Michigan Transportation Construction Price Index

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REPORT ON DEVELOPMENT OF
MICHIGAN HIGHWAY CONSTRUCTION COST INDEX

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16. Abstract
A highway construction cost index (HCCI) measures the price changes over time in the highway construction industry. It allows Departments of Transportation (DOTs) to monitor highway construction market conditions so that they can more accurately project long-term funding needs. Michigan has not yet established a methodology for HCCI calculation or calculated historical index values. Hence, the primary goal of this research is to develop a state-level HCCI and historical trend index values for Michigan based on available bid data and establish a framework for their maintenance and use. A three-step methodology for Michigan highway construction cost index (MHCCI) calculation is proposed that encompasses (1) data cleaning, where inconsistent bid items, primarily caused by changes in specification books, are cleaned; (2) bid item sampling, which helps to ensure the reliability of the HCCI as an indicator of changing construction market conditions by statistically selecting the bid items suitable for calculation purposes; and (3) HCCI calculation, where the chained Fisher index formula is applied. Accordingly, the MHCCI at the state level, as well as indices for specific regions and item categories as defined by MDOT, are calculated. (These MHCCI and sub-MHCCIs provide further insights into Michigan's construction market conditions. For example, spikes in quarterly MHCCI correspond to higher costs for hot mix asphalt (HMA) pavement, earthwork, bases, and drainage features.) Moreover, the MHCCI is projected for the next five years, and a general discussion of the impacts of labor trends and economic factors such as unemployment on highway construction costs is provided. Finally, recommendations are provided to local units of government for their consideration as they endeavor to index and measure their highway construction costs.

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TABLE OF CONTENTS

List of Figures

List of Tables

EXECUTIVE SUMMARY

Purpose and Scope of Report

The report documents the methodology for calculating the Michigan Highway Construction Cost Indexes (MHCCIs) based on bid items for the period from the second quarter of the 2010 fiscal year to the first quarter of the 2020 fiscal year. With the methodology, the MHCCIs are calculated quarterly and annually at both the statewide and region levels (as defined by the Michigan Department of Transportation) using selected bid items. In addition, ten bid item categories are defined and used to calculate the sub-indices both quarterly and annually.

The report also provides a comparison of the calculated MHCCIs and the Federal Highway Administration's recent NHCCI 2.0, the HCCI of peer states, as well as the major construction material Producer Price Indices (PPIs). Further, forecasting of the MHCCI based on normal economic conditions for the next five years is presented in the report. The current pandemic and economic recession are not considered in the prediction. However, the report discusses the impacts of labor trends and economic factors such as unemployment on highway construction costs and the HCCI. Lastly, recommendations are provided to local units of government for measuring and indexing their highway construction costs.

MHCCI Development

The methodology for calculating historical MHCCI was developed through an extensive investigation of the current best practices of peer states and of the FHWA. As shown in Figure 1, the MHCCI development consists of three main steps: (1) data cleaning, (2) bid item selection, and (3) index calculation.

The purpose of data cleaning was to remove lump-sum items and non-standard items and address any inconsistent items. Lump-sum items were excluded because their price change over time is generally caused by such factors as project type, duration, location, and size, rather than any specific price trend (Jeong, et al., 2017). Non-standard items were also excluded, as these are special work items for particular projects awarded on an infrequent and irregular basis (MDOT, 2020). "Inconsistent item", it should be noted, refers to bid items whose item number, description, and/or unit are inconsistent across different Michigan Department of Transportation (MDOT) pay item code books throughout the analysis period. Specifically, MDOT projects from

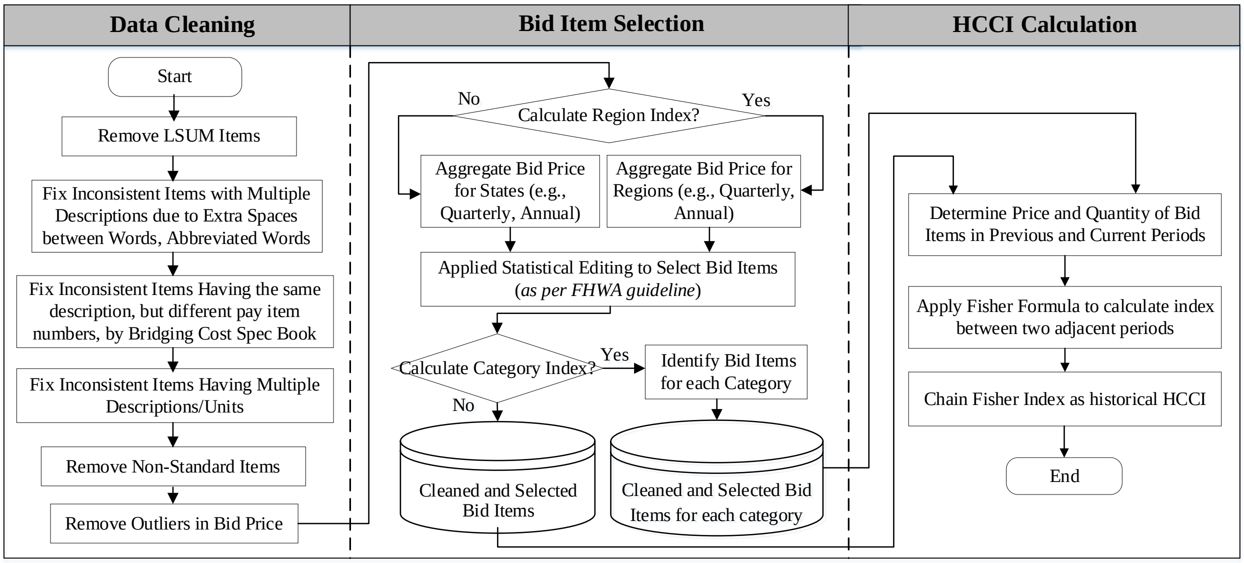


Figure 1. Methodology underlying Michigan HCCI development

2010 to 2012 used the 2003 edition of MDOT's pay item code book, while the projects from 2012 to 2019 used the 2012 pay item code book. To address inconsistencies in bid items, a map was developed linking the bid items across different pay item code books. In addition, data outliers in the unit price of bid items were identified and removed in this step.

Following data cleaning, the second step was to select bid items for the HCCI calculation, as shown in Figure 1. Two criteria were used in the bid item selection: (1) aggregation level of HCCI to be calculated, such as state, region, and category; and (2) the six steps of statistical editing used by the FHWA. The statistical editing is to remove bid items that are subject to quantity discounts and have extreme price fluctuations and price changes by large increments. It should be noted that statistical editing was applied to aggregate prices of bid items, i.e., the unit prices of bid items were aggregated to obtain quantity-weighted quarterly and annual unit prices for states and regions prior to the statistical editing.

In the third and final step, the chained Fisher index formula was used to calculate the MHCCI based on the cleaned and selected bid items as described above. It should be noted that HCCI was calculated using unit prices and quantities of bid items. Unit prices of bid items include the cost of labor, equipment, materials, overhead, and the profit margin included in estimates from contractors. The Fisher Index was selected for calculation because it provides an accurate estimation of the theoretical index (FHWA, 2014). In addition, it is widely used for this purpose among many other states and is also the formula of choice of the FHWA for applications of this nature. Given the available cost data and the proposed methodology, quarterly and annual MHCCIs were calculated for the period, January, 2010, to December, 2019 and tabulated in Table 1 and Table 2.

Table 1. Quarterly MHCCI, base 2010 Q2

Year	FISCAL QUARTER	MHCCI	Year	FISCAL QUARTER	MHCCI
2010	Q2	1.0000	2015	Q2	1.1074
	Q3	0.9847		Q3	1.1543
	Q4	0.9894		Q4	1.2843
2011	Q1	1.0046	2016	Q1	1.1359
	Q2	0.9740		Q2	1.1428
	Q3	1.0630		Q3	1.1791
	Q4	1.0819		Q4	1.2197
2012	Q1	1.0478	2017	Q1	1.0901
	Q2	1.0444		Q2	1.0790
	Q3	1.0695		Q3	1.0749
	Q4	1.0213		Q4	1.2304
2013	Q1	1.0522	2018	Q1	1.1861
	Q2	1.0531		Q2	1.2076
	Q3	1.0961		Q3	1.3510
	Q4	1.0906		Q4	1.3812
2014	Q1	1.0571	2019	Q1	1.3352
	Q2	1.0797		Q2	1.3227
	Q3	1.0944		Q3	1.4672
	Q4	1.2051		Q4	1.4851
2015	Q1	1.1624	2020	Q1	1.4956

Table 2. Annual MHCCI, base year 2010

CALENDAR YEAR	MHCCI
2010	1.0000
2011	1.0248
2012	1.0734
2013	1.0938
2014	1.1995
2015	1.2239
2016	1.2572
2017	1.2691
2018	1.3567
2019	1.4540

Comparison of MHCCI and Other Indices

The calculated MHCCI was compared with the National Highway Construction Cost Index (NHCCI) 2.0 and peer states' HCCI, as well as major material PPIs, through two approaches: (1) index trend visualization and (2) a statistical method, i.e., the Pearson correlation coefficient. For example, Figure 2 shows the HCCI trends for Michigan, the FHWA (i.e., NHCCI 2.0), and the average of selected peer states (Ohio, Iowa, and Wisconsin). Figure 3, meanwhile, presents the comparison of MHCCI with construction material PPI. It can be seen that the quarterly MHCCI exhibits a similar trend with other indices over the period under study.

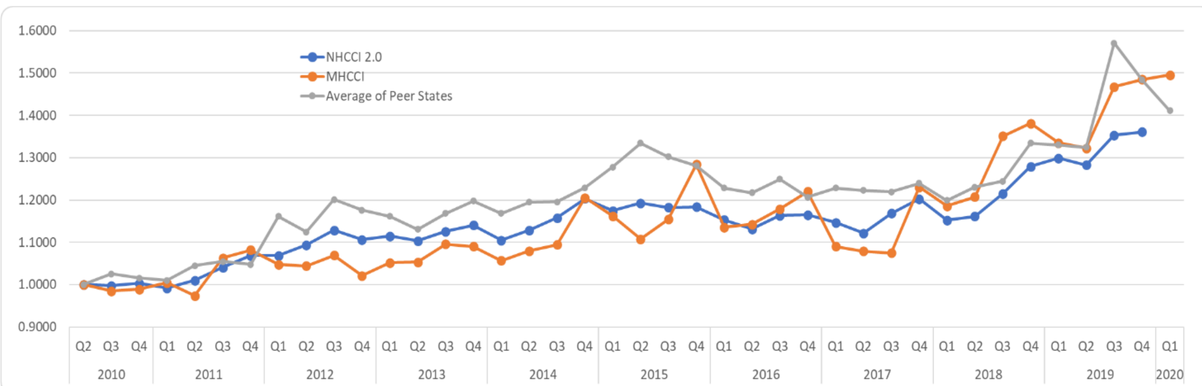


Figure 2. Comparing quarterly HCCI: Michigan, peer states, and FHWA, base 2010 Q2

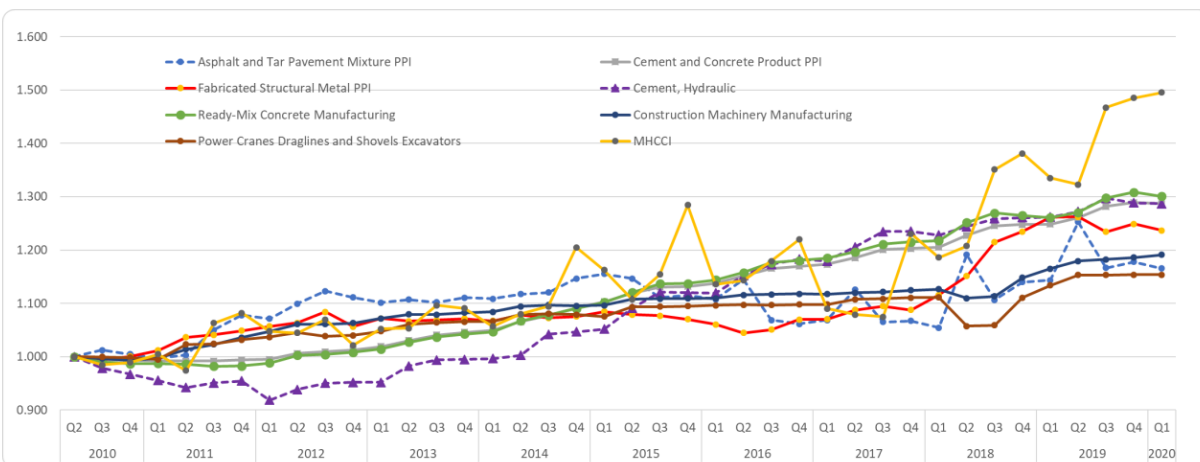


Figure 3. Comparing quarterly MHCCI with construction material PPIs, base 2010 Q2

The Pearson correlation coefficient is a variable ranging from 0 to 1, with higher values indicating a stronger linear relationship. In the context of price index, a higher value is indicative of a higher degree of similarity in market conditions and changes in market conditions between the states under comparison for a given period of time. The statistical comparison results between MHCCI and other indices are summarized below.

1. The quarterly MHCCI shows a strong positive correlation with the NHCCI 2.0 (0.92) and the peer states of Ohio (0.79), Iowa (0.76), and Wisconsin (0.88). Similarly, the annual MHCCI shows a strong positive correlation with the NHCCI 2.0 (0.93) and with peer states such as Iowa (0.77) and Washington (0.9). The coefficients indicate that Michigan's HCCI trend is very similar to that of the FHWA's NHCCI, as well as to those of peer states Washington, Wisconsin, Ohio, and Iowa.
2. The annual HCCI trend of North Dakota is following the annual MHCCI with a time lag of one year, while Utah's and Minnesota's annual HCCI trends are following the annual MHCCI with a two-year lag. Statistically, this observation suggests that the effect of regional construction market conditions may be first observed in Michigan, Iowa, and Washington, among the peer states, followed by North Dakota, and, finally, Utah and Minnesota. However, the HCCIs of other peer states are calculated using different methods, and hence these inferences should be made with caution.
3. Quarterly MHCCI is also highly correlated with the PPIs of other materials, having positive Pearson correlation coefficients with the asphalt and tar pavement mixture PPI (0.61), the cement and concrete product PPI (0.87), the fabricated structural metal PPI (0.89), the ready-mix concrete manufacturing PPI (0.86), and the construction machinery manufacturing PPI (0.85). However, the correlation coefficient between MHCCI and asphalt and tar pavement mixture PPI was also found to increase from 0.61 to 0.73 when a two-quarter lag was applied to the MHCCI. From this finding, it can be inferred that the quarterly MHCCI is following the asphalt and tar pavement mixture PPI with a two-quarter lag. Moreover, both the MHCCI and the asphalt and tar pavement mixture PPI saw similar spikes during the period under study.
4. The spikes in 2014 Q4, 2015 Q4, 2017 Q4, 2018 Q3, and 2019 Q3 in the quarterly MHCCI are primarily attributable to higher costs for hot mix asphalt (HMA) pavement, earthwork, bases, and drainage features. As shown in Figure 4, the percentage changes in the category-level MHCCI for HMA pavement, earthwork, bases, and drainage features are, in general, greater than those of the state-level MHCCI for these quarters. In particular, earthwork is driving up the state index, as its category index and index percentage change are much higher

than those of the state overall. HMA pavement is largely governing the MHCCI trend, as it constitutes the highest share of the awarded amount. HMA pavement accounts for 42.4% of the total construction cost of selected bid items for the period, 2010 to 2019, while earthwork and bases account for 8.9% and 6.2%, respectively. It should be noted that HCCI is aggregated based on bid items, rather than labor items, material items, and so forth. Major bid items contributing to the index spikes are identified and summarized in Appendix B of the report.

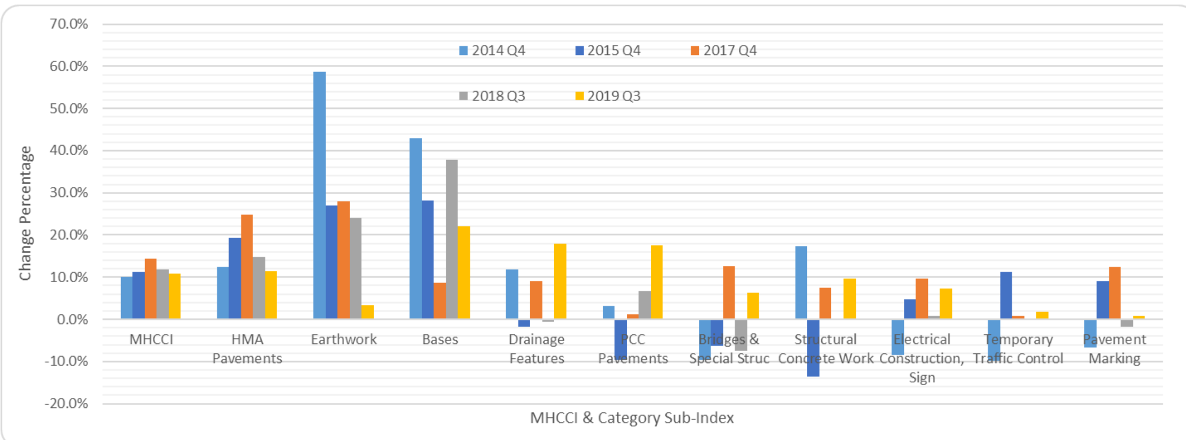


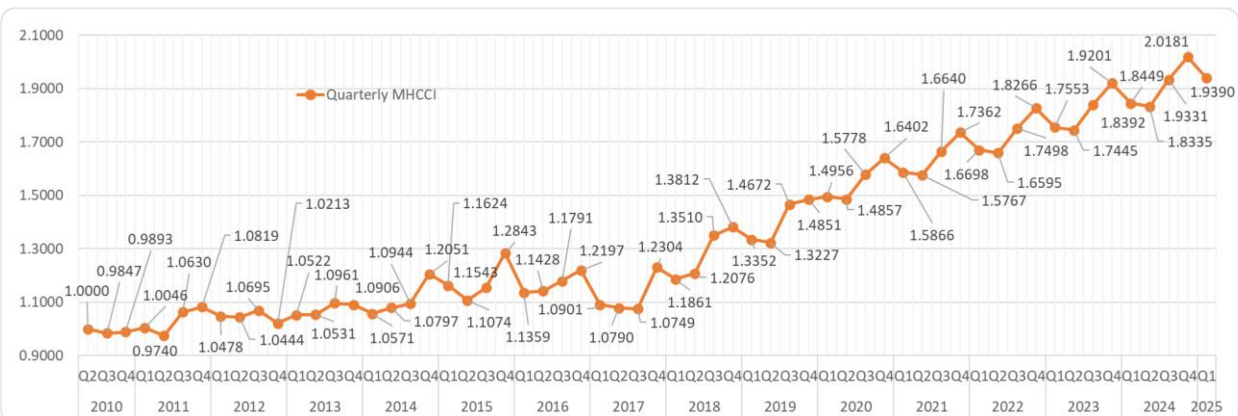
Figure 4. Percentage changes in overall MHCCI and in category sub-indices by quarter showing spikes during the period under study

5. Compared with other MDOT regions and with the state as a whole, the University region has a higher annual index value for the period under study. In contrast, the Metro region index is higher than the state index in eight out of ten years analyzed. Furthermore, the Metro and University regions account for 28.1% and 15.9 %, respectively, of the total construction cost for the period under study. From this observation it can be inferred that the Metro and University regions have an upward impact on the state index.

