Civil and Project Journal, 2026, 8(5), 11-32
https://doi.org/10.22034/cpj.2026.584929.1445

Civil and Project Journal
http://www.cpjournals.com/

Research Article

Highway Construction Cost Escalation in the United States: Component-Level NHCCI Evidence and Project Management Implications

Ali Shahbazi*[1], Ali Sayyad[2]

*1 – Ms in Civil Engineering, Department Civil Engineering, Islamic Azad University, Science and Research Branch, Tehran, Iran
2 - Ms in Civil Engineering ,Department Civil Engineering, Islamic Azad University, Pardis Branch, Tehran,Iran

Received: 03 May 2026; Revised: 06 June 2026; Accepted: 10 June 2026; Published: 23 July 2026

Abstract

Highway construction cost escalation poses a persistent challenge for transportation agencies, yet the component-level structure of this growth remains poorly understood. This study analyses 91 quarterly observations of the U.S. National Highway Construction Cost Index (NHCCI) from 2003 Q1 to 2025 Q3, applying component-level contribution analysis, volatility ranking, pre- versus post-2020 comparison, and ARIMA time-series modeling. The aggregate NHCCI grew by 230.8% over the study period, with 68.0% of that growth occurring in just 23 quarters after 2020. While asphalt was the dominant long-run contributor, the post-2020 period revealed a fundamentally different pattern ; traffic control (+468%), concrete (+341%), and electrical (+292%) recorded the largest proportional increases, indicating that recent cost escalation extended well beyond petroleum-linked materials and became broad-based across all major pay-item groups. ARIMA(3,1,3) forecasting projects near-term stabilisation of the index between 3.29 and 3.40 through 2026 Q3. The central message of this study is that infrastructure agencies can no longer rely on aggregate escalation factors alone. Cost forecasting, contingency allocation, and price adjustment clause design must be grounded in component-specific evidence , because in the post-2020 environment, the risk is everywhere, not just in asphalt.

Keywords: *Highway construction cost, NHCCI, cost escalation, component-level analysis, infrastructure project management, contingency planning.*

Cite this article as Shahbazi,A and Sayyad,A . (2026). Highway Construction Cost Escalation in the United States: Component-Level NHCCI Evidence and Project Management Implications. (e245257). Civil and Project, 8(5), e245257 doi: https://doi.org/10.22034/cpj.2026.584929.1445

ISSN: 2676-511X / **Copyright:** © 2026 by the authors.

*Corresponding author E-mail address: *alishahbazi.civilengineer@gmail.com*

1. Introduction

Highway infrastructure plays a central role in supporting economic activity, regional connectivity, freight movement, and public accessibility in the United States. Highway construction cost change is therefore a critical issue for transportation agencies because it affects infrastructure planning, programming, and delivery FHWA (2024). Highway projects are also capital-intensive and are commonly delivered over long planning, design, procurement, and construction horizons. Anderson et al. (2007) argue that cost estimation should therefore be treated as a continuous management process across the project development cycle. Cost escalation in this context is not simply a matter of general inflation. Shane et al. (2009), based on evidence from more than 20 U.S. state highway agencies, classify cost escalation drivers into internal factors, such as scope changes, procurement strategy and estimating practice, and external factors, such as inflation, market conditions and unforeseen events. Touran and Lopez (2006) further show that escalation risk becomes especially important in multi-year infrastructure projects, where uncertainty compounds over time.

The problem has become more visible since 2020. Davis (2024) reports that the NHCCI increased for eleven consecutive quarters and was approximately 69% higher in 2023 Q3 than in 2020 Q4. Rising highway construction costs have also reduced the real purchasing power of federal infrastructure funding. The Bureau of Transportation Statistics (2024) estimates that, under a high-inflation scenario, IIJA highway funding could lose nearly 40% of its 2021 purchasing power, meaning that the same nominal funding would deliver substantially less highway construction than originally expected. Yet escalation did not affect all pay-item groups equally. Wong and Swei (2021) show that disaggregated highway cost indices provide more useful management information than aggregate indices alone. Shrestha et al. (2017) further demonstrate that multidimensional indices can reveal variation across project type, size, region, and pay-item composition. The National Highway Construction Cost Index (NHCCI) is particularly suitable for examining this issue because it is based on winning-bid prices reported by state transportation agencies rather than on broad consumer or producer prices (FHWA, 2024). As an output-based construction cost index, it captures the prices actually paid for highway construction work and reflects market conditions embedded in contractors' bids. In addition to the aggregate index, the NHCCI provides component-level classifications at 9, 13, and 25 pay-item groupings, allowing researchers to examine how different categories of highway construction work contribute to overall escalation. Shahandashti and Ashuri (2016) also demonstrate the usefulness of NHCCI for modeling highway construction cost movements in relation to broader economic indicators.

