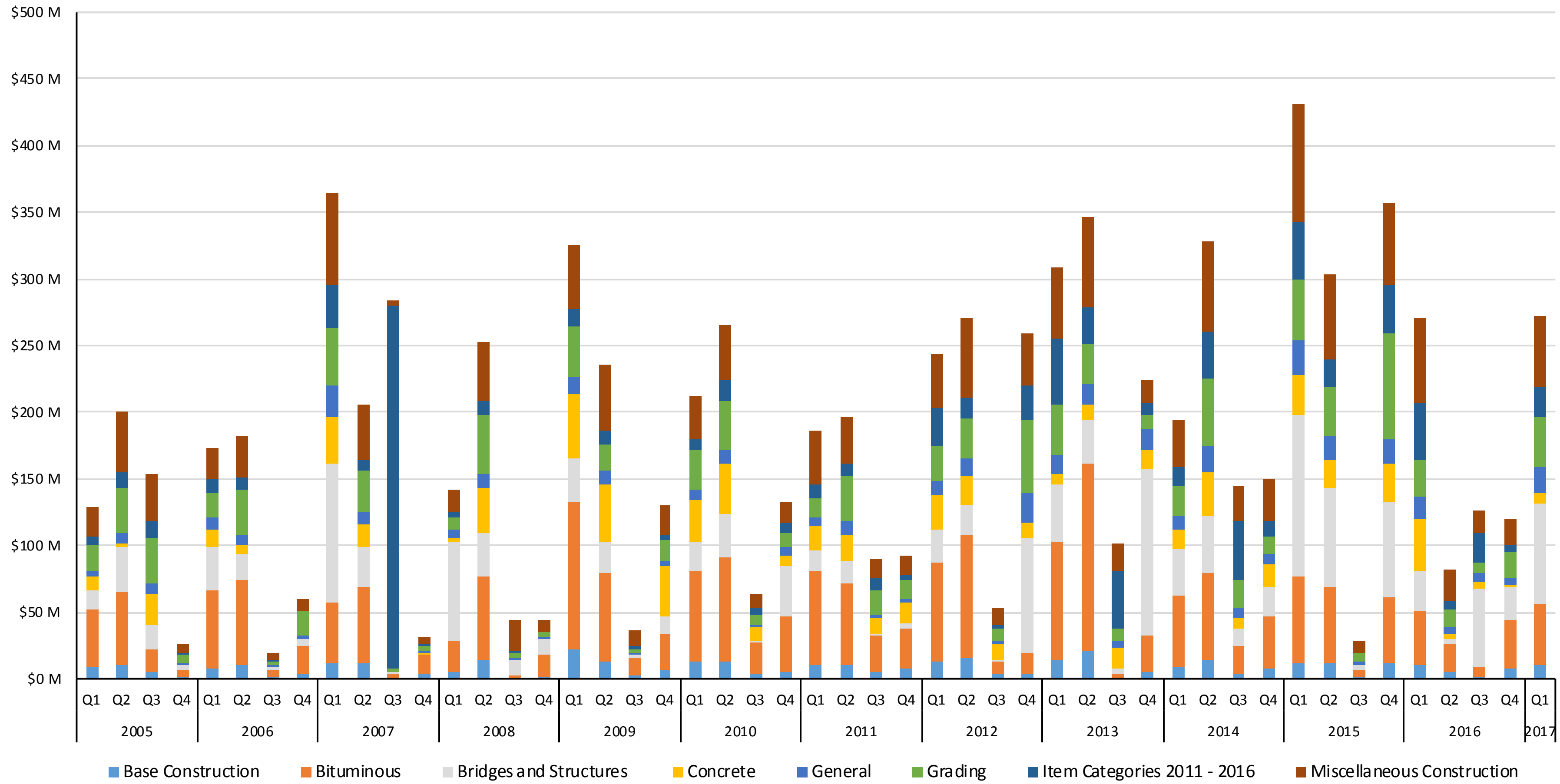

Figure 28: 2016 Dollar Breakdown of MnDOT Total Awarded Project Costs by Item Category, Quarterly