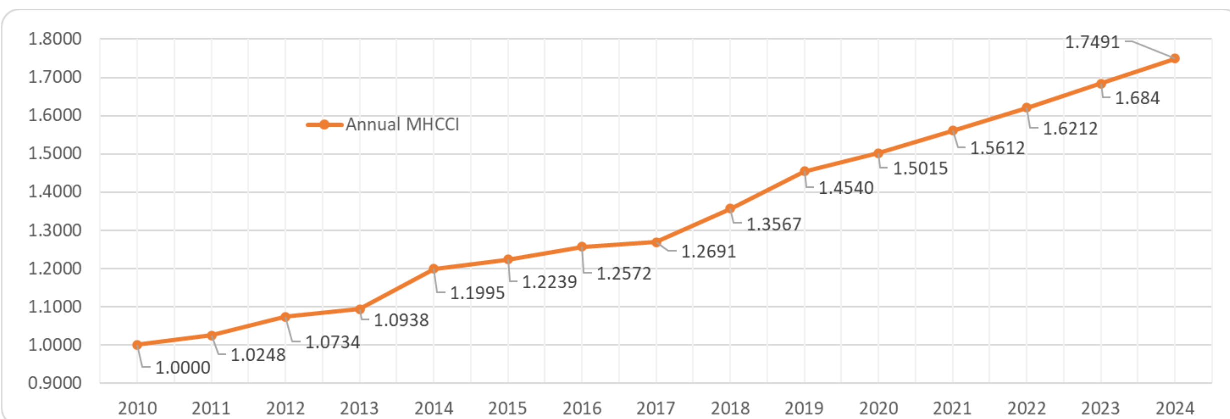
MHCCI Forecast

Time-series analysis has been recognized for its ability in providing accurate HCCI forecasts. It employs a statistical model designed to predict future values solely based on previously observed values (Hamilton, 1994). In particular, time-series models such as the autoregressive integrated moving average model (ARIMA) and Seasonal ARIMA could forecast the HCCI with reasonable accuracy (Ashuri and Lu, 2010). Therefore, the ARIMA model and the Seasonal

ARIMA model were thus employed in the present research to predict the HCCI for the next five years. The calculated historical MHCCI values, i.e., 40 quarterly index values and ten annual index values, were used to train and test the time series models with the 80/20 rule, respectively. The statistical results showed the ARIMA model with parameters of (2, 0, 2) could predict the annual MHCCI with higher accuracy, while the Seasonal ARIMA (0, 0, 0) (1, 1, 1)4 model performed better than ARIMA in the quarterly MHCCI forecast. The MHCCI values are then predicted by these two trained models and are summarized in Table 3 and Table 4. Based on this analysis, the quarterly MHCCI can be expected to increase to 1.9390 in the first quarter of the 2025 fiscal year, whereas annual MHCCI is forecast to be 1.7491 for the 2024 calendar year (as shown in Figure 5). The prediction results imply that the average annual prices of highway construction bid items in the 2024 calendar year are anticipated to increase by 74.91% in comparison with the average prices in the 2010 calendar year.



(a) Quarterly MHCCI



(b) Annual MHCCI

Figure 5. MHCCI forecast

In addition, the predicted index values were transformed to year-over-year percentage changes. During the period, 2020-2024, the year-over-year percentage changes in annual MHCCI (i.e., annual inflation rates) were found to be 3.26%, 3.98%, 3.84%, 3.87%, and 3.87%, respectively. The percentage changes average at 3.76%, indicating unit prices are anticipated to have an annual increase of 3.76% for the next five years. However, with the ongoing pandemic and economic recession, which are not considered in the model, those forecasts should be considered with high caution.

Table 3. Quarterly MHCCI prediction for the next five years

Fiscal Year	Quarter	Quarterly MHCCI
2020	Q2	1.4857
	Q3	1.5778
	Q4	1.6402
2021	Q1	1.5866
	Q2	1.5767
	Q3	1.6640
	Q4	1.7362
2022	Q1	1.6698
	Q2	1.6595
	Q3	1.7498
	Q4	1.8266
2023	Q1	1.7553
	Q2	1.7445
	Q3	1.8392
	Q4	1.9201
2024	Q1	1.8449
	Q2	1.8335
	Q3	1.9331
	Q4	2.0181
2025	Q1	1.9390

Table 4. Annual MHCCI prediction for the next five years

Calendar Year	Annual MHCCI
2020	1.5015
2021	1.5612
2022	1.6212
2023	1.6840
2024	1.7491

Labor Trends and Economic Factors

Michigan highway construction labor index values were calculated based on available labor data from the first quarter of the 2015 fiscal year to the third quarter of 2019 fiscal year. The labor index was found to have a positive Pearson correlation coefficient of 0.73 with the MHCCI, indicating a high correlation. The MHCCI value was found to be higher than the labor index in fifteen out of the nineteen quarters—a finding which leads to the conclusion that labor cost is not a significant driver for MHCCI.

The COVID-19 pandemic has already wreaked havoc on the national and Michigan economies, and the full extent of the damage brought by this pandemic remains to be seen. The impact of this epidemic on highway construction labor cost will be reflected in resulting changes in labor demand and supply. Extensive layoffs and unemployed workers available and eager to work will increase labor supply, while labor demand will decrease under the depressed economic conditions. Given these conditions, wages in general are likely to fall, but it is not clear whether wages of highway construction workers will follow the general trend, and this will be largely dependent on the level of post-pandemic spending on infrastructure in Michigan. Considering the increasing labor supply during an economic downturn, it is likely that highway construction labor costs may decrease. However, the material cost may undergo a spike during this unfolding economic recession, as indicated by the trend of the asphalt and tar pavement mixture PPI during the 2008 recession.

Recommendations to Local Units of Government

After investigating best practice for HCCI calculation and implementing this practice in the development of the MHCCI, the report provides a few suggestions to local units of government for measuring and indexing their highway construction costs. The recommendations are summarized as follows:

1. *Data Storage:* It is suggested that local units of government, including County Road Commissions, cities, transit agencies, etc., develop a structured database for bid items so that data can be readily retrieved for HCCI calculation purposes.
2. *Bid Item Sampling:* Ideally, the statistical editing method used by the FHWA would be applied to the selection of bid items. More practically, local units can identify major bid

items based on the project characteristics and use those identified bid items in the calculation. This method of manual bid item selection is more straightforward and is still being used by many other states.

3. *Base Year:* It is recommended that 2010 be used as the base year for the HCCI calculation so that the calculated index is directly comparable with the MHCCI.
4. *Index Formula:* A chained Fisher index formula should be used in the calculation, as weights of bid items in the Fisher index are constantly updated over time, and it represents the current best practice.
5. *Frequency:* HCCIs for local units of government should be calculated and published on an annual basis. This is because local units have a lower volume of projects and may not even award construction projects for some quarters, which makes quarterly HCCI calculations practically impossible.
6. *Benchmarking*: It is also recommended to local units of government to benchmark and closely monitor the MHCCI, especially the Michigan region sub-index.

1. INTRODUCTION

1.1 Background and Objectives

Over the years and most recently when assessing the funding of an augmented program, the Michigan Department of Transportation (MDOT) has been tasked with projecting construction costs based on historical highway construction cost indices. The Highway Construction Cost Index (HCCI), it should be noted, is an indicator of cost fluctuations in highway construction market conditions (Jeong et al., 2017). As early as 1987, the Federal Highway Administration (FHWA) started to develop a National Highway Construction Cost Index (NHCCI) based on six major bid items. However, NHCCI does not reflect the actual market conditions of individual states because the data used in the NHCCI calculation is provided by multiple states. For this reason, a number of states (such as Iowa, Ohio, etc.) have developed their own state-level HCCI in order to better manage the funding of an augmented program. In the absence of a state-level HCCI in Michigan, Senate Bill no. 515 was introduced in 2019 requiring MDOT to establish a state-level cost index by May 1, 2020, and to subsequently provide quarterly updates to the house and senate transportation appropriations sub-committee. In this context, the aim of the research presented in this report was to develop the Michigan state HCCI and historical trend index for Michigan that would span the period 2010 to the present. This would allow MDOT to use HCCI to project future funding needs, develop more accurate construction cost estimates, and identify the root causes of trends in cost estimation.

2. DEVELOPMENT OF HISTORICAL MICHIGAN HCCI (MHCCI)

With the objective of developing a historical trend index for Michigan, a three-step methodology, as illustrated in Figure 1, was proposed: (1) data cleaning, (2) bid item sampling, and (3) HCCI calculation. The methodology was developed through an extensive investigation of current best practices in peer states and in the FHWA. The methodology developed addresses the major limitations of the calculation methods used by other states, such as low coverage of bid items, exclusion of inconsistent items, and lack of sub-index. For example, a pay item code book map was developed to account for inconsistent items in the MHCCI calculation during the data cleaning stage. A larger amount of bid items can be selected by implementing the six-step statistical editing used by the FHWA. In the methodology developed, the chained Fisher formula is employed to calculate the quarterly and annual indices with the base year of 2010. Table 5 compares the various HCCI development methods used by the FHWA and peer states. It should be noted that “Partially” in Table 5 denotes certain data is not cleaned and used for HCCI calculation. For example, differences in item descriptions due to substantive changes in item definitions are not addressed by peer states. The items with such inconsistent descriptions are not included in calculating the index value.

Table 5. Summary of DOT HCCI

States/Agency	**HCCI Development**				
	Data Cleaning (e.g., pay item code book)	Bid Item Sampling	Base year/quarter	Interval	Index Formula
Michigan	**Fully**	**Statistical**	**2010**	**Quarterly/ Annually**	**CF**
FHWA (NHCCI 2.0)	Partially	Statistical	2003	Quarterly	CF
Montana	Partially	Manual	2010	Annually	CF
Washington	Partially	Manual	1990	Quarterly	CF
Minnesota	Partially	Manual	1987	Quarterly	L
Wisconsin	Partially	Manual	2010	Quarterly	CF
Iowa	Partially	Manual	1987	Quarterly/ Annually	L
Ohio	Partially	Manual	2012 Q1	Quarterly	CF
Utah	Partially	Manual	2003	Quarterly/ Annually	ML

Note: CF stands for Chained Fisher; ML is Modified Laspeyres, L represents Laspeyres, and Y is Young.

2.1 Data Cleaning

MDOT provided bid item data for its design–bid–build construction projects for the period from the second quarter of the 2010 fiscal year to the first quarter of the 2020 fiscal year, where the bid dataset contains the data attributes required to calculate the MHCCI and sub-HCCIs. Typical attributes include item quantity, bid price, unit, item description, pay item code book spec year, and so forth. (The complete list of data attributes for MHCCI development is presented in Table A-1 in Appendix A.) This section presents the analyses and data cleaning of the available bid dataset.

To begin with, lump-sum items were removed in the data because their price change over time is generally caused by such factors as project type, duration, location, and size, rather than any specific price trend (Jeong et al., 2017). Non-standard items are special work items for particular projects and have low statistical validity, such that they were also eliminated. Apart from this, bid items were limited to the ones from the first low bid in the bid dataset.

As mentioned above, one of the major challenges in HCCI development is data cleaning, especially for inconsistent items. In particular, different MDOT pay item code books (i.e., the 2003 and 2012 editions) were used across the analysis period, resulting in inconsistency in item numbers, descriptions, and/or units. Table 6 shows one example of a bid item (item No. 2080020) whose description and unit are inconsistent in two pay item code books. To address this issue, the research team reviewed the 2003 and 2012 editions of MDOT pay item code book and identified three types of inconsistencies: (1) differences in descriptions, (2) differences in units, and (3) differences in item numbers.

Table 6. Examples of items having multiple units and descriptions

LETTING DATE	ITEM	DESCRIPTION	ITEM QUANTITY	UNIT	BID PRICE
2012-01-06	2080020	Erosion Control, Inlet Protection, Fabric Drop	105	Ea	65.23
2012-02-03	2080020	Erosion Control, Sediment Basin	20	Cyd	17

Furthermore, some discrepancies in descriptions between the editions (as shown in Table 7) are the result of typographical errors and differences such as extra spaces between words, the presence/absence of a comma between words, and use of abbreviations versus full terms. The research team addressed this issue by updating the descriptions in cases where there were two different descriptions of the same item. In contrast, other differences in descriptions, as well as differences in units as shown in Table 6, were due to substantive changes in item definition. Accordingly, these bid items were treated as different items, and temporary item numbers were assigned to the bid items for HCCI calculation purposes. Finally, some items with different item numbers shared the same description, as shown in Table 8. For these cases, the research team developed a map table to combine bid items having the same description under a single item number.

Table 7. Examples of inconsistent descriptions due to differences in spacing, punctuation, and abbreviation use

ITEM	DESCRIPTION	replace by
2010002	Clearing, Fence	Clearing for Fence
2020003	Tree, Rem, 37 inch or larger	Tree, Rem, 37 inch or Larger
2020007	Stump, Rem, 37 inch or larger	Stump, Rem, 37 inch or Larger
2030005	Culv, End, Rem, Less than 24 inch	Culv End, Rem, Less than 24 inch
8200384	Video Traf Detection Camera, Rem	Video Traffic Detection Camera, Rem
8210005	Monument Box, Adj	Monument Box Adjust

Table 8 Examples of inconsistent item numbers in different pay item code books

DESCRIPTION	BOOK 2003	BOOK 2012
Curb, Rem	2040005	2040021
Curb and Gutter, Rem	2040006	2040020
Gutter, Rem	2040007	2040040
Guardrail, Rem	2040008	2040035
Culv, Other Than Pipe, Rem	2040025	
Utility Pole, Rem	2040030	2040070
Asbestos Materials, Removal and Disposal	2040035	2040001
Impact Attenuator, Rem & Disposal	2040040	
Erosion Control, Inlet Protection, Fabric Drop	2080006	2080020

2.1.1 Outlier Removal

On this basis, the research team performed various statistical analyses to eliminate the outliers in unit prices of each bid item, i.e., bid price in the dataset. ***Outlier detection techniques,*** including standard deviation, Inter-Quartile Range (IQR) method, and extraordinary price ratio, were applied sequentially in order to eliminate any specific bid prices for a given bid item that met the following criteria:

1) bid price is at least three standard deviations from the mean
2) bid price is greater than 1.5 times the interquartile range
3) bid price's ratio (i.e., its price over the average price of the item) is greater than 30

Figure 6 illustrates the outlier removal process for bid item '*5010052, HMA, 4E10'*. Statistically, the bid price of *HMA, 4E10* should fall within the range from $21.67 per Ton to $130.21 per Ton, where any bid price that is not within the range is identified as an outlier (marked as orange in Figure 6) and is eliminated from the dataset.

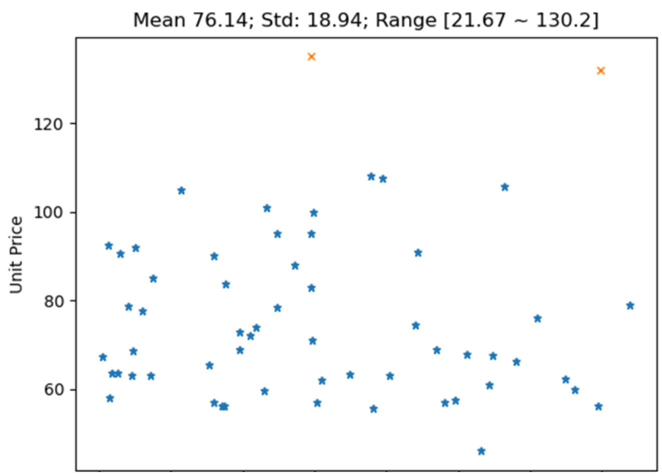


Figure 6. Outlier removal for HMA, 4E10

2.2 Item Sampling

The coverage of bid items in the HCCI calculation is of particular importance in ensuring the reliability of the HCCI as an indicator of changing market conditions. For this reason, the research team reviewed related work conducted by other state DOTs and by the FHWA. The six-step statistical editing from FHWA was identified as the best practice (HDR, 2018; Joseph, et al., 2016). They are applied sequentially to select and edit bid items for the MHCCI calculation, summarized as follows:

1) A bid item must have a lagged observation, i.e., bid prices for two adjacent periods, which is required by the price index formula. Consequently, bid items that do not have a lagged value are excluded from the calculation.

2) A bid item must have the bid price for at least eight quarters for the period under study. The justification for this edit is that the influence of bid items that are awarded on an infrequent basis should be reduced.
3) Outliers of aggregated bid prices are adjusted using the average change in logged price for non-outlier observations in the same period. That is, the average change in logged price for non-outlier observations (i.e., non-outlier bid items) in the same period is first calculated; then, the average changes are used to determine the bid price of outlier bid items.
4) Any bid item whose adjusted R-squared value is greater than the 95th percentile of the distribution of adjusted R-squared statistics is eliminated. Notably, adjusted R-squared is calculated as "*the regression of the log change in bid price on the log change in item quantity*" (HDR, 2018). This edit eliminates bid items that are likely to be subject to quantity discounts or volume penalties. In this step, the distribution of adjusted R-squared for all bid items is first calculated; then, the 95th percentile of R-squared values is used as the exclusion threshold. Figure 7 shows the bid price against item quantity for *Pavt Mrkg, Sprayable Thermopl, 6 inch, Yellow*, which was removed in this edit.