Existing research has examined transportation cost overruns, highway construction cost indices, material-price forecasting, and cost management practices. Flyvbjerg et al. (2003) show that transport infrastructure cost escalation is systematic and statistically significant, with average escalation of about 20% for roads and 34% for fixed links, including bridges and tunnels, across 20 nations. Forecasting studies have examined construction cost indices using statistical and time-series methods, but they often focus on aggregate indices rather than component-level attribution (Ashuri & Lu, 2010). Project management studies discuss contingency planning, year-of-expenditure estimates, and price adjustment clauses, but they do not always connect these practices to long-run component-level evidence from national highway construction cost data (Alsharef et al., 2024).

This gap is particularly important for the post-2020 period. If recent escalation was driven mainly by asphalt or petroleum-linked materials, management responses could focus primarily on asphalt price adjustment clauses and fuel-sensitive estimates. Damnjanovic and Zhou (2009) show that crude oil market behavior affects highway unit bid prices, while Ilbeigi et al. (2017) highlight the distinctive volatility of asphalt-cement prices. However, (Abdul Nabi et al., 2024) show that inflationary shocks can transmit across multiple construction materials with lag effects. If post-2020 escalation became broad-based across multiple pay-item groups, infrastructure agencies need a more comprehensive component-specific approach to budgeting, contingency allocation, procurement strategy, and contract risk allocation.

Accordingly, this study examines highway construction cost escalation in the United States from 2003 Q1 to 2025 Q3 using the NHCCI and its component-level classifications. The analysis is guided by three research questions:

RQ1. Which NHCCI components contributed most to highway construction cost escalation in the United States between 2003 and 2025, and how did their relative contributions evolve across economic cycles?

RQ2. Did the post-2020 inflationary period change the hierarchy of highway construction cost drivers?

RQ3. How can component-level NHCCI evidence inform infrastructure project management decisions, particularly in relation to cost forecasting, contingency planning, procurement strategy, and price adjustment clause design?

To answer these questions, the study applies a quantitative longitudinal design using 91 quarterly NHCCI observations. The analysis combines descriptive trend analysis, four-period comparison, component-level contribution analysis, and supporting ARIMA time-series modeling. It first examines the long-run trajectory of the aggregate NHCCI, then compares escalation across four economic sub-periods, and finally decomposes cost growth into major component categories. Particular attention is given to the pre- and post-2020 comparison to assess whether recent inflation represents a structural shift in highway construction cost dynamics.

The study makes three contributions. First, it provides a long-run component-level analysis of U.S. highway construction cost escalation from 2003 to 2025, extending earlier NHCCI and disaggregated cost-index studies into the post-pandemic period. Second, it identifies whether the post-2020 cost surge was concentrated in traditional high-risk components such as asphalt or distributed across a wider set of pay-item groups. Third, it translates component-level NHCCI evidence into project management implications, particularly for cost forecasting, contingency planning, procurement strategy, and price adjustment clauses. In this way, the study positions NHCCI not only as a descriptive cost index, but also as a decision-support tool for managing budget risk in highway infrastructure programs.

2. Literature Review

2.1. Cost Escalation in Transportation Infrastructure Projects

Cost escalation is a major source of budget risk in transportation infrastructure projects because these projects are typically delivered over long planning, procurement, and construction periods(Etesami et al., 2024; Maniat, 2024; Raufi & Maniat, 2024). In highway projects, escalation is driven not only by general inflation, but also by material-price volatility, labour costs, contractor capacity, procurement conditions, project complexity, and weaknesses in early-stage estimating. Touran and Lopez (2006) show that escalation risk becomes especially important in multi-year infrastructure projects, while Shane et al. (2009) identify both internal drivers, such as scope change and estimating practice, and external drivers, such as inflation and market conditions. The broader literature shows that transport infrastructure cost growth is not merely a technical estimating error. Flyvbjerg et al. (2003) demonstrated that cost overruns are systematic across transport infrastructure projects rather than random deviations from initial estimates. Flyvbjerg et al. (2004) further showed that longer implementation periods increase escalation risk, making time itself a source of financial exposure in infrastructure delivery. Together, these studies shifted the discussion from isolated estimating errors toward cost escalation as a recurring structural problem in transport infrastructure projects. This distinction links NHCCI-based market signals to project-management responses such as forecasting, contingency planning, procurement timing and contract design. International evidence further shows that cost escalation is not limited to the U.S. context. (Cantarelli et al., 2013) classify cost-overrun explanations into technical, economic, psychological and political categories. In a related empirical study, (Cantarelli et al., 2012) found mean cost overruns of 18.6% for Dutch road projects and showed that each additional year in the pre-construction phase increased cost growth by about five percentage points. Odeck (2004) analysed 620 Norwegian road projects and reported a mean overrun of 7.9%, with smaller projects showing higher overrun rates. These findings suggest that escalation is recurrent across transport infrastructure, but its magnitude and drivers vary across institutional and project contexts. Cost escalation should be distinguished from cost overrun. While cost overrun refers to the gap between an approved budget and final project cost, cost escalation refers to changes in construction prices or bid costs over time. This distinction is important because the NHCCI measures average prices paid for highway construction work, not project-level budget overruns. Welde and Dahl (2021) found average contract escalation of 17% in 712 Norwegian road contracts, mainly driven by change orders, showing that market-level price movements can interact with project complexity to create budget pressure.