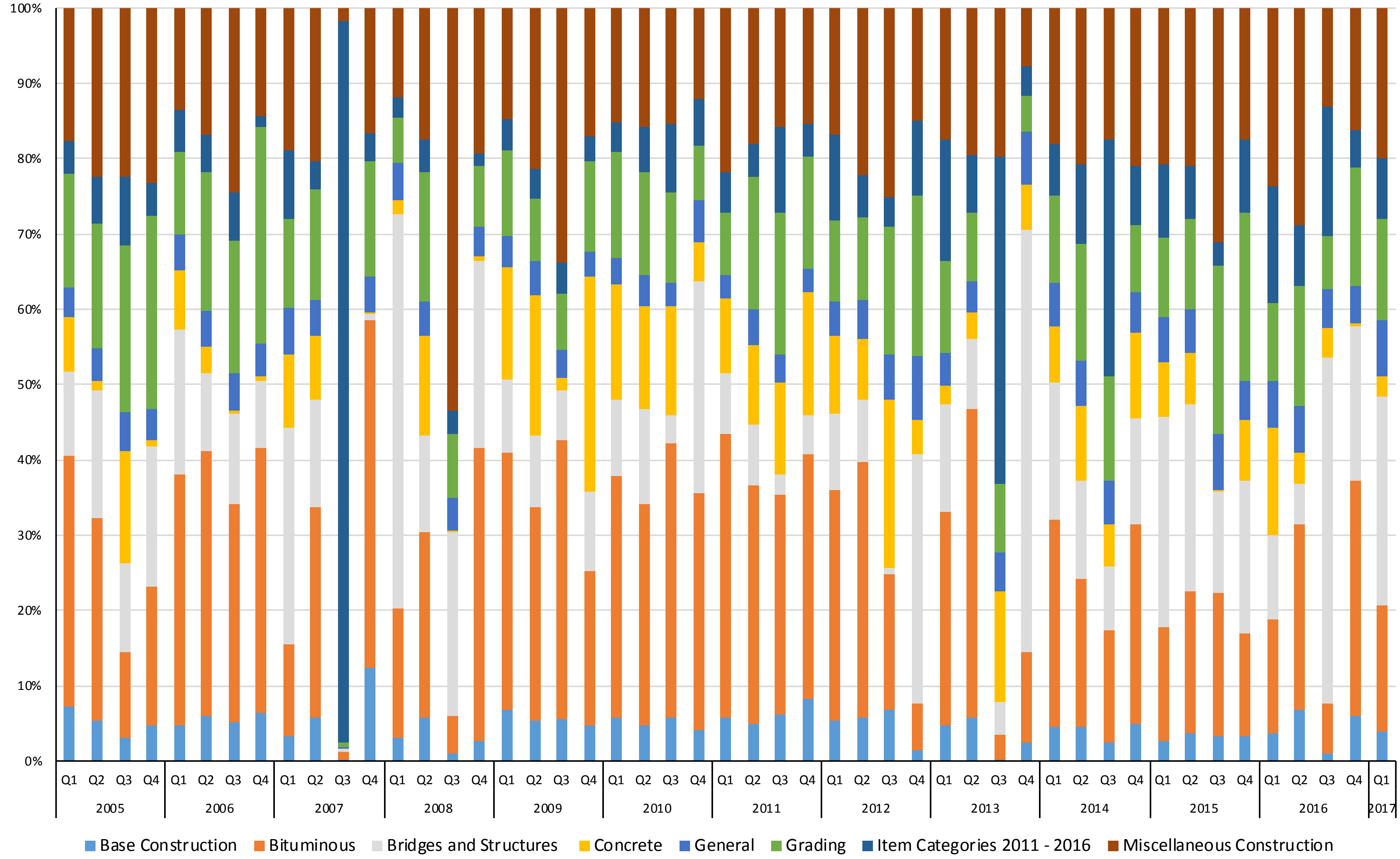

Figure 29: Percent Breakdown of MnDOT Total Awarded Project Costs by Item Category, Quarterly

Appendix L: Data Cleaning Procedure for the National Highway Construction Cost Index

The following procedure is applied to edit and clean the Bid Tabs data used for calculating the NHCCI 2.0.

Data Editing

FHWA's approach attempts to reliably reflect changes in the prices of the underlying goods. To achieve this goal, FHWA implements the following data editing steps:

- **Non-standard pay items** – These are pay items that have the same pay item number but have different pay item descriptions (or units of measure) from project to project or from one period to another. The differences in descriptions are largely due to extra spaces between words, abbreviated words or truncations. For these pay items, the methodology ignores the differences in descriptions and treats the pay items as the same. There are also records having the same description, but different pay item numbers within a state. To address this issue, a crosswalk table is developed to combine pay items having the same description into a single pay item number.
- **Unit of measure problems** – There are some pay items where the unit of measure makes it difficult to track prices changes. Many of these items are lump sum items where the quantity of the item is "1." The prices on these types of items are generally not related to any specific price trend but are more due to many other factors such as project type, duration, location, size, traffic patterns, etc. The procedure excludes these observations from index calculation. However, there are pay items with unit of measure problems because of truncation or abbreviation of unit of measurement in the data. The data editing procedure creates a crosswalk that translates those units into a correct unit so that the observations with those issues are included in index calculation.
- **Suspect categories** – All the pay items in the historical Bid Tabs database are categorized into 31 predefined work categories. Some of these categories relate to aspects of a contract such as start-up costs, incentives, etc. Some of these categories generally relate to groups of pay items that are generally not related to any specific price trend but are more due to the project type, location, size, etc. (just like the unit of measure problems as listed above). These categories are: Uncategorized, Mobilization and Alternates/Bonuses/Time.

Statistical Editing

Statistical edits are used to eliminate pay items that are unlikely to have constant price-determining characteristics with the objective of improving the quality of the data. The statistical edits used for the NHCCI 2.0 data are applied sequentially, and are as follows:

1. An observation must have a lagged observation to mathematically construct the index, so observations that do not have a lagged value will be eliminated from the analysis.