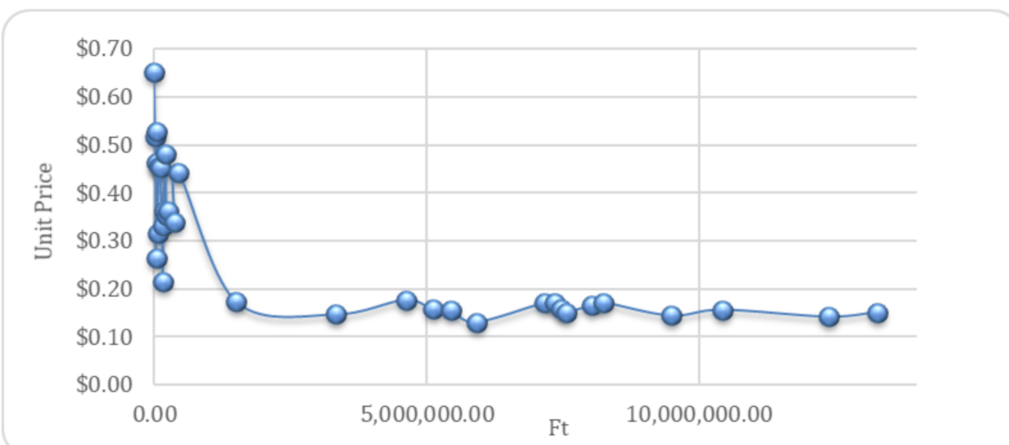


Figure 7. Items having quantity discounts or volume penalties

5) Any bid item whose maximum-to-minimum price ratio is greater than the 95th percentile of the distribution of price ratios is excluded. The reason for this edit is that "*prices of a single constant-quality highway construction good or service rarely change by large increments*" (HDR, 2018). In this edit, the distribution of maximum-to-minimum price ratio for all bid items is calculated, and the bid items with a value greater than the 95th percentile value are eliminated.

6) Any bid item whose coefficient of variation of 100 times the log change in price is greater the 95th percentile threshold is eliminated. The reason for this edit is that "*bid items having extremely variable prices are unlikely to represent goods/services with constant price-determining factors*" (HDR, 2018). This step calculates the distribution of coefficient of variation statistics of all bid items, and those bid items with a value greater than the 95th percentile value are eliminated.

It is worth noting that statistical editing was applied to aggregated prices of bid items. That is, the unit prices of bid items were aggregated to obtain quantity-weighted quarterly and annual unit prices for the state and regions prior to carrying out the statistical editing. Through this statistical editing, a larger amount of bid items were selected for the HCCI calculation, compared with traditional manual selection. Figure 8 presents the number of bid items selected for calculating the quarterly MHCCI. On average, there were approximately 500 bid items selected per quarter, accounting for more than 50% of the total awarded amount in each quarter. A total of 1,274 bid items were selected for quarterly HCCI calculation for the period, 2010 to 2019.

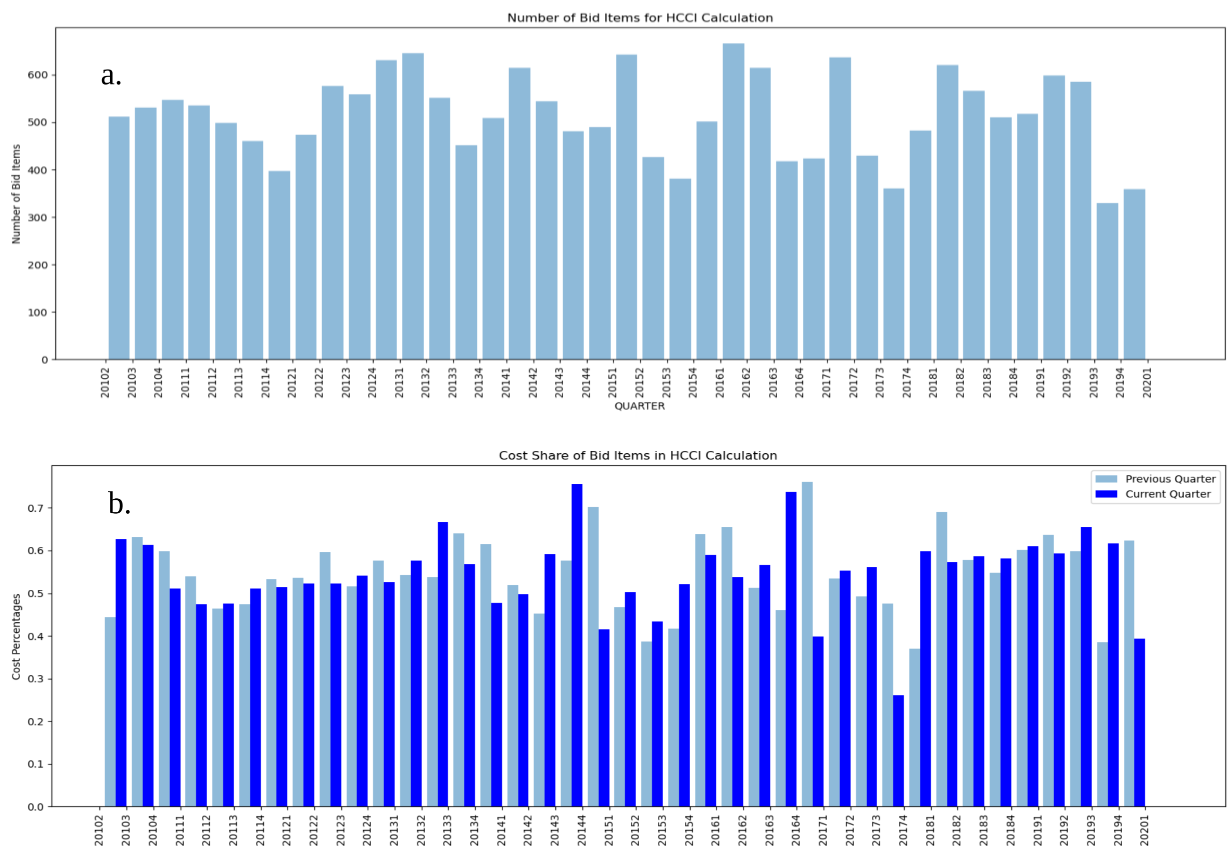


Figure 8. Bid items appearing in two adjacent quarters: a. number; b. cost percentage

2.3 Index Formula Selection

There are three widely used formulas for HCCI calculation: (1) the Laspeyres price index (see Eq. [1]); (2) the Paasche price index (see Eq. [2]); and (3) the Fisher price index (see Eq. [3]) (FHWA, 2017). All three are aggregate price indices, as bid items for highway projects, are measured in different units, and as such they are not directly comparable and not additive. Given this, these price indices are calculated using quantities (i.e., q) of individual cost items as weights to their respective unit prices (i.e., p) in the calculation. It should be noted that unit prices of bid items include the cost of labor, equipment, materials, overhead, and profit estimated by contractors to complete the work outlined for bid items. Specifically, the Laspeyres price index, expressed in Eq. (1), is calculated using quantities of the base period (0) as weights, while the Paasche price index in Eq. (2) is computed using quantities of the current period (t) as weights. The Fisher price index in Eq. (3), meanwhile, is the geometric mean of the Laspeyres price index and the Paasche price index.

$$L(p,q) = \frac{\sum_{j=1}^{N} p_{j,t} \times q_{j,0}}{\sum_{j=1}^{N} p_{j,0} \times q_{j,0}} \qquad \text{Eq. (1)}$$

$$P(p,q) = \frac{\sum_{j=1}^{N} p_{j,t} \times q_{j,t}}{\sum_{j=1}^{N} p_{j,0} \times q_{j,t}} \qquad \text{Eq. (2)}$$

$$F(p,q) = \sqrt{\frac{\sum_{j=1}^{N} p_{j,t} \times q_{j,0}}{\sum_{j=1}^{N} p_{j,0} \times q_{j,0}} \times \frac{\sum_{j=1}^{N} p_{j,t} \times q_{j,t}}{\sum_{j=1}^{N} p_{j,0} \times q_{j,t}}} \qquad \text{Eq. (3)}$$

The Fisher index considers the weights of both the base period and the current period, hence its ability to accommodate the effects of substitutions (FHWA, 2017). As such, the Fisher formula was applied in the present study to selected bid items for two adjacent periods. However, only one index value can be calculated for two adjacent periods. Accordingly, the MHCCI values of adjacent periods were chained into a time series of indices using Eq. [4].

$$I_t = I_{t-1} \times F_t = F_1 \times F_2 \times F_3 \times \ldots \times F_{t-1} \times F_t \qquad \text{Eq. (4)}$$

Following the proposed methodology, an MHCCI calculation tool was developed with a computer programming language, *Python*. The developed system can automatically clean, edit, and select bid items, and can calculate quarterly and annual MHCCI based on the encoded algorithms and index formula. Although at present the system only has data analysis and calculation functionalities, a Graphical User Interface (GUI) for MDOT staff use will be developed in Task 3 of the project.

2.4 Michigan Quarterly HCCI (Fiscal Quarters 2010 Q2 to 2020 Q1)

Given the selected bid data, the quarterly MHCCI was calculated for the period from the second quarter of the 2010 fiscal year to the first quarter of the 2020 fiscal year. The base for the quarterly MHCCI calculation was the second quarter of the 2010 fiscal year. (The calculated MHCCI is shown in Figure 9, and also tabulated in Table 1.) During this period, the MHCCI value was found to have increased from 1.0000 to 1.4956.

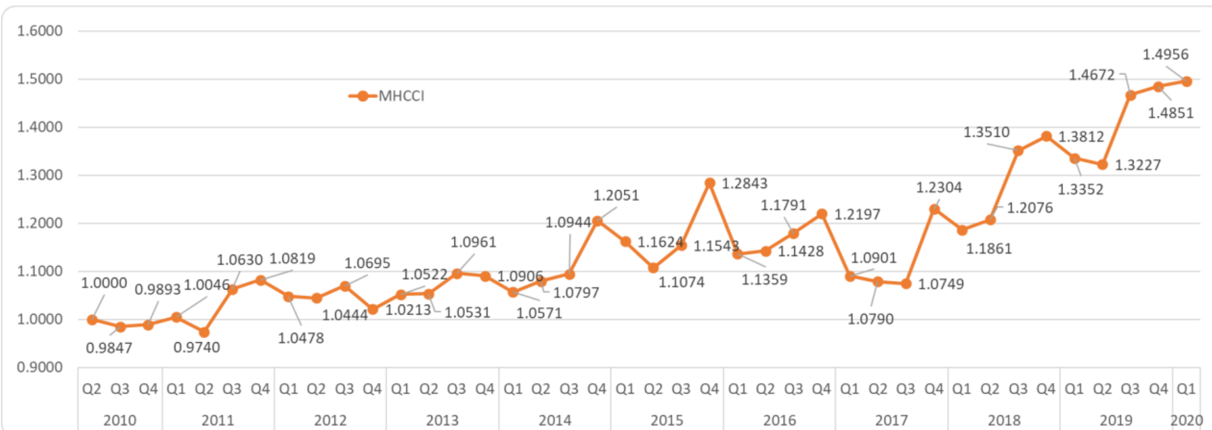


Figure 9. Quarterly MHCCI, base 2010 Q2

As shown in Figure 9, the MHCCI experienced spikes in 2014 Q4, 2015 Q4, 2017 Q4, 2018 Q3, and 2019 Q3. The spikes in the quarterly MHCCI, it should be noted, are primarily attributable to higher costs for HMA pavement, earthwork, bases, and drainage features. In particular, bid items of earthwork and bases are likely driving up the state index, as their item price index is found to be higher than the state index. In contrast, HMA pavement items are more likely governing the MHCCI trend, as they were found to account for the highest share of awarded amount among the different costs. Figure 10 presents the cost percentage of item categories over the total cost of bid items selected for MHCCI calculation during the period under study. During the quarters showing spikes, HMA pavement was found to account for 54.4%, 31.9%, 22.6%, 50.6%, and 48.9%, respectively. In particular, the bid item, *5010057, HMA, 5E3*, was found to account for 9.1 % of the total cost of selected bid items in 2018 Q2, while its bid price was increased by 25%. Since HCCI is aggregated based on bid items, rather than labor items, material items, and so forth, the major bid items identified as contributing to the index spikes are summarized in Table A-2 in Appendix B.

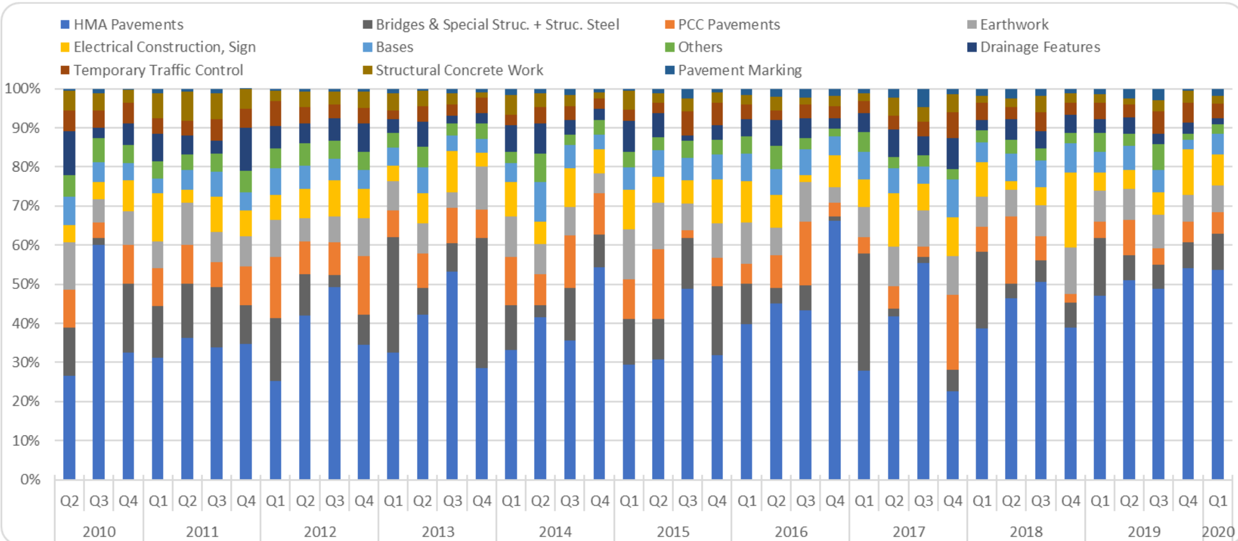
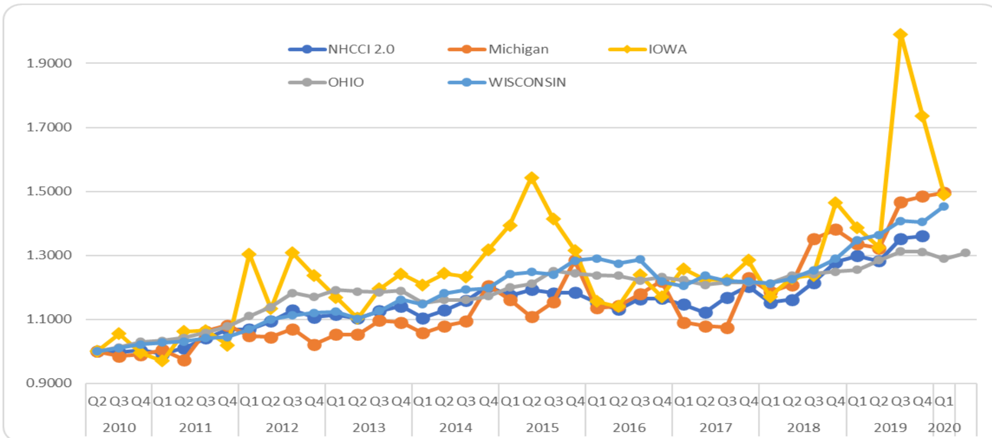


Figure 10. Cost Percentage of each category during the period under study

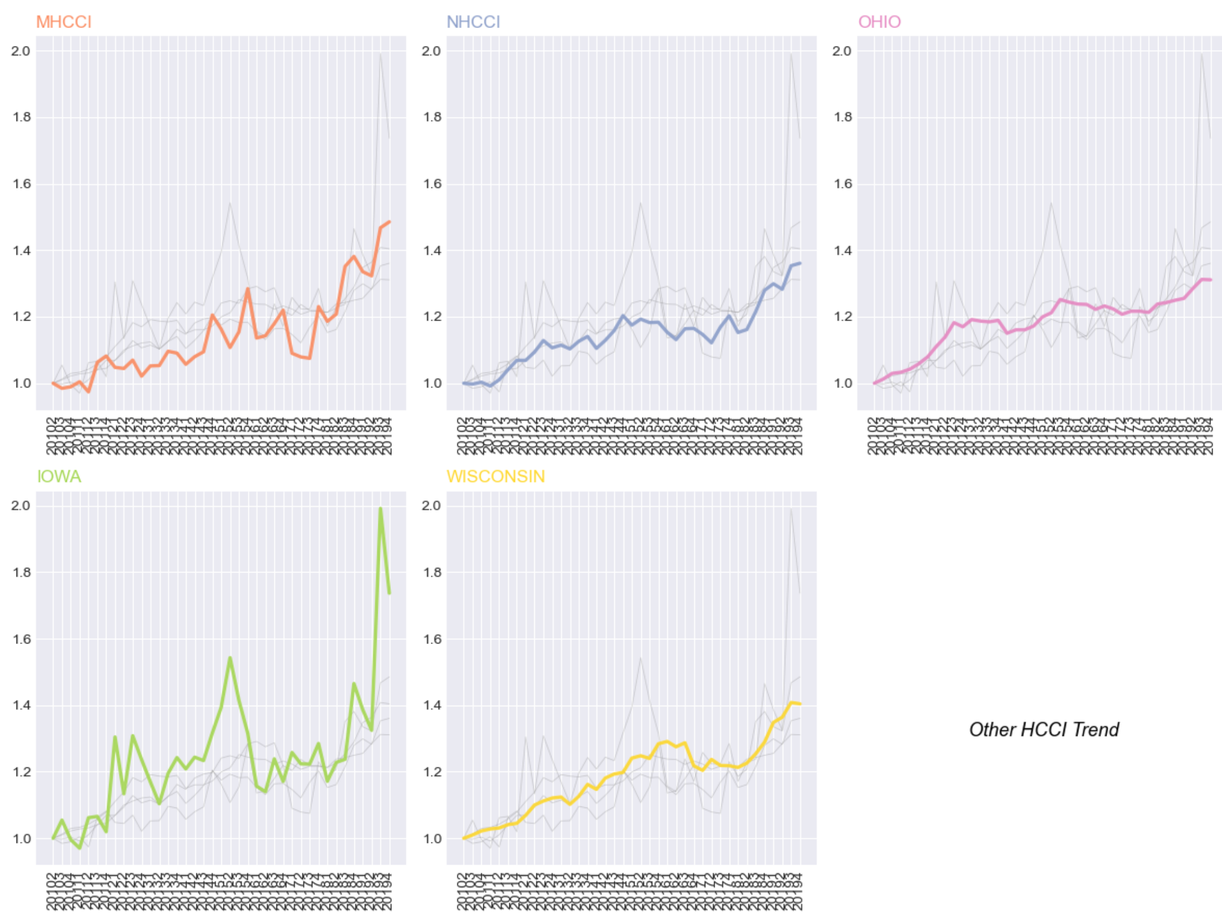
2.4.1 Comparison of MHCCIs and Other HCCIs

The calculated MHCCI was then compared with the NHCCI 2.0. The FHWA's NHCCI 2.0, it should be noted, was selected for the comparison because its sophisticated methodologies, such as item sampling, have been widely regarded as representing the best practice in HCCI calculation (HDR, 2018). The MHCCI was computed using a methodology very similar to that of the NHCCI 2.0, which, in turn, was used to validate the calculated MHCCI. The MHCCI was also compared with other states' HCCIs to provide insights to the extent to which Michigan's local construction market conditions are related to the trends of peer states. Two criteria were considered in the peer state selection: (1) similarities in geography and climate, and (2) HCCI frequency (i.e., the peer states must calculate their HCCI on a quarterly basis). Consequently, the peer states of Ohio, Iowa, and Wisconsin were selected for the comparison, and historical HCCI data was obtained from the respective DOTs as well as from the FHWA. It should be noted that the FHWA's and the select peer states' HCCIs are calculated for calendar quarters, so they had to be adjusted to align with the fiscal quarters used in MDOT's cost management practice. In addition, the select states' HCCIs were normalized by rebasing each index series to the second quarter of the 2010 fiscal year for comparison, as the respective HCCIs had been calculated using different base quarters.