2.2. Highway Construction Cost Indices and the Role of NHCCI

Highway construction cost indices are used to support cost estimation, budgeting, inflation adjustment, and program-level financial planning. Wilmot and Cheng (2003)developed a state-level highway construction cost index incorporating labour, equipment, materials, and contract characteristics, showing that highway costs vary substantially over time and require index-based forecasting in long-duration programs. Cheng and Wilmot (2009) further showed that external shocks can produce sharp and uneven cost increases; after Hurricanes Katrina and Rita, highway construction costs in affected zones rose by approximately 51% within two quarters, with asphalt and structural components as the main drivers. This provides an important precedent for examining how discrete shocks affect different highway construction components, a logic that is directly relevant to the post-2020 period analysed in this study. In the United States, the National Highway Construction Cost Index (NHCCI) is the main national reference for monitoring highway construction cost changes. Maintained by the Federal Highway Administration, the NHCCI is based on winning-bid data reported by state transportation agencies (FHWA, 2024). Unlike input-price indices, which track the prices of individual inputs such as asphalt, cement, steel, or labour, the NHCCI is an output-based index. It therefore reflects the prices actually paid for highway construction work, including materials, labour, equipment, transport, installation, overhead, profit, contractor expectations, and market risk embedded in bids. This distinction is important because NHCCI movements cannot be explained solely by commodity price indices or broad Producer Price Indices. Methodologically, the NHCCI uses a chained Fisher Ideal Index based on pay-item quantities and costs. This structure makes it suitable for longitudinal analysis because it captures highway construction price changes while accounting for shifts in the composition of construction work. FHWA also provides component-level contributions across three levels of disaggregation: grp9, grp13, and grp25, representing 9, 13, and 25 pay-item categories respectively (FHWA, 2021). These categories include major highway construction components such as asphalt, concrete, bridge work, grading/excavation, drainage, base stone, traffic control, electrical work, and utilities. (Shrestha et al., 2016) show that the Fisher Ideal Index is widely used in highway construction cost index practice, supporting the methodological relevance of this approach. The component-level structure is central to the present study. Aggregate indices show whether highway construction costs are rising, but they do not identify which types of work are responsible for that increase. A component-level approach makes it possible to distinguish whether escalation is driven by asphalt, structures, earthwork, traffic control, drainage, or other pay-item groups. This matters because each component's effect on aggregate escalation depends on both its price movement and its cost share. Recent FHWA evidence indicates that post-2020 NHCCI movements cannot be explained by asphalt prices or general inflation alone. The 2024 Q3 narrative shows that NHCCI diverged from CPI and broad PPI measures: while NHCCI increased by 6.5% from 2024 Q2 to 2024 Q3, CPI increased by only 0.3% and PPI declined by 0.4% (Federal Highway Administration, 2025). The report also notes that the asphalt PPI declined even as NHCCI increased, suggesting that highway construction cost escalation reflects more than asphalt input prices alone. Component contributions further show that grading/excavation and bridge work were the largest contributors to quarterly NHCCI growth, while concrete, utilities-related work, and traffic control also made notable contributions(Federal Highway Administration, 2025). Figure 1 reinforces this interpretation. It shows that NHCCI rose much faster than general inflation after 2020, while material-related PPIs followed uneven and highly volatile trajectories. Asphalt showed extreme volatility, fabricated structural metal rose sharply during 2021–2022, and paving mixtures increased more gradually. This pattern supports a component-level approach because aggregate NHCCI movements reflect not only material prices, but also labour, transport, overhead, contractor risk, and the cost share of each pay-item group.