2. A pay item must have at least eight quarters worth of data to be included. This is done to reduce the influence of items that have low statistical validity.

3. Outlier observations, defined as being at least three standard deviations from the mean, are set to the average change in logged price for non-outlier observations for the state in the same period. This threshold represents the 99.73th percentile of pay items, so that only less than 1 percent of all pay items have a value exceeding the cut-off value.

4. Pay items for which the adjusted R-squared is greater than the 95th percentile threshold from a regression of the log change in price on the log change in quantity are eliminated. The procedure calculates distribution of R-squared statistics over the data, and the 95th percentile R-squared value is used as the exclusion threshold. Pay items meeting this criterion represent a break in the price-quantity relationship required by an index. Pay items for which the price is highly related to quantity are likely to be subject to quantity discounts or volume penalties and are therefore eliminated.

5. Pay items for which the maximum-to-minimum observed price ratio of more than the 95th percentile threshold are eliminated. The procedure calculates the distribution of maximum-to-minimum price ratio statistics, and those pay items with a value greater than the 95th percentile value are excluded. Prices of a single constant-quality highway construction good or service rarely change by very large amounts in the Bid Tabs data.

6. Pay items for which the coefficient of variation of 100 times the log change in price is greater the 95th percentile threshold are eliminated. The coefficient of variation is the standard deviation divided by the absolute value of the mean. The procedure calculates distribution of coefficient of variation statistics, and those pay items with a value greater than the 95th percentile value are excluded. Using the log change in price to control for trends makes the standard deviation ill-defined. Dividing by the mean of the log-change in price because the coefficient of variation is used rather than the standard deviation itself is used. Prices that have a high average change are also likely to have a higher standard deviation (the standard deviation is used directly in cases where the absolute value of the mean is less than one). The justification for this edit is that pay items having prices that are extremely variable are unlikely to represent goods/services with constant price-determining factors.

Appendix M: Minnesota Cost Index Notes

Eliminate all projects under $100,000.
Do not include Design Build Projects or Negotiated Contract projects.

I. **EXCAVATION**
   A. Combined quantities must be over 25,000 C.Y. (19,114 m3).
   B. Quantities used*:
      1. Common Excavation & Excavation - Common (CV)
      2. Subgrade Excavation & Excavation - Subgrade (CV)
      3. Common Borrow (No other borrow) & Common Embankment (CV)
         a. Excavated Volume (EV) – Face Value
         b. Loose Volume (LV) – divide by 1.1
         c. Compacted Volume (CV) – multiply by 1.35
   C. Price:
      1. All of the above.

   *Note: When the items for Excavation - Common & Embankment - Common are both used together: If the excavation quantity is higher than the embankment quantity use only the excavation quantity but the cost for both. And when the embankment quantity is higher than the excavation quantity use only the embankment quantity but the cost for both.

II. **REINFORCING STEEL** (convert kg to lbs)
   A. Quantities used:
      1. Rebar paving
      2. Bridges
      3. Poured Box Culverts
      4. Spiral rebars
      5. Epoxy rebars
   B. Price:
      1. All of the above

III. **STRUCTURAL STEEL** (convert kg to lbs)
   A. Quantities used:
      1. From bridges only (Not on overhead signs)
   B. Price:
      1. Figured on Structural Steel

      occasionally jobs are let in two contracts: 1) furnish steel and 2) erecting structural metals. Combine those two costs.

IV. **STRUCTURAL CONCRETE**
   A. Quantities used (in C.Y.):
      1. Concrete used in bridges / poured box culverts (NOT pre-cast)
         a. Include conc. in deck slabs
         b. Include conc. in wear courses
         c. Include conc. in railings, sidewalks, median barrier.
      2. Concrete used in retaining walls
      3. Special mixes:
         a. Include low slump for bridge deck repair.
   B. Price:
      1. All of the above.

2. Wear Course Finish
3. Special Surface Finish (Architectural and color treatment, anti-graffiti Coating)
4. Bush hammering
5. Reverse Batten Surface treatment

V. **BITUMINOUS**

A. Combined quantities must be over 5,000 tons. (4536 Metric tons)

B. Quantities used: (if necessary, convert S.Y. to Tons)
1. Wearing Course
2. Non Wearing Course
3. Tight Blade Leveling
4. Do not use Bit. Patch Material

C. Price:
1. Figured on all of the above.
2. Bituminous material for mixture
3. Tack, Shoulder Tack, and Fog Seal (not seal coat)
4. Include Bituminous Removal on recycle jobs
5. Do not use Bituminous Mixture Production (FOB)

VI. **CONCRETE PAVEMENT**

A. Combined quantities must be over 1,000 C.Y. (765 m3)

B. Quantities used. (no rehab. type work)
1. Structural Concrete (includes H.E.)

C. Price:
1. Figured on Structural Concrete (includes H.E.)
2. S.Y. Price of pavement (Regular & Irregular widths)
3. Cost of joints (Except E8S or other specials, - just expansion joints)
4. Do not include cost of mesh or dowel bars.
5. Conc. Removal on Recycle jobs.

Updated Feb. 04, 2009