The comparisons were conducted through two approaches: (1) index trend visualization and (2) a statistical method, i.e., the Pearson correlation coefficient. Figure 11 shows the HCCI trend for Michigan and for the FHWA (i.e., NHCCI 2.0), as well as for peer states.



(a) Michigan HCCI, NHCCI 2.0, and peer states' HCCI trends



(b) Individual trend visualization

Figure 11. Comparing Quarterly HCCI: Michigan, peer states, and FHWA, Base 2010 Q2

As shown in the figure, it was found that the quarterly MHCCI visually exhibits a similar trend with other indices, except Iowa's, over the period under study.

2.4.1.1 Correlation Analysis of Quarterly HCCI: Michigan, FHWA, and Peer States

To identify relationships between Michigan and peer states, correlation analysis was performed on quarterly HCCI. Figure 12 presents the correlation coefficients, where the correlation coefficient is a variable ranging from 0 to 1, with higher values indicating a stronger linear relationship. In other words, in such cases, an increase in one variable (i.e., index) is likely to be accompanied by an increase in the second variable (i.e., the compared index). In the context of price index, a higher value is indicative of a higher degree of similarity in market conditions and changes in market conditions between the states under comparison for a given period of time.

Quarterly MHCCI was found to exhibit a strong positive correlation with the NHCCI 2.0 (0.92) and the peer states of Ohio (0.79), Iowa (0.76), and Wisconsin (0.88). The coefficients indicate that Michigan's HCCI trend is most similar with that of the FHWA's NHCCI, followed by those of Wisconsin, Ohio, and Iowa.

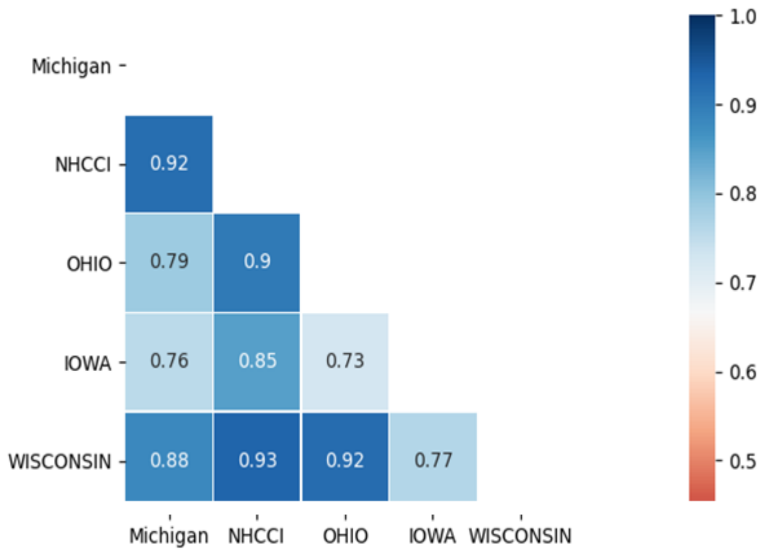
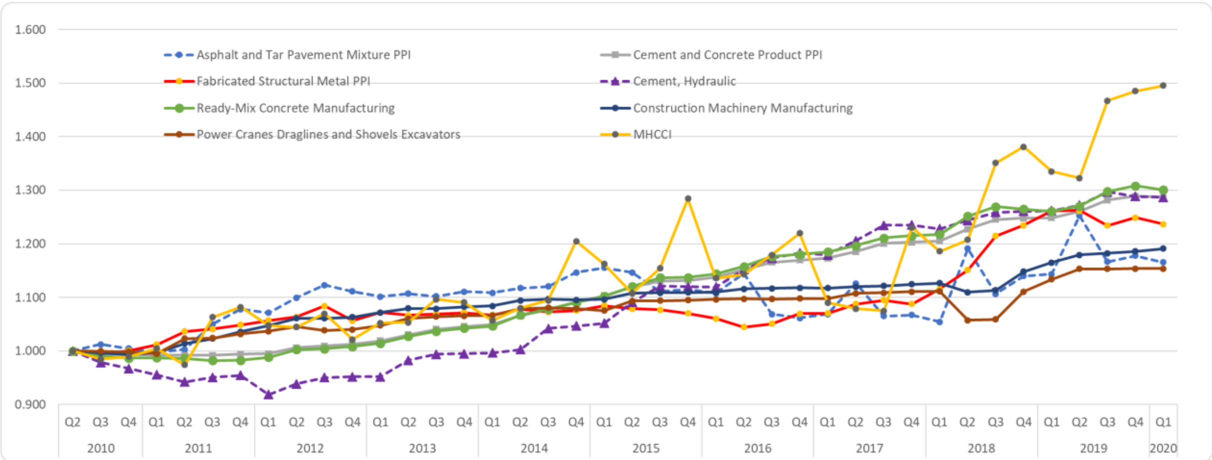


Figure 12. Color map of correlation coefficient matrix: Michigan, peer states, and FHWA

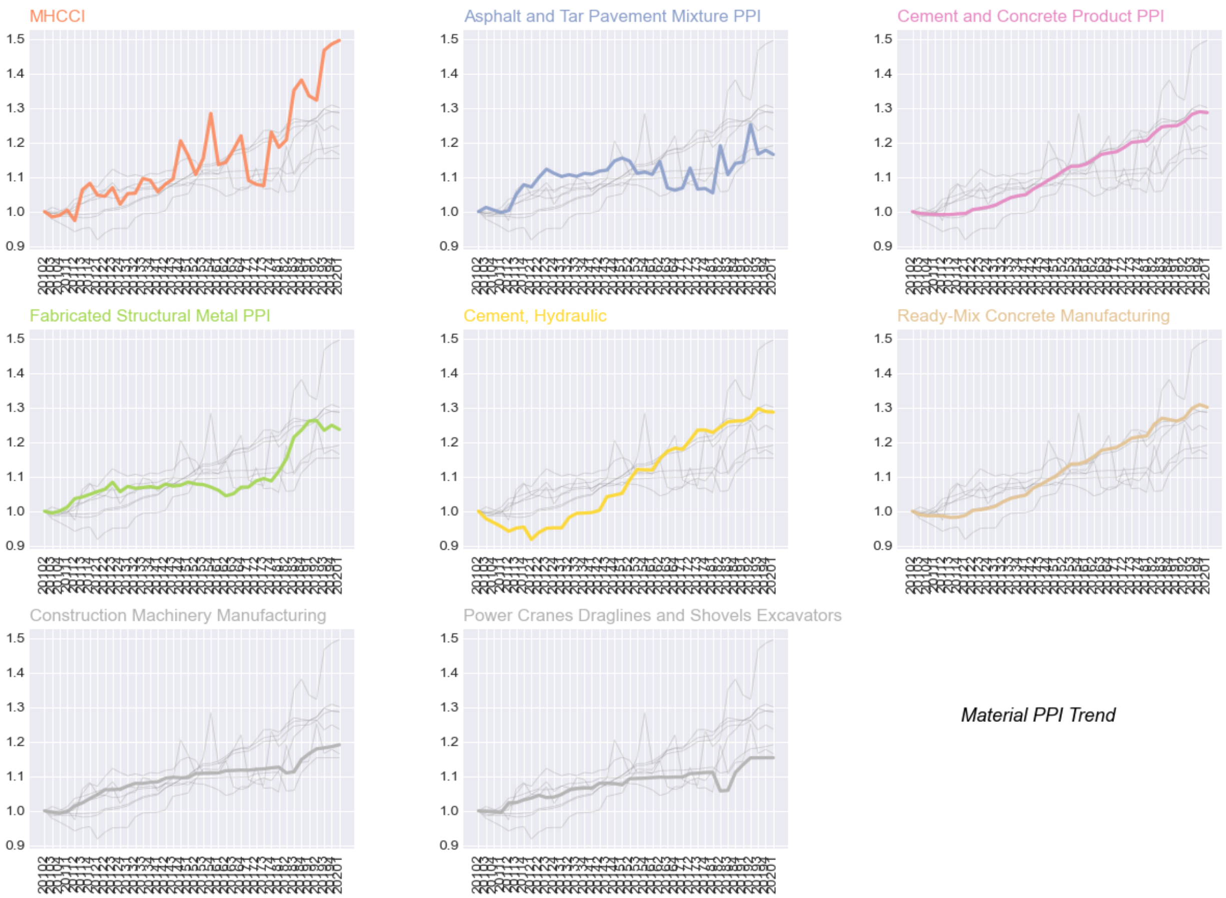
2.4.2 Comparison of MHCCIs and Construction Material PPI

In general, the Producer Price Indices (PPIs) published by the Bureau of Labor Statistics (BLS) measure the trend of selling prices received by domestic producers of goods and services (BLS 2020). Some states keep track of the PPIs relevant to highway construction as a way of monitoring general inflation. As such, the calculated MHCCI values were compared with selected PPIs such as those for asphalt and tar pavement mixture; cement and concrete products; fabricated structural metal; cement, hydraulic; ready-mix concrete manufacturing; construction machinery manufacturing; and power cranes, draglines, and shovels/excavators.

The monthly PPI data was obtained from the Bureau of Labor Statistics. The PPI data retrieved was then transformed into quarterly indices by averaging the data. Figure 13 presents the visual comparison of the MHCCI with the PPIs of various individual construction materials. As shown in the figure, the quarterly MHCCI visually exhibits a similar overall trend with the various material indices over the period under study. In particular, the MHCCI and the asphalt and tar pavement mixture PPI experienced similar spikes during the period under study, although not at the same time. This suggests a time-lag/lead correlation between MHCCI and Asphalt and Tar Pavement Mixture PPI. The next subsection discusses this in more details.



(a) Michigan HCCI and Construction material PPI trends



(b) Individual trend visualization

Figure 13. Comparing MHCCI with construction material PPI (2010–2019), base 2010 Q2

2.4.2.1 Correlation Analysis of Quarterly HCCI: Michigan and PPI

The correlation coefficients characterizing the relationship between the MHCCI and the various material PPIs are summarized in Table A-7 in Appendix D. In general, it was found that the quarterly MHCCI is highly correlated with the various material PPIs. Quarterly MHCCI was found to have positive Pearson correlation coefficients with the asphalt and tar pavement mixture PPI (0.61), the cement and concrete product PPI (0.87), the fabricated structural metal PPI (0.89), the ready-mix concrete manufacturing PPI (0.86), and the construction machinery manufacturing PPI (0.85). It was also noted that the correlation coefficient between MHCCI and the asphalt and tar pavement mixture PPI increased from 0.61 to 0.73 when a two-quarter lag was applied to the MHCCI (as shown in Figure 14). This finding implies that the quarterly MHCCI trend is following the trend of the asphalt and tar pavement mixture PPI with a two-quarter lag.

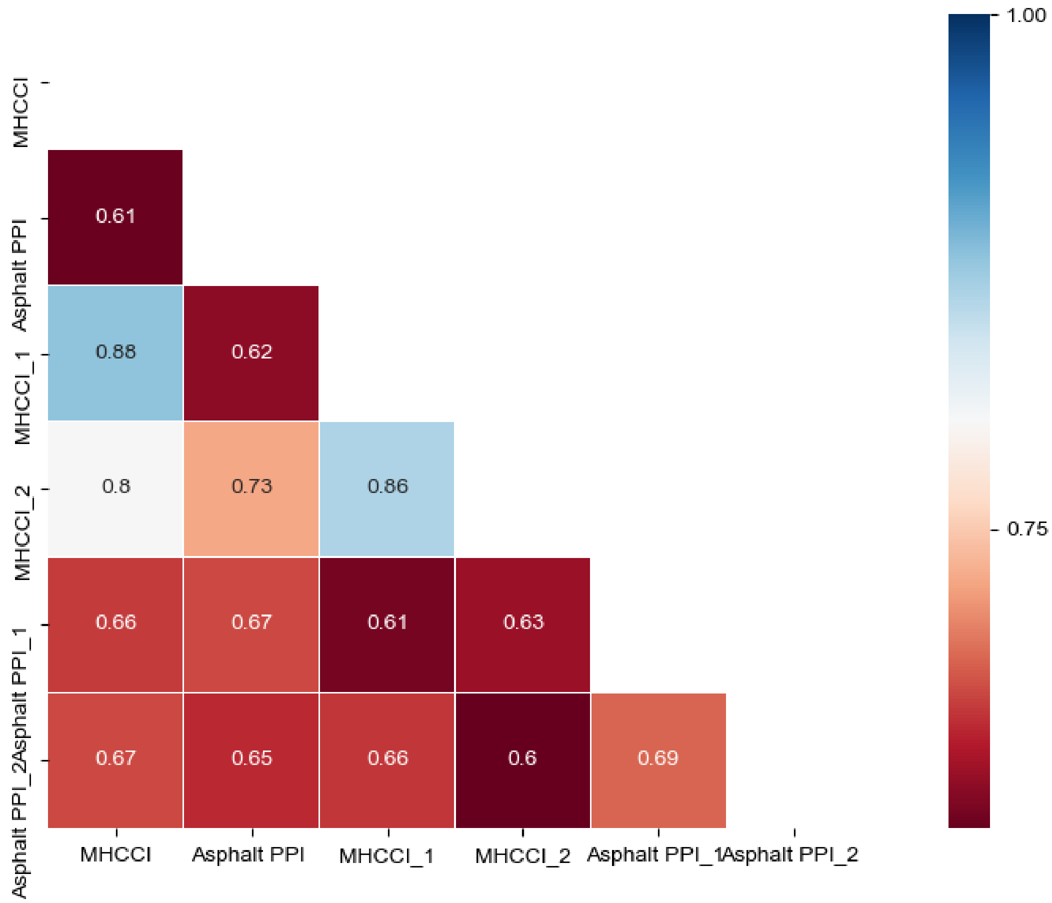


Figure 14. Cross-correlation between Asphalt PPI and MHCCI

2.5 Michigan Annual HCCI (Calendar Years 2010–2019)

The annual MHCCI was also calculated for the period, 2010 to 2019, where the base for the annual MHCCI calculation was the 2010 calendar year. (The calculated MHCCI value is shown in Figure 15 and also tabulated in Table 2.) During this period, the MHCCI value was found to have increased from 1.0000 to 1.4540, as shown in Figure 15.

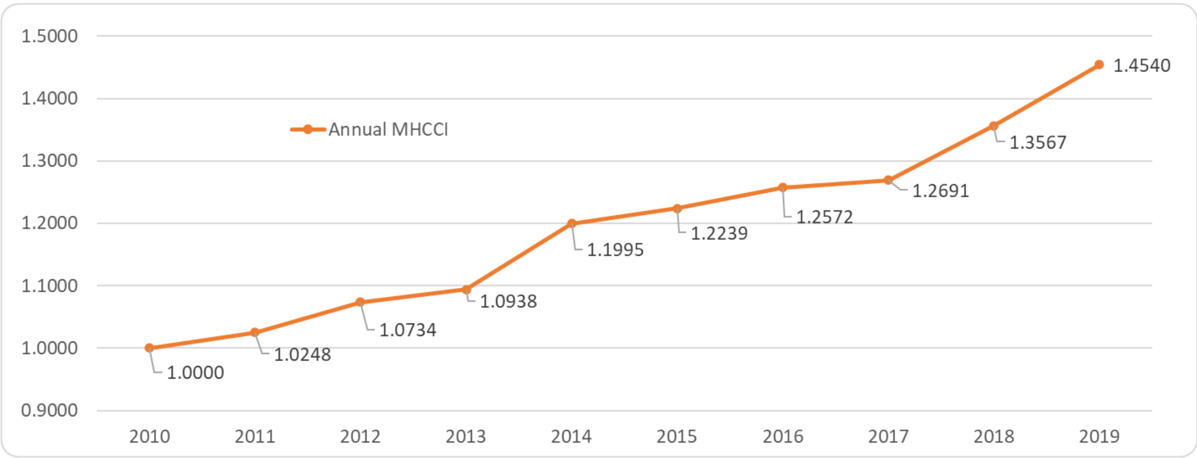


Figure 15. Annual MHCCI, base year 2010

2.5.1 Comparison of MHCCIs and Other HCCIs

The annual MHCCI was then compared with the HCCIs of peer states and FHWA. The peer states, including Iowa, Utah, North Dakota, Washington, and Minnesota, were selected in consideration of the HCCI frequency. Historical HCCI data was then obtained from the respective DOTs. All index values were rebased to the year 2010. In addition, the annual index values of NHCCI 2.0 were estimated based on the average of the quarterly NHCCI values (because the NHCCI 2.0 is calculated on a quarterly basis). It should be noted that averaging the quarterly index to obtain an annual index is statistically not advisable; therefore, the annual NHCCI 2.0 calculated this way should be interpreted with caution. Figure 16 presents the annual HCCI trends for the period under study. All the peer states considered, with the exception of North Dakota, exhibited a similar HCCI trend with Michigan, as was the FHWA's NHCCI 2.0.