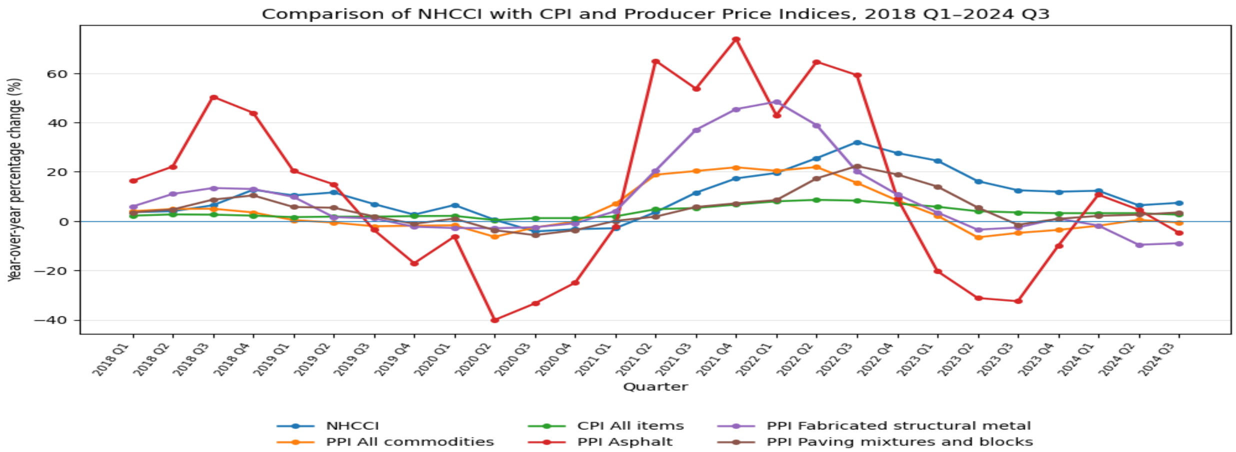

Figure 1. Year-over-year comparison of NHCCI with CPI and selected Producer Price Indices, 2018 Q1–2024 Q3.

Source: NHCCI data are from the Federal Highway Administration, Office of Transportation Policy Studies, *National Highway Construction Cost Index: 2024 Q3 Estimates*. CPI and PPI data are from the U.S. Bureau of Labor Statistics.

2.3. Component-Level Cost Escalation: Materials, Pay Items, and Market Drivers

Highway construction cost escalation is heterogeneous across pay-item groups because each component is exposed to different market and project-level drivers. Asphalt is closely linked to crude oil and petroleum markets, but asphalt bid prices also include transport, installation, labour, overhead, and contractor margins. Concrete and bridge-related items are shaped by cement, steel, fabrication, structural complexity, and labour availability, while grading/excavation is more sensitive to fuel prices, equipment costs, haul distance, earthwork quantities, and site conditions. Damnjanovic and Zhou (2009) show that crude oil market behavior affects highway unit bid prices beyond asphalt-related items, including concrete and operational items. This suggests that energy-price shocks can diffuse across several highway construction components. Ilbeigi et al. (2017) further show that asphalt-cement prices have strong time-series dependence and seasonality, supporting the need to treat asphalt as a distinct and highly volatile cost component.

Long-run material price studies show that highway cost components should not be treated as interchangeable. Swei et al. (2017) found different volatility patterns between asphalt and concrete pavements, while Abdul Nabi et al. (2024) show that inflationary shocks can transmit across construction materials with measurable lag effects. This suggests that cost pressures may move sequentially across components rather than appearing simultaneously in the aggregate index. Liu et al. (2024) add project-level evidence from Michigan DOT bid data, showing that item-specific indices can improve budgeting and identify which pay items are driving cost pressure. Together, these studies support the need for a component-level NHCCI analysis that can identify dominant cost drivers, detect post-2020 shifts, and inform project-management responses.

2.4. Forecasting Construction Cost Escalation

Forecasting construction cost escalation is important because transportation agencies often estimate project costs years before construction is completed. Early studies used statistical time-series models such as ARIMA and SARIMA. (Ashuri & Lu, 2010) showed that ARIMA-based models provide a useful benchmark for construction cost index forecasting and can outperform subjective forecasting approaches. Later studies emphasised that highway construction costs are influenced by broader economic conditions. Shahandashti and Ashuri (2016), using vector error correction models, identified crude oil prices, producer price indices, money supply, and construction wages as leading indicators of NHCCI movements. Their findings suggest that multivariate models can improve forecasting because highway construction prices are linked to material markets, labour costs, and macroeconomic dynamics. Recent work has introduced machine learning and hybrid models. Huseynov et al. (2018) applied Lasso, Ridge, Elastic Net, and Random Forest models to Texas highway cost index data and reported strong predictive performance. Such methods are useful in volatile periods, but forecasting is not the central contribution of the present study. Here, time-series modeling is used only as a supporting analysis, while component-level contribution analysis remains the methodological core.