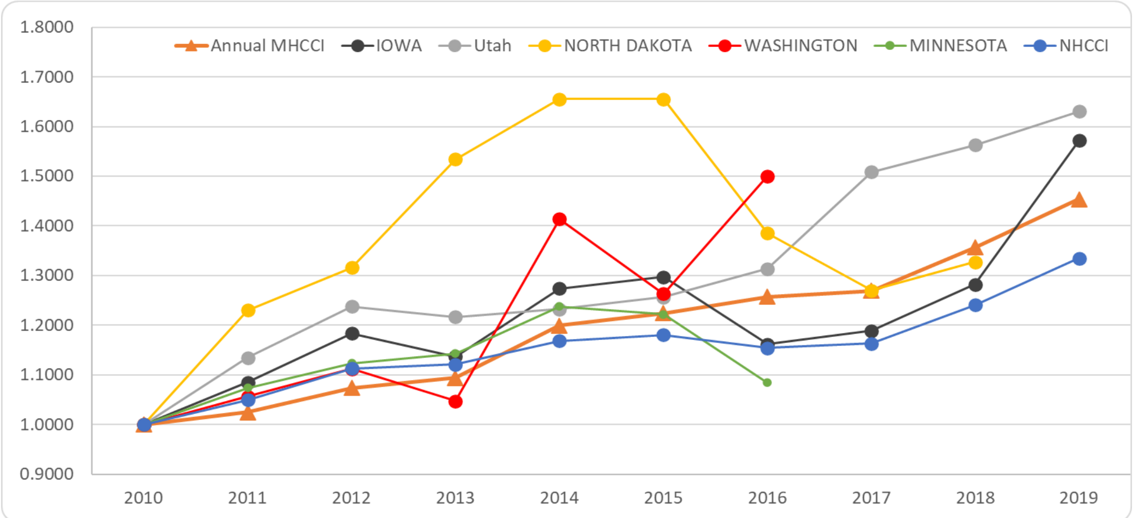


Figure 16. Comparing annual HCCI: Michigan, peer states, and FHWA, base year 2010

Annual index values were transformed to year-over-year percentage changes, as shown in Figure 17. As can be seen in the figure, the annual MHCCI trend was found to follow closely with the annual NHCCI trends and peer states' average HCCIs, with the exception of the years 2011, 2014, and 2016. For example, the NHCCI 2.0 and the average of the peer states decreased by 2.23% and 3.71% in 2016, respectively, while the MHCCI increased by 2.72% in the same year. The differences between the year-over-year change of the MHCCI, the NHCCI 2.0, and the peer states' HCCIs averaged at 2.92% with a median of 2.03%. These results show that the annual MHCCI trend follows closely with the annual trends of the NHCCI and of the average of the peer states' HCCIs.

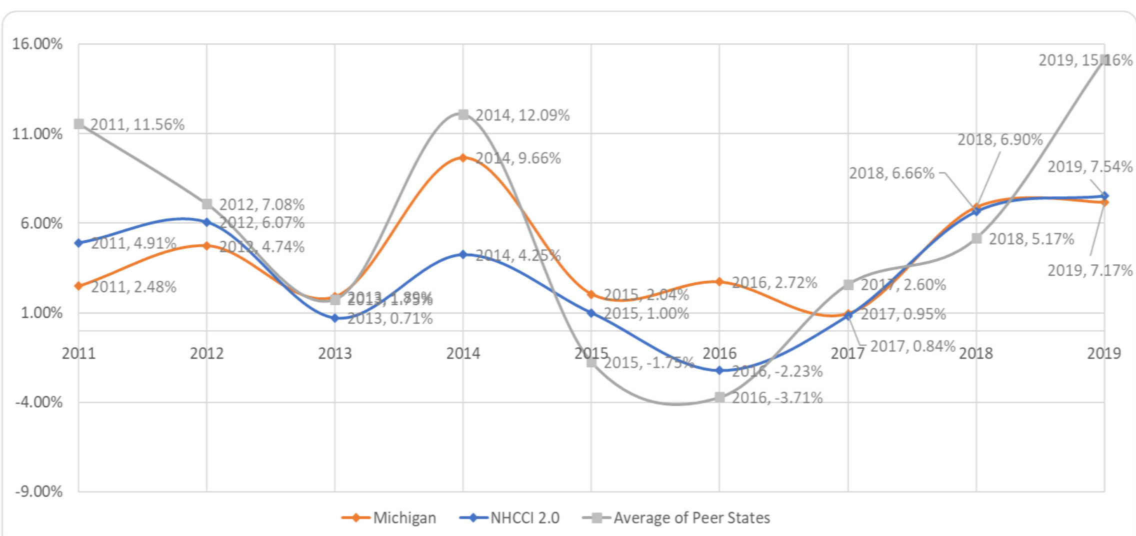


Figure 17. Year-over-year change of MHCCI, peer states' average HCCI, and NHCCI 2.0

2.5.1.1 Correlation Analysis of Annual HCCI: Michigan and Peer States

Correlation analysis was also performed on annual HCCI between Michigan and the peer states. Different time lags, such as one-year lag and two-year lag, were applied to the annual HCCIs in the analysis. The purpose of applying the time lag was to ascertain which state's market condition changes in *previous* years might be reflected in Michigan market condition changes for a given year. Accordingly, the current year's market condition changes in the identified peer state/s could shed light on a future year's market condition changes in Michigan (i.e., one or two years in the future).

Table 9 shows the coefficient results for annual HCCIs. The annual MHCCI was found to exhibit a strong positive correlation with the NHCCI 2.0 (0.93), and the peer states of Utah (0.89), Iowa (0.77), and Washington (0.9). Meanwhile, these coefficient results show that the annual HCCI trend of North Dakota is following the annual MHCCI with a time lag of one year (as indicated by the coefficient of 0.99), while Utah's and Minnesota's annual HCCI trends are following the annual MHCCI with a two-year lag (as implied by the coefficient of 0.95 and 0.93). Statistically, this observation means that the effect of the regional construction market conditions may be first observed in Michigan, Iowa, and Washington, among the selected peer states, followed by North Dakota, and, finally, Utah and Minnesota. However, it should be noted that the HCCIs of the peer states were calculated using different methods, and hence these patterns should be considered with caution.

Table 9. Correlation coefficients of annual HCCI: Michigan, peer states, and FHWA

	Correlation Coefficients				
	No lag	Michigan 1 year ahead	Michigan 2 years ahead	Michigan 1 year behind	Michigan 2 years behind
FHWA	**0.93**	0.90	0.82	0.83	0.76
Utah	0.89	0.92	**0.95**	0.88	0.91
IOWA	**0.77**	0.59	0.58	0.65	0.51
WASHINGTON	**0.9**	0.65	0.70	0.69	0.86
NORTH DAKOTA	0.36	**0.99**	0.94	0.23	0.01
MINNESOTA	0.18	0.90	**0.93**	−0.03	−0.24

2.5.2 Comparison of MHCCI and Construction Material PPI

The year-over-year changes in annual MHCCI were compared with those for material PPIs, as shown in Figure 18 and Table A-8 in Appendix E. The differences between the year-over-year changes of the MHCCI and those of the material PPIs were found to average at 2.16 % with a median of 2.48 %, while the maximum differences were in the years 2014 and 2016. This means that the annual MHCCI trend follows closely those of the various material PPIs, except in the years 2014 and 2016. It is noted that, in 2016, most of the material PPIs, such as asphalt and structural metal PPIs, decreased at varying rates, whereas the MHCCI increased by 2.72 % in the same year.

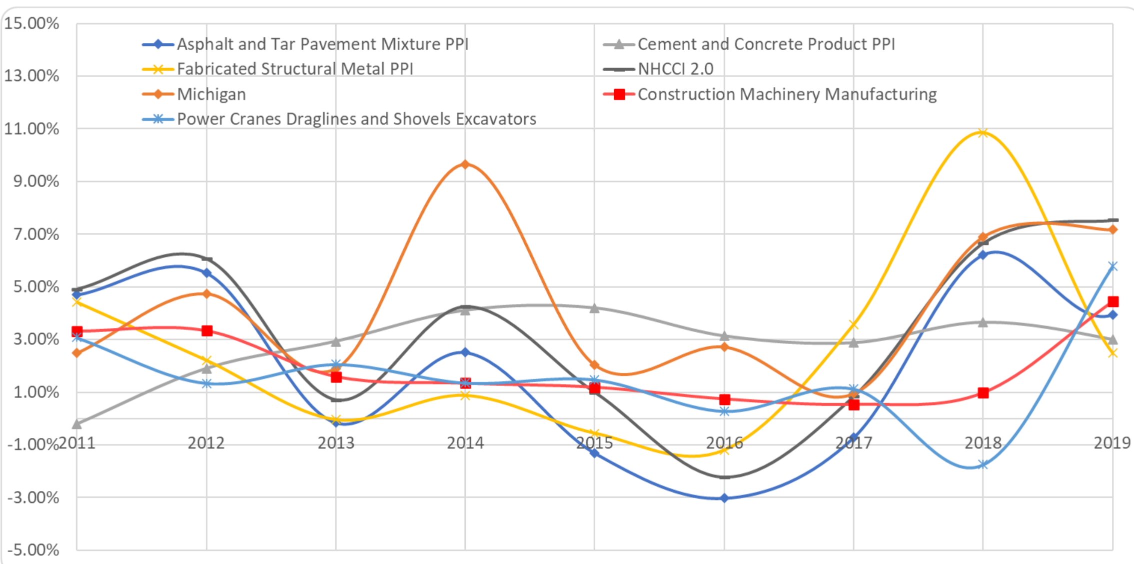


Figure 18. Year-over-year change in Michigan HCCI and PPIs

2.6 Category Sub-MHCCI

Sub-HCCI can provide insights into the specific aspects of the highway construction market, such as trends with respect to particular regions and construction items. It allows DOTs to understand the construction market conditions with higher granularity (Jeong et al., 2017). As such, some of the peer states, such as Iowa, have calculated HCCI for specific regions and item categories. The research team thus reviewed the item categories and further calculated HCCIs for each defined item category for Michigan.

2.6.1 Item Classification

Currently, MDOT uses two different classification systems in bid item management: (1) item class and (2) item type. In total, 46 item classes and 21 item types were used in the bid dataset to classify MDOT bid items. Figure 19 summarizes the cost percentage of each item type and item class over the total construction cost for the period under study. As shown in the figure, some item types and classes account for a very low percentage of the total cost; for example, the item type 'Bridges and Special Struct (i.e., Fa)' was found to account for approximately zero percent of the total cost.

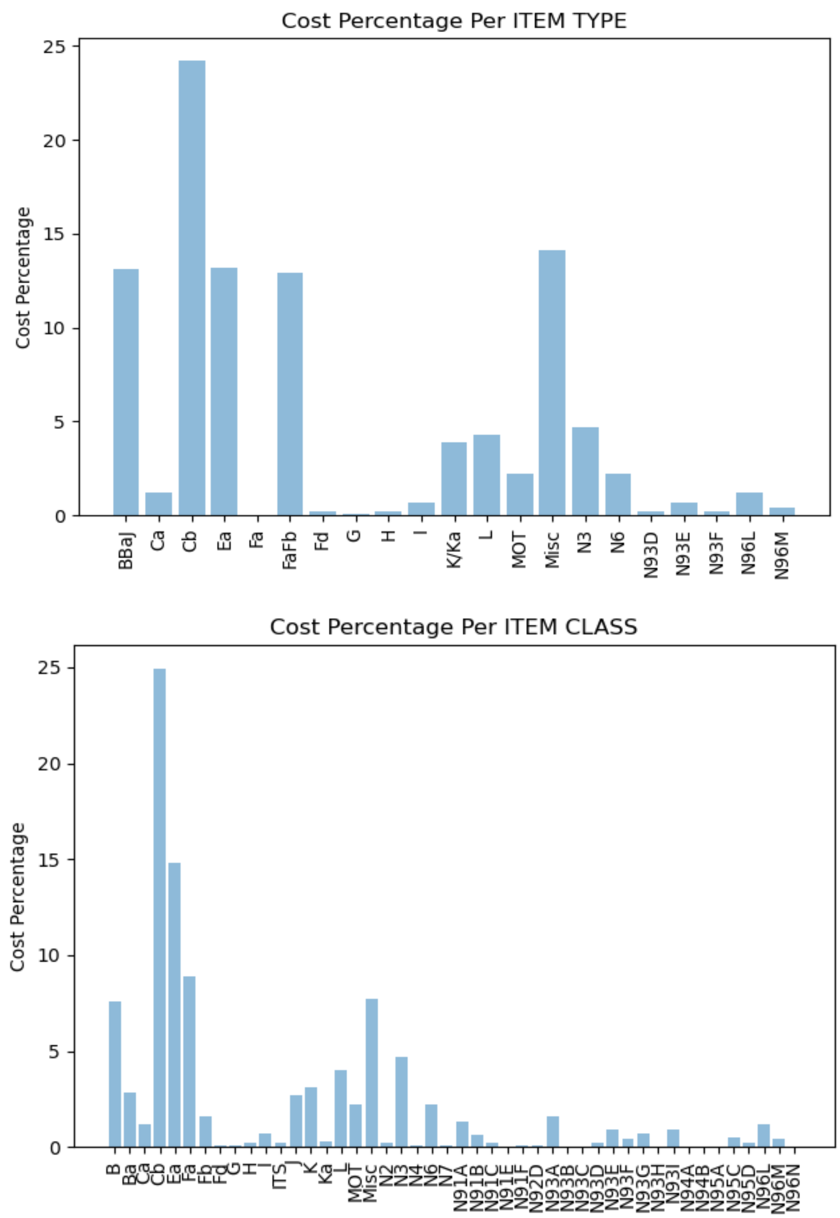


Figure 19. Percent breakdown of total award project costs by item type/class, 2010–2019

Consequently, the research team did not adopt the existing item classification in calculating the category sub-index. In contrast, ten categories were defined in consideration of peer states' practice and the cost percentage of existing item classes/types. These ten categories are summarized in Table 10. The first seven listed in the table are categories commonly used by all the states under study, while the last three categories—*Electrical Construction, Sign; Traffic Control; and Pavement Marking (denoted by L & N6, MOT, and N3 in* Figure 19, *respectively)*—were selected because they account for a relatively high cost percentage of the awarded amount in Michigan, i.e., 7.27%, 3.01%, and 2.26 %, respectively.

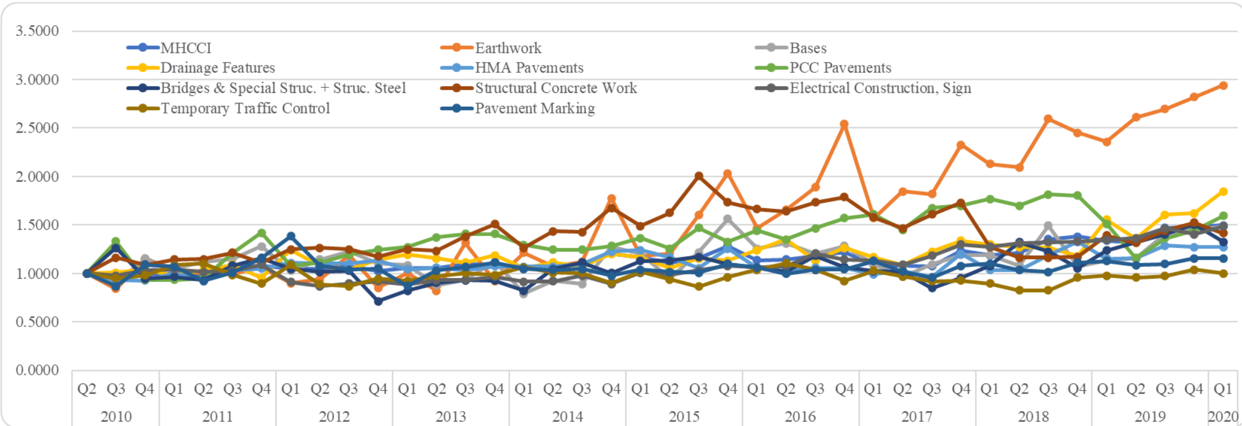
Table 10. Item category for sub-index

Category	***Item Numbers (first three digits)***
Earthwork	201, 202, 203, 204, 205, 206, 207, 208, 209
Bases	301, 302, 303, 304, 305, 306, 307, 308
Drainage Features	401, 402, 403, 404, 405, 406
HMA Pavements	501, 502, 503, 504, 505, 506
PCC Pavements	601, 602, 603, 604, 605
Bridges & Special Struc. + Struc. Steel	704, 705, 706, 707, 710, 711, 712, 713, 717, 718
Structural Concrete Work	701, 708, 801,802, 803, 804
Electrical Construction, Sign	810, 819, 820, 826
Temporary Traffic Control	812
Pavement Marking	811

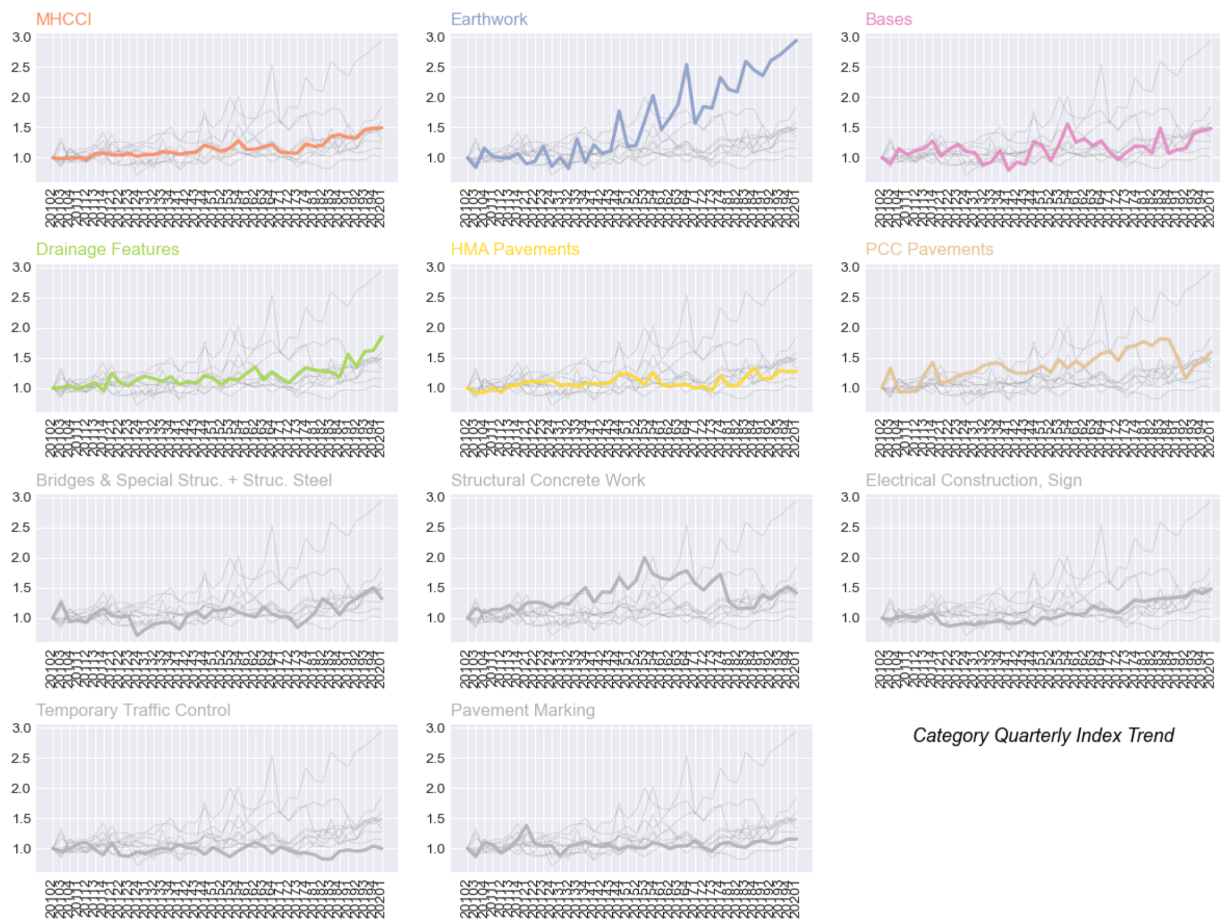
With ten categories defined, the methodology in Figure 1 was applied to calculate the index value for the period under study, where both quarterly and annual index values were calculated for each category. The base for category-level quarterly MHCCI was set to the second quarter of the 2010 fiscal year, whereas the base for category-level annual MHCCI was the calendar year 2010. The calculated index values, as tabulated in Table A-3, Table A-4, and Table A-5 in Appendix C, were found to fall within the range 0.85 to 2.94. The comparison and analysis of the category sub-indices are described in the next section.