2.5. Cost Escalation and Infrastructure Project Management

The project-management implications of highway cost escalation are substantial. Cost escalation affects budget reliability, contingency planning, procurement timing, contract strategy, and risk allocation(Welde & Dahl, 2021). If agencies underestimate future construction price growth, project budgets may become insufficient before procurement or during construction. This may lead to scope reductions, delayed letting, rebidding, contract modifications, or additional funding requests(Morad, 2023).

The literature on cost estimation and management for highway projects emphasises the importance of incorporating escalation and risk into early-stage estimates. Anderson et al. (2007) argued in NCHRP Report 574—the benchmark cost-estimation and management guidance for U.S. state DOTs—that cost estimation for highway projects should be treated as a continuous management process from planning through programming and preconstruction, specifying that estimates must include year-of-expenditure escalation adjustments reflecting local market conditions. Similarly, Touran and Lopez (2006) showed that contingency should be treated probabilistically rather than as an arbitrary percentage added to the base estimate, and Touran and Lopez extended this to show that failure to account for escalation correlation across years in multi-year programs leads to systematic underestimation of cost-to-complete. These studies are important because they show that escalation is not only an economic issue but also a fundamental project-management problem that requires structured, evidence-based responses.

Price adjustment clauses represent another important management response. In fixed-price contracts, material price volatility leads contractors to embed risk premiums in bids; adjustment clauses can redistribute this risk by linking payments to specified indices (Alsharef et al., 2024). Most U.S. DOTs apply a 5% threshold trigger with an indexed material-usage formula, but rarely connect clause design to long-run NHCCI component patterns (Naghdi et al., 2026). This creates an opportunity for the present study. By identifying which components are most volatile and which contribute most to aggregate escalation, the analysis can support more targeted management strategies — including component-specific contingency thresholds and contract clauses tailored to the most cost-significant pay-item groups (Liu et al., 2024).

2.6. Research Gap

The reviewed literature shows that highway construction cost escalation has been examined from several perspectives: infrastructure cost overruns(Cantarelli et al., 2012), highway cost index construction, material-price forecasting(Ilbeigi et al., 2017), macroeconomic leading indicators, and project management practice. However, these strands remain only partially connected. General cost-overrun studies explain why transportation projects often exceed budgets, but they do not provide component-level evidence from U.S. highway construction bid data. Forecasting studies provide useful models for aggregate indices(Shahandashti & Ashuri, 2016), but they often do not identify which pay-item groups drive escalation. Management studies discuss contingencies, inflation, and contract adjustment, but they rarely connect these practices to long-run NHCCI component contributions. Three convergent gaps define the contribution of the present study. First, no longitudinal study has systematically decomposed NHCCI component contributions across the full 2003–2025 period, which uniquely encompasses four economically distinct regimes: the commodity-driven boom of 2003–2008, the post-financial-crisis contraction of 2009–2012, a period of relative stability through 2019, and an unprecedented post-COVID surge that produced the highest annual NHCCI growth rate in the index's history during 2022. Existing component-level work is either state-specific (Liu et al., 2024), material-type limited (Swei et al., 2017), or focused on shorter pre-2020 windows (Shahandashti & Ashuri, 2016). Second, FHWA reports indicate that NHCCI has diverged from broad CPI and PPI measures in recent years and that different construction components dominate cost escalation in different quarters (FHWA, 2024), yet academic work still relies heavily on aggregate index forecasting rather than sustained attribution across changing component hierarchies. Third, the project-management literature on contingencies (Anderson et al., 2007), PAC design , and DOT practice ((Alsharef et al., 2024) references construction cost escalation as context but does not use component-level index decomposition to generate specific managerial thresholds or decision rules. Accordingly, the present study is positioned to address three research questions. First, which NHCCI components contributed most to highway construction cost escalation in the United States between 2003 and 2025, and how did their relative contributions evolve across economic cycles? Second, did the post-2020 inflationary period represent a structural shift in the hierarchy of cost drivers compared with earlier periods? Third, how can component-level escalation evidence inform infrastructure project management decisions—particularly in relation to year-of-expenditure cost forecasting, contingency planning, procurement strategy, and price adjustment clause design?

By answering these questions, the study contributes to both transportation infrastructure cost research and construction project management. It moves beyond aggregate cost escalation to provide a more operational understanding of how specific highway construction components shape budget risk. It also translates index-based evidence into practical implications for public agencies and project managers responsible for planning, funding, and delivering highway infrastructure in the United States.

Table 1. Summary of Key Prior Studies Relevant to the Present Research

Study	Country	Data / Period	Method	Main Finding	Gap Addressed by Present Study
Flyvbjerg et al. (2003)	20 nations	258 transport projects	Comparative statistics	20–44% avg. overrun by mode; systematic, not random	No NHCCI; no component attribution; not bid-index based
Shane et al. (2009)	U.S.	20+ state DOT interviews	Factor taxonomy	18 escalation factors; ~50% of projects overrun	Qualitative taxonomy; no quantitative NHCCI decomposition
Cantarelli et al. (2012)	Netherlands	712 road contracts, 2003–2012	Regression analysis	Mean 18.6% overrun; +5 pp per extra pre-construction year	International; no U.S. bid-index component analysis
Shahandashti & Ashuri (2016)	U.S.	NHCCI pre-2015	VECM / Granger	Oil & wages lead NHCCI; multivariate > univariate	Aggregate NHCCI only; no grp9/grp25 component analysis; no post-2020
Shrestha et al. (2017)	U.S. (Montana)	Montana DOT bids	Dynamic item basket	Multidimensional HCCIs reveal hidden patterns	State-specific; not national; no post-2020 period
Wong & Swei (2021)	U.S.	FHWA / state data	Disaggregated HCCI	AC 3.5%/yr vs PCC 2.1%/yr; $6–8B savings potential	Material-type split only; no 25-component temporal decomposition
Alsharef et al. (2024)	U.S.	13 state DOTs, survey	Practice survey	Contingency & YOE inflation practices documented	Management practice; no NHCCI component linkage
Abdul Nabi et al. (2024)	U.S.	PPI for 16 materials	VAR / Granger	Asphalt/steel inflation transmits with 1–3 quarter lag	PPI-based; does not use NHCCI bid-tabs component hierarchy
Liu et al. (2024)	U.S. (Michigan)	MDOT item-level bids	Item/contract index	Granular indices improve budgeting & risk management	State-level; not national 22-year panel with grp25 hierarchy
Naghdi et al. (2025)	U.S.	State PAC documents & survey	Practice review	Most DOTs use 5% PAC trigger; asphalt-indexed formula	Contract clauses studied without long-run NHCCI component analysis

2.7 Novel Contribution

Against this background, the present study makes three specific contributions that distinguish it from prior work. First, it provides a comprehensive component-level decomposition of NHCCI escalation across the full 2003–2025 period, covering four economically distinct regimes: the pre-crisis commodity boom, the financial crisis contraction, the post-recession stability phase, and the unprecedented post-COVID surge. This extends earlier NHCCI-related studies into a period that has not yet been comprehensively examined at the component level. Second, the study evaluates whether the post-2020 inflationary episode represents a structural shift in the hierarchy of highway construction cost drivers by moving beyond aggregate index comparisons and identifying which specific pay-item groups became disproportionately inflationary after 2020. Third, it translates component-level index evidence into project management implications by providing infrastructure agencies and project managers with a more targeted basis for cost forecasting, contingency allocation, procurement timing, and price adjustment clause design than aggregate escalation factors alone can offer. In this way, the study positions the NHCCI not merely as a descriptive monitoring tool, but as an operational decision-support instrument for managing budget risk in highway infrastructure programs.

3. Methodology

3.1. Research Design

This study adopts a quantitative and longitudinal research design to examine highway construction cost escalation in the United States from 2003 Q1 to 2025 Q3. Following the logic of disaggregated highway cost index studies (Shrestha et al., 2017; Wong & Swei, 2021), the analysis is grounded in two central premises. First, aggregate construction cost indices may conceal heterogeneous component-level dynamics. Second, the post-2020 period may represent a structurally distinct inflationary regime that requires separate empirical treatment.

The methodology combines descriptive trend analysis, component-level contribution analysis, period comparison, volatility assessment, and time-series modeling. The component-level decomposition represents the core analytical contribution of the study, while the time-series modeling is used as a supporting analysis to assess the predictability of aggregate NHCCI movements. All analyses are conducted using the publicly available NHCCI dataset published by the Federal Highway Administration(FHWA, 2024).

3.2. Data Source and Variables

The empirical analysis is based on quarterly NHCCI data covering 91 observations from 2003 Q1 to 2025 Q3. The dataset includes three main groups of variables. The first group includes the aggregate National Highway Construction Cost Index (NHCCI) and its seasonally adjusted version (NHCCI-SA), which are used for trend analysis and time-series modeling. The second group includes the quarterly growth rate of NHCCI, calculated as:

$$g_t = \left(\frac{NHCCI_t - NHCCI_{t-1}}{NHCCI_{t-1}}\right) \times 100 \quad (1)$$

where $g_t$represents the percentage change in the aggregate NHCCI from quarter $t-1$to quarter t.