2.6.2 Comparison of MHCCI and Category Sub-Index

Figure 20 and Figure 21 show the index trends of each item category for the period under study. In general, the index values of earthwork, bases, and drainage features were found to be higher than the state's overall index during the period under study. For example, the sub-index for earthwork increased from 1.0000 in 2010 Q2 to 2.9395 in 2020 Q1.

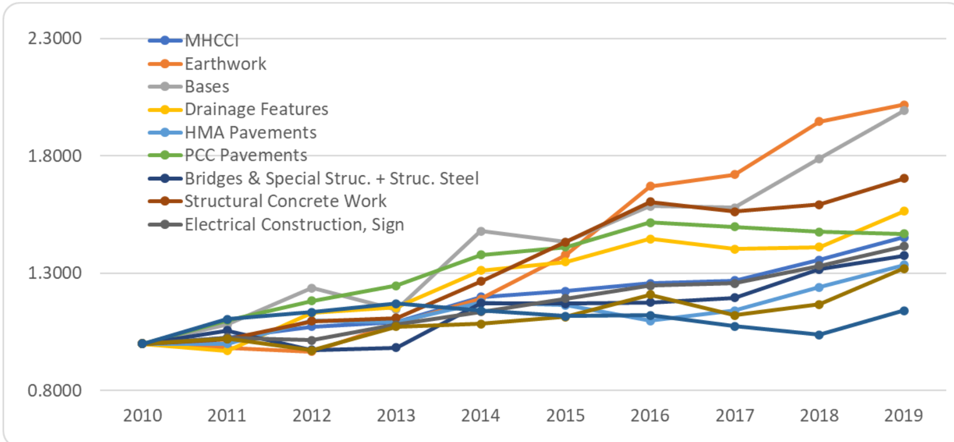


(a) Overall MHCCI and category-level MHCCI trends, quarterly

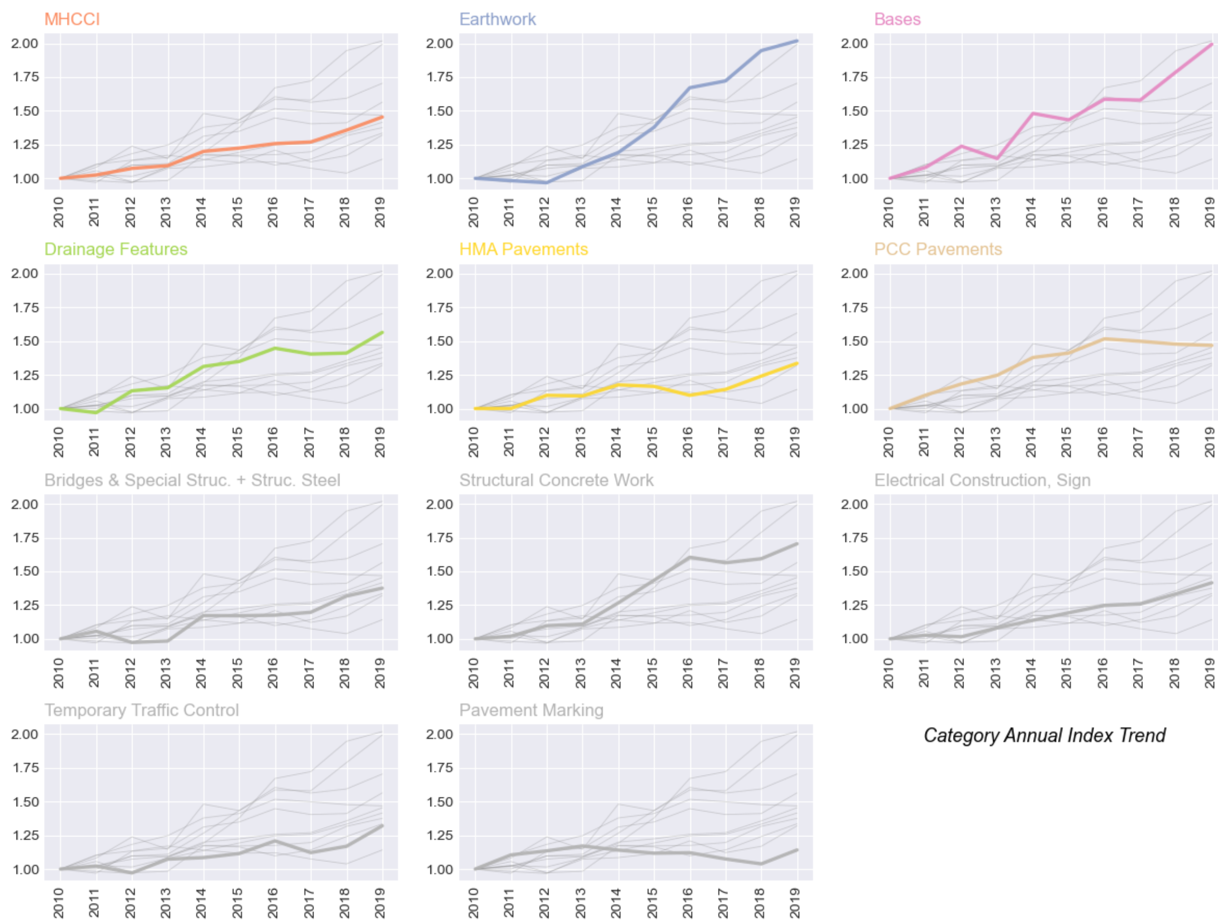


(b) Individual trend visualization

Figure 20. Category-level quarterly MHCCI, base 2010 Q2



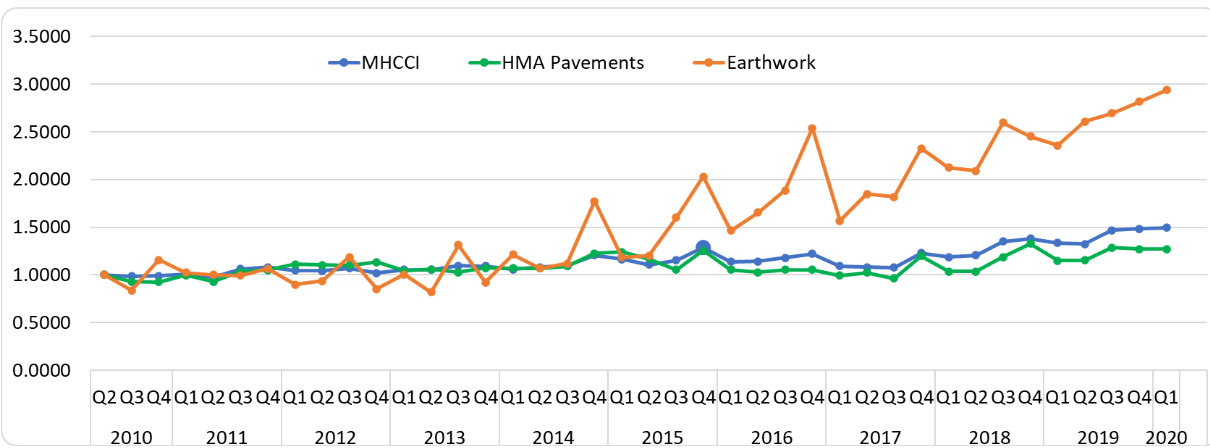
(a) Overall MHCCI and category-level MHCCI trends, annual



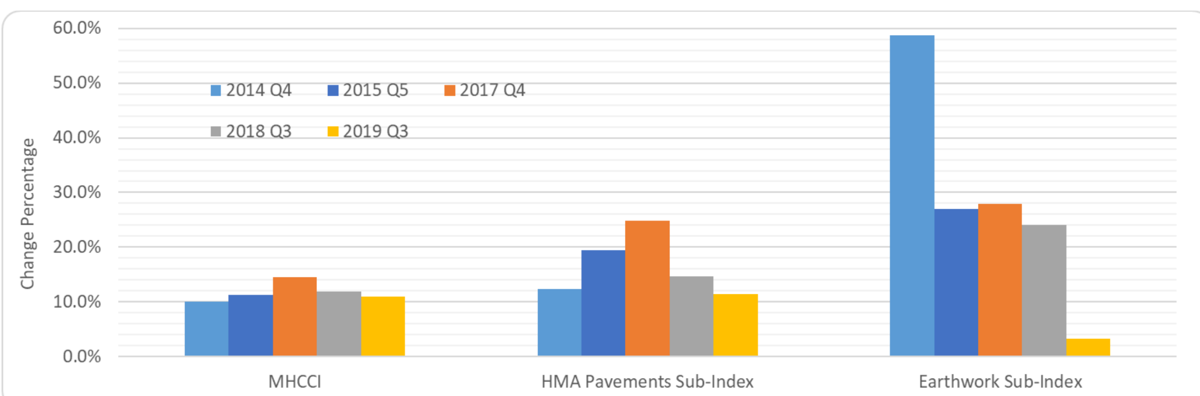
(b) Individual trend visualization

Figure 21. Category-level annual MHCCI, base 2010 Q2

As mentioned earlier, the quarterly MHCCI experienced spikes in 2014 Q4, 2015 Q4, 2017 Q4, 2018 Q3, and 2019 Q3 during the period under study. These spikes in the quarterly MHCCI, it should be noted, are primarily attributable to higher costs for HMA pavement, earthwork, bases, and drainage features. As shown in Figure 4, the percentage changes of category-level MHCCI for HMA pavement, earthwork, bases, and drainage feature were found to be, in general, much greater than the one of the overall MHCCI during these quarters. In particular, earthwork would seem to be driving up the state index, as its category index and index percentage change were found to be higher than those of the state overall, as shown in Figure 22. In contrast, HMA pavement would seem to be governing the MHCCI trend, as it was found to account for the highest share of awarded amount among the different costs (Figure 23). HMA pavement was found to account for 42.4% of the total construction cost of selected bid items for the period, 2010 to 2019, while earthwork and bases were found to account for 8.9% and 6.2%, respectively.



(a) Quarterly MHCCI trends



(b) Change percentage

Figure 22. Comparing Quarterly MHCCI: Overall, HMA, and Earthwork

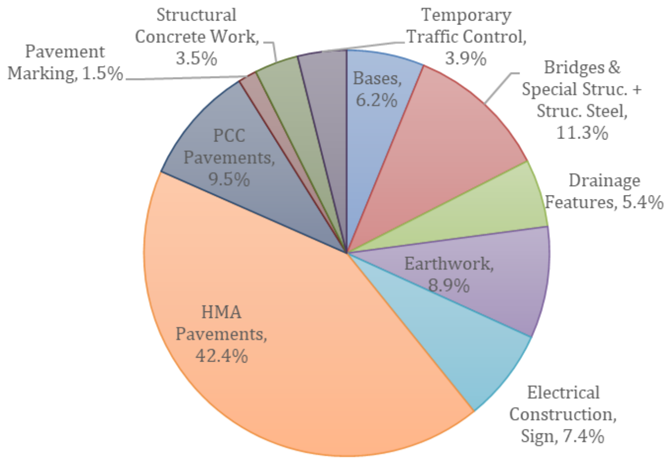


Figure 23. Cost percentage of item categories, 2010–2019

2.7 Region Sub-MHCCI

Depending on the project location, highway construction costs may vary. The reason for this is that such factors as the level of development in the surrounding area influence construction cost. Hence, the research team further calculated sub-HCCIs for each MDOT region, as shown in Figure 24. This region-level breakdown of MHCCI will allow MDOT to better understand how construction prices change across different locations within the state.

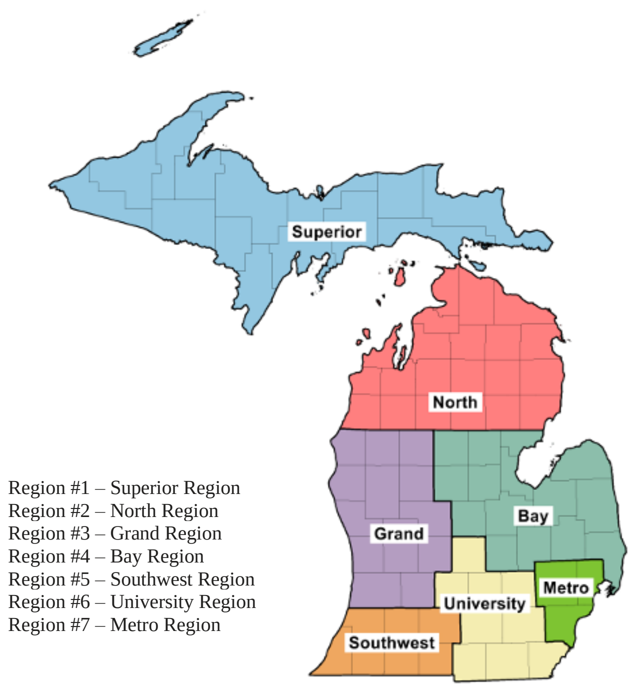


Figure 24. MDOT region map

The bid dataset contains the regional information for each bid item. Figure 25 summarizes the cost percentage of each region in the total construction cost for the period under study. In general, the Metro and University regions were found to account for the highest percentage of total construction, with 28.1% and 15.9%, respectively.

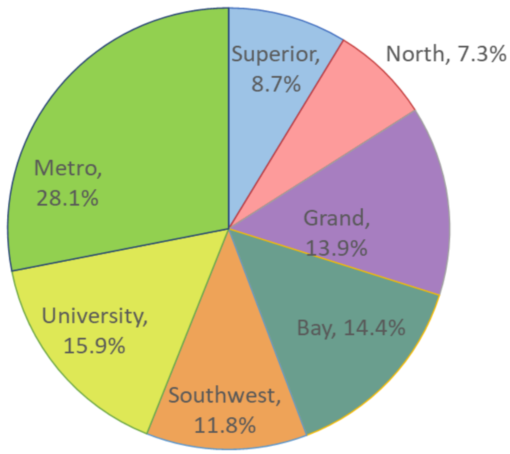


Figure 25. Cost percentage of MDOT regions: 2010–2019

The methodology for HCCI development (see Figure 1) was applied to calculate the index value for each region. During bid item selection, the research team came to realize that the Bay region did not have the bid items required for the index calculation in 2012 Q1 and 2019 Q4, as shown in Figure 26, which made quarterly HCCI calculation practically impossible. As a result, only the annual index was calculated for each region, where the base for the region-level annual MHCCI calculation was the calendar year 2010.

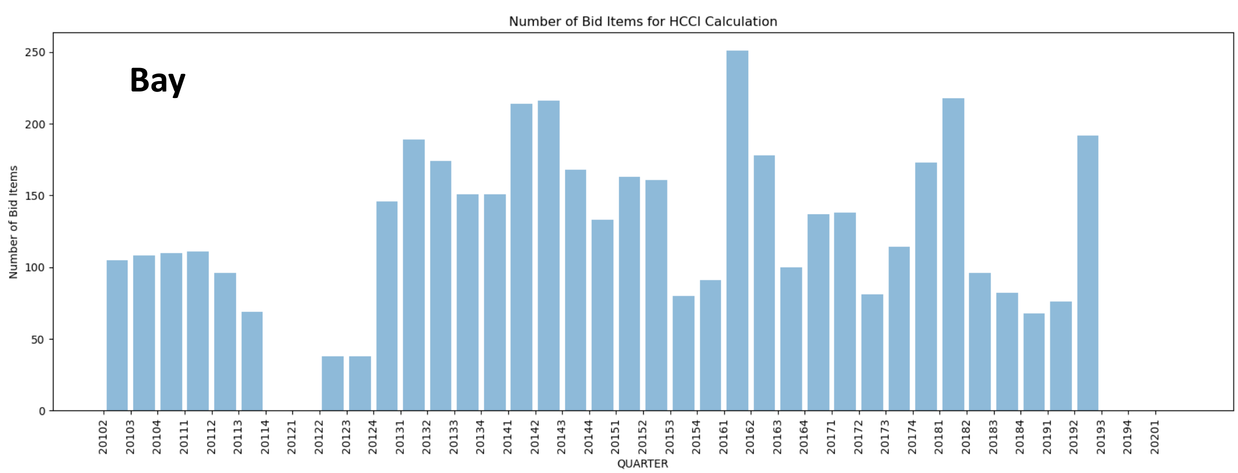
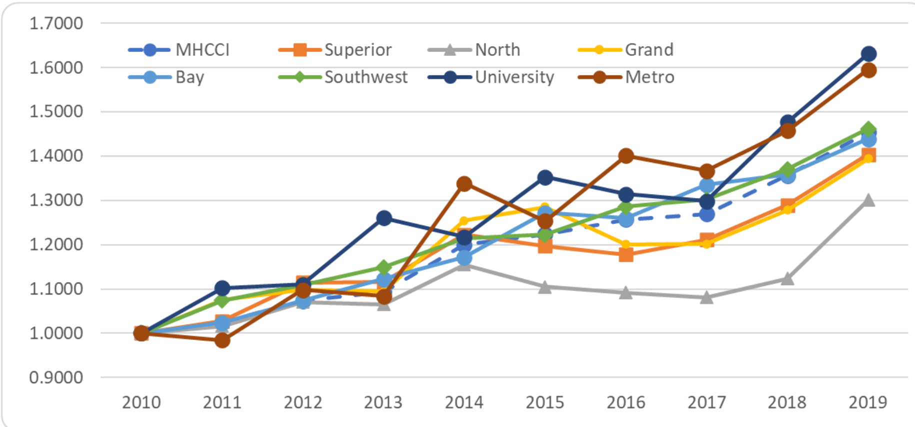


Figure 26. Bid item distribution for Bay region by quarter

The calculated index values, as tabulated in Table A-6, were found to fall within the range of 0.98 and 1.63. Figure 27 shows the index trend for each region from 2010 to 2019. Compared



(a) Region MHCCI trends

(b) Individual trend visualization

Figure 27. Region annual MHCCI, base year 2010

with other MDOT regions and with the state overall, the University region was found to have a relatively higher annual index value for the period under study. In contrast, the Metro region index was found to be higher than the state index in eight out of ten years analyzed. Moreover, the Metro and University regions were found to account for 28.1% and 15.9%, respectively, of the total construction cost for the period under study (see Figure 25). It can be inferred from this observation that the Metro and University regions have an upward impact on the state index.