The third group includes component-level percentage changes, denoted as $C_{i,t}$, derived from three levels of disaggregation: 9 components (grp9), 13 components (grp13), and 25 components (grp25). The 9-component classification is used as the primary analytical framework because it provides a clear and interpretable structure for identifying major cost drivers. This classification includes asphalt, concrete, bridge, grading/excavation, base stone, drainage, traffic control, electrical work, and utilities or related categories. The 13- and 25-component classifications are used for robustness checks to examine whether the main findings remain stable under finer levels of disaggregation.

3.3. Analytical Procedure

The analysis is conducted in five sequential stages. First, descriptive trend analysis is used to examine the long-run trajectory of NHCCI and NHCCI-SA between 2003 Q1 and 2025 Q3. This stage includes the calculation of total growth, annualised growth, quarterly growth rates, and visual inspection of major periods of acceleration and decline. Second, a period comparison is conducted by dividing the dataset into four sub-periods: 2003 Q1 to 2007 Q4, representing the pre-financial crisis expansion period; 2008 Q1 to 2010 Q4, representing the financial crisis and immediate recovery period; 2011 Q1 to 2019 Q4, representing the post-recession stability period; and 2020 Q1 to 2025 Q3, representing the post-COVID inflationary period. For each period, descriptive statistics including mean, median, standard deviation, minimum, and maximum quarterly growth rates are calculated.

Third, component-level analysis is used to decompose aggregate cost escalation into major pay-item groups. For each component i, three indicators are calculated:

Mean_i = (1/T) Σ C_i,t (2)

Cum_i = Σ C_i,t (3)

Vol_i = SD(C_i,t) (4)

where Mean_i represents the average quarterly component contribution, Cum_i represents the cumulative contribution across the study period, and Vol_i represents the volatility of component i. Components are ranked by cumulative contribution and volatility to identify the dominant cost drivers and the most unstable cost categories.

Fourth, a pre- versus post-2020 comparison is conducted for each component to examine whether the hierarchy of cost drivers changed after the COVID-19 period. The difference in average component contribution is calculated as:

ΔC_i = C_i,post2020 − C_i,pre2020 (5)

where ΔC_i represents the change in the average contribution of component i after 2020. To formally test whether this shift was statistically significant, a Mann-Whitney U test was applied to each component, comparing the distribution of quarterly contributions in the pre-2020 (n = 68) and post-2020 (n = 23) sub-periods. This non-parametric test was selected because it does not assume normality and is robust to the unequal sample sizes of the two sub-periods. Additionally, a Chow Test was applied to the NHCCI quarterly growth rate series to formally evaluate whether a structural break occurred at 2020 Q1.

Fifth, time-series modelling using ARIMA is applied to the aggregate NHCCI to assess the predictability of cost movements and produce a near-term forecast. Full model diagnostics — including the Ljung-Box Q(12) test for residual autocorrelation, AIC, BIC, and in-sample forecasting performance indicators (MAE, RMSE, MAPE) — are reported to support the adequacy of the selected specification.

3.4. Time-Series Modeling

To complement the component-level analysis and assess the predictability of aggregate NHCCI, an ARIMA or SARIMA model is estimated as a supporting analysis. Stationarity is first evaluated using the Augmented Dickey-Fuller test. Since aggregate construction cost indices are typically non-stationary in levels, first differencing is applied if required.

The general ARIMA specification is expressed as:

$$\Delta NHCCI_t = \alpha + \sum_{j=1}^{p} \phi_j \, \Delta NHCCI_{t-j} + \sum_{k=1}^{q} \theta_k \, \varepsilon_{t-k} + \varepsilon_t \quad (6)$$

where $\Delta NHCCI_t$ represents the differenced NHCCI series, ϕ_j represents autoregressive parameters, θ_k represents moving-average parameters, and ε_t is the error term. Model selection is based on the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). If seasonal patterns are detected, a SARIMA specification is estimated:

$$SARIMA(p, d, q)(P, D, Q)_4 \quad (7)$$

where the seasonal period is set to four because the data are quarterly. The time-series model is not treated as the central contribution of the study; rather, it provides a benchmark for evaluating the predictability of aggregate NHCCI movements.