3. MHCCI FORECASTS

In previous studies, HCCI has been forecasted using various techniques, including Artificial Neural Network (Williams, 1994), a multiplicative model (Wilmot & Cheng, 2003), time series analysis (Hwang, 2011), and multiple regression (Mill, 2013). For example, Hwang (2011) developed two time-series models— autoregressive moving average (ARMA) (5, 5) and vector autoregression (12)—for forecasting HCCI. Ashuri and Lu (2010) reported that time-series models such as the autoregressive integrated moving average model (ARIMA) and Seasonal ARIMA could forecast the HCCI with reasonable accuracy.

The ARIMA model and the Seasonal ARIMA model were thus employed in the present research to predict the HCCI for the next five years. It should be noted that time series analysis builds a model to predict future values solely based on previously observed values (Hwang, 2011; Hamilton, 1994). As such, the historical MHCCI values, i.e., 40 quarterly index values and ten annual index values, were used to train and test the time series models with the 80/20 rule, respectively. That is, 80% of the historical MHCCI values were used for training, while the trained models were then tested using the remaining 20% of the data. The analysis results revealed that the ARIMA (2, 0, 2) model could predict the annual MHCCI with higher accuracy, while the Seasonal ARIMA (0, 0, 0)(1, 1, 1)4 model performed better than ARIMA in the quarterly MHCCI forecast. The MHCCI values predicted by these two models are summarized in Table 3 and Table 4 and shown in Figure 28 and Figure 29. Based on this analysis, the quarterly MHCCI can be expected to increase to 1.9390 in the first quarter of the 2025 fiscal year, whereas annual MHCCI is forecast to be 1.7491 for the 2024 calendar year.

This finding implies that the average annual prices of highway construction bid items in the 2024 calendar year are anticipated to increase by 74.91% in comparison with the average prices in the 2010 calendar year. The year-over-year changes in annual MHCCI (i.e., annual inflation rates) for the period, 2020-2024, are 3.26%, 3.98%, 3.84%, 3.87%, and 3.87%, respectively. The percentage changes average at 3.76%, indicating unit prices will have an annual increase of 3.76% for the next five years. It should be noted that normal economic conditions were assumed in forecasting the MHCCI. However, with the ongoing pandemic and economic recession, which are not considered in the model, those forecasts should be considered with high caution.

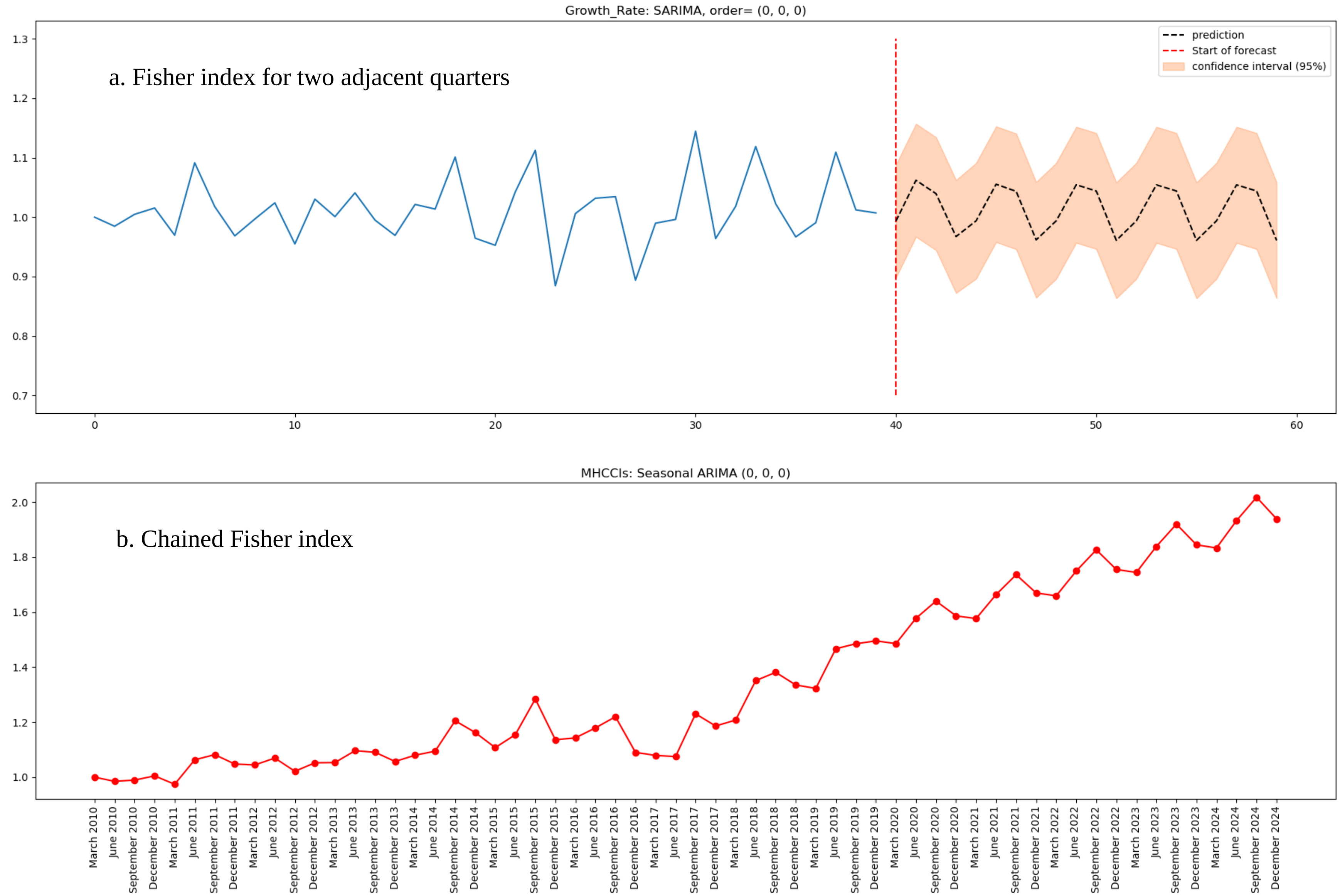


Figure 28. Quarterly MHCCI forcast for the next 5 years

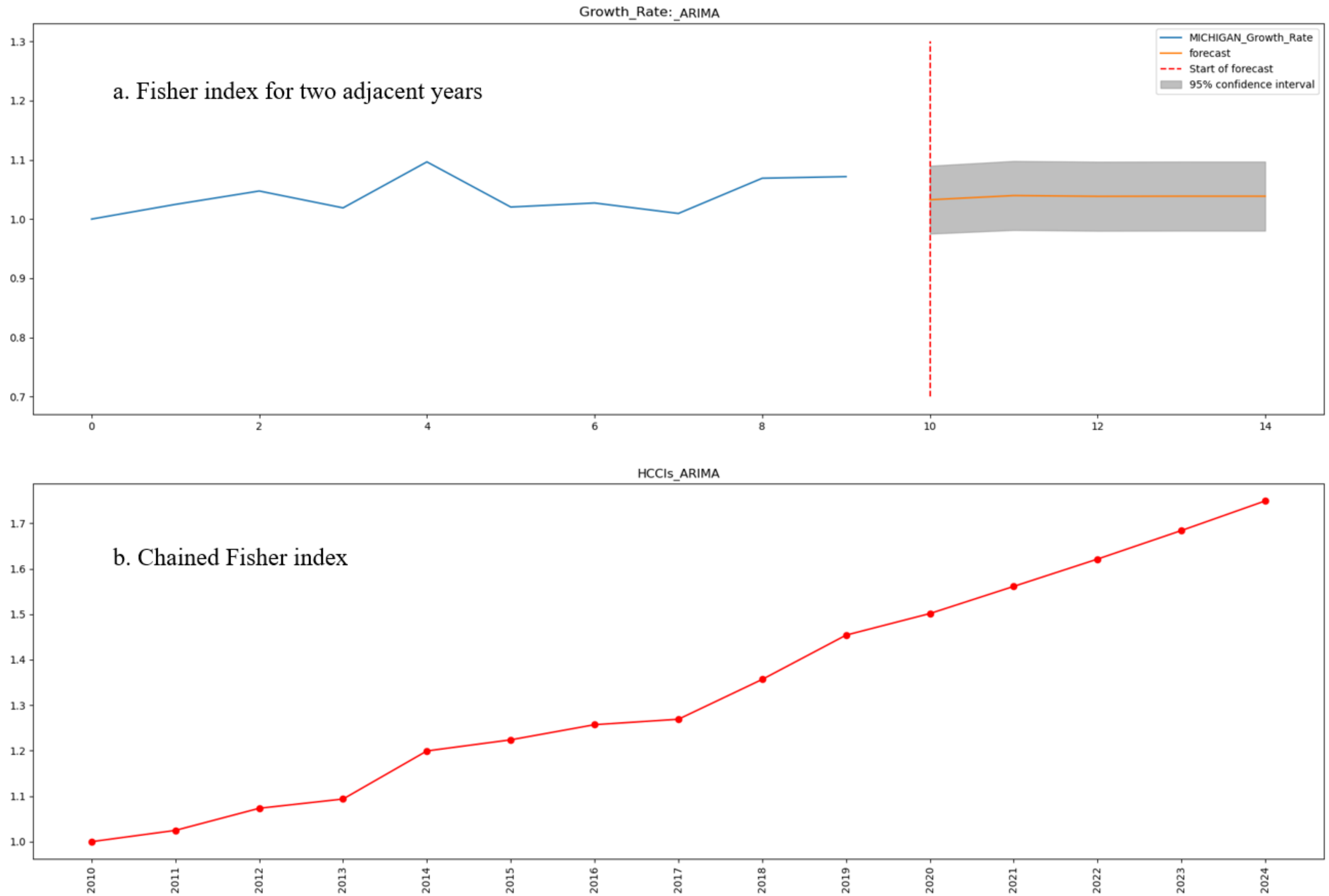


Figure 29. Annual MHCCI forcast for the next 5 years

4. LABOR TRENDS AND ECONOMIC FACTORS IMPACTING HIGHWAY CONSTRUCTION COSTS

4.1 Labor Trends

Labor cost data was available for the period from the first quarter of the 2015 fiscal year to the third quarter of the 2019 fiscal year. The analysis of this data revealed that labor cost accounts for approximately 17.18 % of the total construction cost of MDOT projects during the period under study. Indeed, it was found that there are 167 MDOT projects whose labor cost accounts for 7.6 % to 11.3 % of total construction cost, and 108 MDOT projects for which labor cost falls in the range of 11.03% to 15%, as shown in Figure 30.

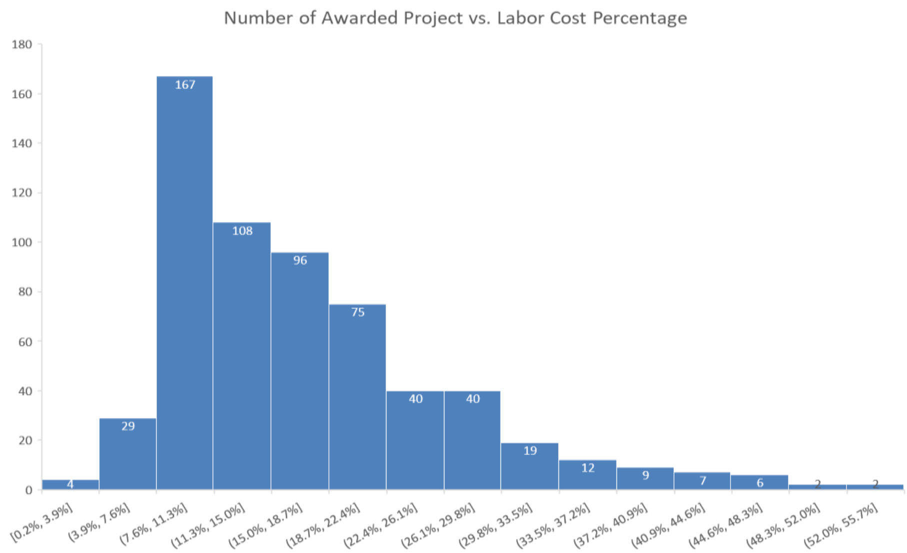


Figure 30. Histogram of labor cost over total awarded amount

The highway construction labor index for the state-level was calculated based on the available labor data, where Figure 31 presents the trend of Michigan's labor index relative to overall MHCCI. As shown in the figure, the MHCCI value was found to be higher than the labor index in fifteen of the nineteen quarters studied—a finding that leads to the conclusion that labor cost is not a primary driver of MHCCI.

Correlation analysis was performed to identify any relationships that might exist between labor index and MHCCI. The labor index was found to have a positive Pearson correlation coefficient of 0.73 with the MHCCI, indicating a high correlation between the MHCCI and the labor index. In addition, time lags were applied between the labor index and MHCCIs for further correlation analysis. The results showed a more similar trend between labor index and MHCCI when a two-quarter lag is applied, with a correlation coefficient of 0.79, as shown in Figure 32. From this finding, it can be inferred that the labor index trend is following the overall MHCCI with a two-quarter lag. This may be due to the fact that the labor rate is the actual rate paid for labor, and payment usually begins a few months after letting dates.

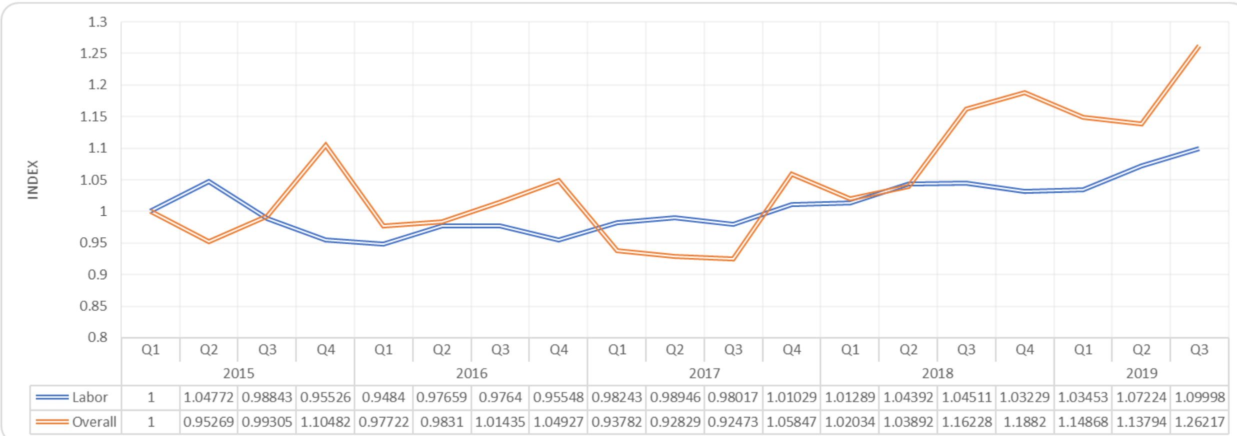


Figure 31. Michigan index comparison: labor vs. overall (rebase 2015 Q1)

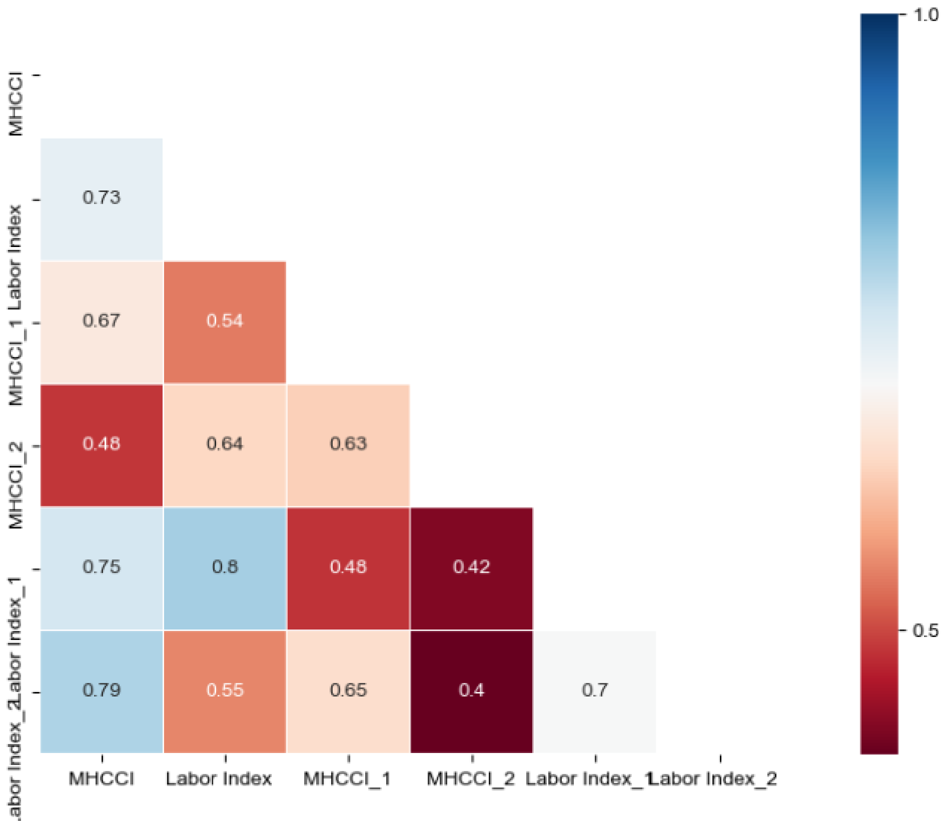


Figure 32. Pearson correlation coefficient between Michigan labor index and overall MHCCI

4.2 Economic Factors

The COVID-19 pandemic has already wreaked havoc on the national and Michigan economies, and the full extent of the economic damage brought by this pandemic remains to be seen. It can be expected that the impact of this epidemic on highway construction labor cost will be reflected in marked changes in labor demand and supply. Extensive layoffs and unemployed workers available and eager to work will increase labor supply, while labor demand will decrease under the depressed economic conditions. Given these conditions, wages in general are likely to fall, but it is not clear whether wages of highway construction workers will follow the general trend, and this will be largely dependent on level of post-pandemic spending on infrastructure in Michigan. Considering the increasing labor supply during an economic downturn, it is likely that highway construction labor costs may decrease. However, the material cost may undergo a spike during this unfolding economic recession, as indicated by the trend of the asphalt and tar pavement mixture PPI during the 2008 recession. It should be noted that the economic downturn resulting from COVID-19 pandemic may not be directly comparable to that of 2008 as it occurred suddenly and the recovery may be different from that of the 2008 downturn.

5. RECOMMENDATIONS TO LOCAL UNITS OF GOVERNMENT

Having investigated the best practice for HCCI calculation and implementing this practice in the development of the MHCCI, we provide a few suggestions to local units of government for measuring and indexing their highway costs. The recommendations are summarized as follows:

1. *Data Storage:* It is suggested that local units of government, including County Road Commissions, cities, transit agencies, etc., need to develop a structured database for bid items so that data can be readily retrieved for HCCI calculation purposes.
2. *Bid Item Sampling:* Ideally, the statistical editing method used by the FHWA would be applied to the selection of bid items. More practically, local units can identify major bid items based on the project characteristics and use those identified bid items in the calculation. This method of manual bid item selection is more straightforward and is still being used by many other states.
3. *Base Year:* It is recommended that 2010 be used as the base year for the HCCI calculation so that the calculated index is directly comparable with the MHCCI.
4. *Index Formula:* A chained Fisher index formula should be used in the calculation, as weights of bid items in the Fisher index are constantly updated over time, and it represents the current best practice.
5. *Frequency:* HCCIs for local units of government should be calculated and published on an annual basis. This is because local units have a lower volume of projects and may not even award construction projects for some quarters, which makes quarterly HCCI calculations practically impossible.
6. *Benchmarking*: It is also recommended to local units of government to benchmark and closely monitor the MHCCI, especially the Michigan region sub-index.

6. CONCLUSIONS

This research project has developed a methodology for MHCCI calculation, where MHCCIs are calculated quarterly and annually at the state level based on bid item data for the period from the second quarter of the 2010 fiscal year to the first quarter of the 2020 fiscal year. Further, sub-indexes at the category level and region level have been calculated for the same period. The results of a comparison of various MHCCIs with indices of peer states and specific material types have been found to provide insights into Michigan construction market conditions. For example, the quarterly MHCCI trend was found to be following the asphalt and tar pavement mixture PPI with a two-quarter lag. This means that MDOT could use the asphalt and tar pavement mixture PPI as an indicator of Michigan's construction market conditions, especially when a significant amount of asphalt is required for MDOT project at hand. The annual HCCI trend of North Dakota, meanwhile, was found to be following the annual MHCCI with a time lag of one year, while Utah's and Minnesota's annual HCCI trends were found to be following the annual MHCCI with a two-year lag. In addition, the comparison between state MHCCI and category-level sub-indices revealed that the spikes in 2014 Q4, 2015 Q4, 2017 Q4, 2018 Q3, and 2019 Q3 in the quarterly MHCCI are primarily attributable to higher costs of HMA pavement, earthwork, bases, and drainage features. It was also found that the Metro and University regions have an upward impact on the overall state index.

Based on the calculated historical index values, the MHCCI was also forecasted for the next five years, and a general discussion of the impacts of labor trends and economic factors such as unemployment on highway construction costs and the HCCI was undertaken. (We note that the current pandemic and economic recession are not factored into the forecast.) It was concluded that labor cost is not a primary driver of highway construction cost as reflected in the MHCCI. Finally, recommendations to local units of government regarding the measurement and indexing of highway construction costs were outlined, addressing such considerations as data storage, bid item sampling, base year, index formula, and frequency.

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APPENDIX A: AVAILABLE DATASETS AND DATA ATTRIBUTES

Table A-1. Data attributes in available datasets

ID	Description
1	LETTING DATE
2	CONTRACT NUMBER
3	AWARDED AMOUNT
4	PRIMARY COUNTY
5	DISTRICT
6	ITEM LINE NUMBER
7	ITEM SPEC BOOK
8	ITEM
9	DESCRIPTION
10	SUPPLEMENTAL DESCRIPTION
11	ITEM CLASS
12	ITEM CLASS DESCRIPTION
13	ITEM TYPE
14	ITEM TYPE DESCRIPTION
15	ENGINEER ESTIMATED UNIT PRICE
16	ITEM QUANTITY
17	UNIT
18	BID PRICE
19	EXTENDED AMOUNT
20	VENDOR RANKING
21	WARRANTY
22	ITEM SPEC BOOK

APPENDIX B: ITEMS DRIVING MHCCI PEAKS

Table A-2. A partial list of items driving quarterly MHCCI peaks

ITEM	Description	2014 Q4 Peak	2015 Q4 Peak	2017 Q4 Peak	2018 Q3 Peak	2019 Q3 Peak
7060050	Expansion Joint Device		×			
6030048	Pavt Repr, Nonreinf Conc, 10 inch	×				
6020524	Shoulder, Nonreinf Conc, High Performance					×
5010703	HMA, LVSP	×			×	
5010057	HMA, 5E3			×	×	
5010061	HMA Approach	×	×	×	×	
5010515	HMA, 5E3, High Stress	×				
5010059	HMA, 5E30				×	
5010058	HMA, 5E10	×				
5010056	HMA, 5E1	×		×		×
5010052	HMA, 4E10		×			
5010053	HMA, 4E30				×	
5010051	HMA, 4E3		×			×
5010050	HMA, 4E1	×				
5010045	HMA, 3E3		×		×	
5010025	Hand Patching					×
5010020	Pavt Joint and Crack Repr, Det 7	×				×
5010002	Cold Milling HMA Surface	×	×	×	×	
3020016	Aggregate Base, 6 inch		×	×	×	×
3010002	Subbase, CIP		×			
2050016	Excavation, Earth		×			
2040050	Pavt, Rem			×	×	×

Note: × denotes that this bid item contributes to the index peak

APPENDIX C: MHCCI VALUES

Table A-3. Category-level quarterly index, base 2010 Q2

Year	FISCAL QUARTER	MICHIGAN	Earthwork	Bases	Drainage Features	HMA Pavements
2010	Q2	1.0000	1.0000	1.0000	1.0000	1.0000
	Q3	0.9847	0.8389	0.9044	1.0085	0.9280
	Q4	0.9893	1.1562	1.1524	1.0389	0.9249
2011	Q1	1.0046	1.0229	1.0469	0.9798	0.9988
	Q2	0.9740	1.0024	1.1157	1.0347	0.9277
	Q3	1.0630	0.9924	1.1511	1.0879	1.0355
	Q4	1.0819	1.0665	1.2786	0.9535	1.0490
2012	Q1	1.0478	0.8972	1.0246	1.2400	1.1097
	Q2	1.0444	0.9374	1.1437	1.0814	1.1050
	Q3	1.0695	1.1872	1.2227	1.0428	1.0997
	Q4	1.0213	0.8534	1.0989	1.1381	1.1338
2013	Q1	1.0522	1.0049	1.0858	1.1923	1.0422
	Q2	1.0531	0.8197	0.8775	1.1538	1.0590
	Q3	1.0961	1.3141	0.9301	1.1102	1.0287
	Q4	1.0906	0.9199	1.1218	1.1872	1.0731
2014	Q1	1.0571	1.2128	0.7917	1.0565	1.0693
	Q2	1.0797	1.0678	0.9248	1.1101	1.0697
	Q3	1.0944	1.1178	0.8893	1.0738	1.0908
	Q4	1.2051	1.7738	1.2707	1.2008	1.2259
2015	Q1	1.1624	1.1826	1.2016	1.1609	1.2397
	Q2	1.1074	1.2038	0.9476	1.0532	1.1679
	Q3	1.1543	1.5993	1.2185	1.1526	1.0524
	Q4	1.2843	2.0299	1.5609	1.1313	1.2565
2016	Q1	1.1359	1.4658	1.2565	1.2410	1.0534
	Q2	1.1428	1.6543	1.3107	1.3476	1.0256
	Q3	1.1791	1.8859	1.2003	1.1324	1.0558
	Q4	1.2197	2.5411	1.2810	1.2645	1.0542
2017	Q1	1.0901	1.5683	1.0912	1.1669	0.9920
	Q2	1.0790	1.8464	0.9657	1.0831	1.0241
	Q3	1.0749	1.8186	1.0928	1.2257	0.9611
	Q4	1.2304	2.3260	1.1876	1.3369	1.1998
2018	Q1	1.1861	2.1270	1.1911	1.2996	1.0343
	Q2	1.2076	2.0916	1.0815	1.2728	1.0352
	Q3	1.3510	2.5955	1.4905	1.2649	1.1878
	Q4	1.3812	2.4506	1.0720	1.1791	1.3257
2019	Q1	1.3352	2.3563	1.1305	1.5559	1.1503
	Q2	1.3227	2.6092	1.1530	1.3589	1.1532
	Q3	1.4672	2.6952	1.4071	1.6032	1.2848
	Q4	1.4851	2.8172	1.4512	1.6204	1.2690
2020	Q1	1.4956	2.9395	1.4827	1.8439	1.2709

Table A-4. Category-level quarterly index, base 2010 Q2 (continued)

Year	FISCAL QUARTER	Bridges & Special Struc. + Struc. Steel	Electrical Construction, Sign	Pavement Marking	Structural Concrete Work	PCC Pavement	Temporary Traffic Control
2010	Q2	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	Q3	1.2615	0.9744	0.8684	1.1637	1.3273	0.9498
	Q4	0.9450	1.0302	1.0885	1.0874	0.9346	0.9816
2011	Q1	0.9653	1.0421	1.0674	1.1410	0.9326	1.0837
	Q2	0.9295	1.0149	0.9214	1.1470	0.9481	1.0989
	Q3	1.0803	1.0275	1.0085	1.2109	1.2103	0.9824
	Q4	1.1583	1.0873	1.1530	1.1092	1.4200	0.8933
2012	Q1	1.0445	0.9093	1.3822	1.2496	1.0812	1.0897
	Q2	1.0142	0.8678	1.0787	1.2646	1.1116	0.8861
	Q3	1.0278	0.8940	1.0397	1.2486	1.1945	0.8664
	Q4	0.7127	0.9165	1.0488	1.1723	1.2453	0.9445
2013	Q1	0.8216	0.8864	0.8732	1.2467	1.2701	0.9214
	Q2	0.9008	0.9282	1.0299	1.2303	1.3703	0.9713
	Q3	0.9294	0.9348	1.0654	1.3783	1.4071	1.0017
	Q4	0.9270	0.9654	1.1131	1.5072	1.4052	0.9843
2014	Q1	0.8211	0.9122	1.0465	1.2617	1.2940	1.0598
	Q2	1.0463	0.9182	1.0354	1.4330	1.2437	1.0061
	Q3	1.1118	0.9759	1.0463	1.4258	1.2440	1.0019
	Q4	1.0042	0.8924	0.9768	1.6730	1.2832	0.9036
2015	Q1	1.1257	1.0068	1.0379	1.4875	1.3658	1.0154
	Q2	1.1303	0.9875	1.0140	1.6240	1.2558	0.9392
	Q3	1.1710	1.0293	1.0061	2.0026	1.4685	0.8631
	Q4	1.0963	1.0788	1.0972	1.7312	1.3266	0.9593
2016	Q1	1.0547	1.0609	1.0630	1.6618	1.4426	1.0368
	Q2	1.0187	1.0721	0.9970	1.6397	1.3474	1.1039
	Q3	1.1823	1.2043	1.0395	1.7319	1.4650	1.0365
	Q4	1.0666	1.1415	1.0404	1.7852	1.5690	0.9219
2017	Q1	1.0217	1.1308	1.1284	1.5767	1.6076	1.0271
	Q2	1.0204	1.0873	1.0186	1.4650	1.4505	0.9689
	Q3	0.8471	1.1825	0.9565	1.6076	1.6747	0.9194
	Q4	0.9536	1.2961	1.0753	1.7274	1.6963	0.9264
2018	Q1	1.0760	1.2759	1.1005	1.2722	1.7677	0.8962
	Q2	1.3219	1.3095	1.0351	1.1615	1.6995	0.8257
	Q3	1.2241	1.3205	1.0162	1.1625	1.8147	0.8249
	Q4	1.0531	1.3287	1.1106	1.1683	1.8034	0.9547
2019	Q1	1.2354	1.3433	1.1261	1.3914	1.5116	0.9749
	Q2	1.3217	1.3656	1.0850	1.3149	1.1585	0.9550
	Q3	1.4046	1.4657	1.0944	1.4430	1.3606	0.9716
	Q4	1.5051	1.4040	1.1536	1.5225	1.4443	1.0396
2020	Q1	1.3253	1.4836	1.1546	1.4161	1.5940	0.9995

Table A-5. Category-level annual index, base year 2010

CALENDAR YEAR	MHCCI	Earthwork	Bases	Drainage Features	HMA Pavements	PCC Pavements	Bridges & Special Struc. + Struc. Steel	Structural Concrete Work	Electrical Construction, Sign	Temporary Traffic Control	Pavement Marking
2010	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2011	1.0248	0.9828	1.0814	0.9694	1.0005	1.0998	1.0558	1.0196	1.0267	1.0223	1.1047
2012	1.0734	0.9671	1.2381	1.1315	1.0982	1.1827	0.9732	1.0971	1.0151	0.9714	1.1347
2013	1.0938	1.0870	1.1464	1.1541	1.0935	1.2470	0.9837	1.1092	1.0809	1.0733	1.1709
2014	1.1995	1.1908	1.4808	1.3118	1.1757	1.3783	1.1719	1.2659	1.1368	1.0847	1.1404
2015	1.2239	1.3780	1.4331	1.3488	1.1641	1.4112	1.1712	1.4335	1.1930	1.1147	1.1174
2016	1.2572	1.6710	1.5860	1.4472	1.0983	1.5166	1.1753	1.6044	1.2467	1.2086	1.1210
2017	1.2691	1.7215	1.5793	1.4039	1.1418	1.4986	1.1965	1.5634	1.2578	1.1218	1.0747
2018	1.3567	1.9462	1.7888	1.4112	1.2405	1.4774	1.3165	1.5934	1.3327	1.1686	1.0382
2019	1.4540	2.0185	1.9933	1.5643	1.3352	1.4681	1.3755	1.7040	1.4152	1.3203	1.1414

Table A-6. Region annual MHCCI, base year 2010

CALENDAR YEAR	MHCCI	Superior	North	Grand	Bay	Southwest	University	Metro
2010	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2011	1.0248	1.0278	1.0159	1.0747	1.0235	1.0740	1.1025	0.9844
2012	1.0734	1.1146	1.0708	1.0975	1.0741	1.1088	1.1097	1.0978
2013	1.0938	1.1156	1.0649	1.0946	1.1226	1.1488	1.2607	1.0834
2014	1.1995	1.2226	1.1553	1.2542	1.1721	1.2150	1.2173	1.3390
2015	1.2239	1.1973	1.1050	1.2849	1.2715	1.2227	1.3531	1.2536
2016	1.2572	1.1781	1.0920	1.2007	1.2600	1.2858	1.3141	1.4008
2017	1.2691	1.2115	1.0808	1.2012	1.3352	1.3015	1.2985	1.3665
2018	1.3567	1.2893	1.1237	1.2777	1.3578	1.3702	1.4772	1.4571
2019	1.4540	1.4039	1.3013	1.3942	1.4392	1.4617	1.6313	1.5953

APPENDIX D: PEARSON CORRELATION COEFFICIENT

Table A-7. Pearson correlation coefficient matrix, construction material PPI and MHCCI

	MHCCI	*Asphalt and Tar Pavement Mixture PPI*	*Cement and Concrete Product PPI*	*Fabricated Structural Metal PPI*	*Cement, Hydraulic PPI*	*Ready-Mix Concrete Manufacturing*	*Construction Machinery Manufacturing*	*Power Cranes Draglines and Shovels Excavators*
MHCCI	1							
Asphalt and Tar Pavement Mixture PPI	0.64	1						
Cement and Concrete Product PPI	0.87	0.6	1					
Fabricated Structural Metal PPI	0.89	0.72	0.83	1				
Cement, Hydraulic	0.82	0.5	0.99	0.77	1			
Ready-Mix Concrete Manufacturing	0.86	0.59	1	0.82	0.99	1		
Construction Machinery Manufacturing	0.85	0.76	0.92	0.83	0.86	0.91	1	
Power Cranes Draglines and Shovels Excavators	0.8	0.69	0.88	0.75	0.84	0.87	0.98	1

APPENDIX E: INDEX YEAR-OVER-YEAR CHANGE

Table A-8. Year-over-year changes of MHCCI and construction material PPI

YEAR	MHCCI	Asphalt and Tar Pavement Mixture PPI	Cement and Concrete Product PPI	Fabricated Structural Metal PPI	Cement, Hydraulic	Ready-Mix Concrete Manufacturing	Construction Machinery Manufacturing	Power Cranes Draglines and Shovels Excavators
2010	-	-	-	-	-	-	-	-
2011	2.48%	4.70%	-0.20%	4.41%	-3.47%	-0.63%	3.32%	3.08%
2012	4.74%	5.53%	1.91%	2.21%	0.72%	2.29%	3.34%	1.34%
2013	1.89%	-0.16%	2.93%	-0.05%	4.60%	3.08%	1.60%	2.06%
2014	9.66%	2.51%	4.11%	0.87%	4.43%	4.43%	1.34%	1.35%
2015	2.04%	-1.31%	4.19%	-0.56%	7.43%	4.64%	1.19%	1.47%
2016	2.72%	-3.03%	3.14%	-1.21%	5.31%	3.55%	0.74%	0.28%
2017	0.95%	-0.72%	2.88%	3.56%	4.62%	3.03%	0.54%	1.12%
2018	6.90%	6.22%	3.65%	10.86%	2.48%	4.25%	0.98%	-1.75%
2019	7.17%	3.95%	3.00%	2.48%	2.38%	2.59%	4.46%	5.80%