3.5. Robustness Checks

Two robustness checks are applied to verify the reliability of the findings. First, component rankings derived from the grp9 classification are compared with those from the grp13 and grp25 classifications to confirm that the dominant cost drivers remain stable across disaggregation levels. Second, the pre- versus post-2020 comparison is repeated using alternative break points — 2021 Q1 and 2022 Q1 — and independent-samples t-tests are applied at each break point to assess whether the post-break mean quarterly growth rate differs significantly from the pre-break rate. Consistency of results across both checks strengthens confidence in the component-level conclusions of results across both checks would strengthen confidence in the component-level conclusions.

3.6. Interpretation for Infrastructure Project Management

The empirical findings are interpreted in relation to four project management practices: year-of-expenditure cost forecasting, contingency planning, procurement strategy, and price adjustment clause design. For each practice, component-level NHCCI evidence — including cumulative contribution, volatility rankings, and pre- versus post-2020 shifts, is used to derive more targeted management implications than aggregate escalation factors alone can support. This interpretive stage positions NHCCI not only as a descriptive cost index, but as a decision-support tool for budgeting, risk allocation, and contract management in highway infrastructure programs.

3.7. Limitations

Four limitations should be acknowledged. First, NHCCI is a national-level index and does not capture regional variation across states. Second, the index measures bid-based price changes rather than final project cost overruns. Third, component-level values reflect aggregate market movements and do not identify project-level causes such as design changes or scope adjustments. Fourth, the post-2020 sub-period contains 23 quarterly observations, which supports descriptive and comparative analysis but limits the complexity of inferential models. Despite these constraints, the NHCCI dataset provides a consistent, open, and longitudinally complete national measure of U.S. highway construction cost change across more than two decades.

4.Result

This section presents the empirical findings in four stages: long-run NHCCI trajectory, four-period comparison, component-level contribution and volatility analysis, and pre- versus post-2020 comparison. All results are derived from 91 quarterly NHCCI observations covering 2003 Q1 to 2025 Q3 (FHWA, 2024a).

4.1. Long-Run Trajectory of the NHCCI (2003–2025)

The aggregate NHCCI increased from a base value of 1.000 in 2003 Q1 to 3.308 in 2025 Q3, representing cumulative growth of 230.8% over 91 quarterly observations (FHWA, 2024a). As illustrated in Figure 2, the index followed a broadly upward trajectory punctuated by three distinct phases of acceleration and one period of contraction. The annualised growth rate of 5.46% substantially exceeded the U.S. Consumer Price Index average of approximately 2.7% per year over the same period, indicating that highway construction costs escalated at roughly twice the rate of general inflation. The index reached its historical peak of 3.363 in 2024 Q3 before moderating slightly. The mean quarterly growth rate across the full period was 1.40% (SD = 3.53%), reflecting considerable inter-period volatility that aggregate figures alone do not fully capture.

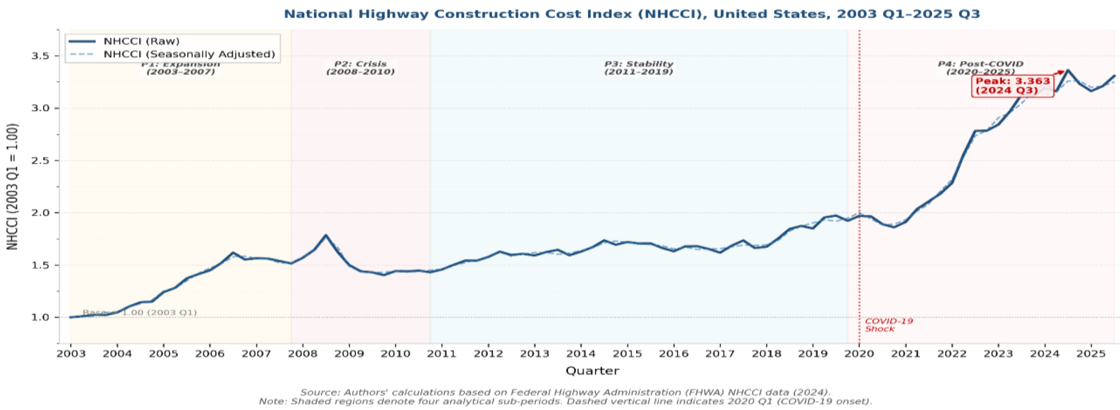

Figure 2. National Highway Construction Cost Index (NHCCI), United States, 2003 Q1–2025 Q3. Source: Authors' calculations based on FHWA NHCCI data (2024). Note: Shaded regions denote four analytical sub-periods. Dashed vertical line indicates COVID-19 onset (2020 Q1).

Table 2. Descriptive Statistics of the NHCCI — Full Period (2003 Q1 to 2025 Q3)

Statistic	Value	Quarter
Base value (2003 Q1)	1	2003 Q1
End value (2025 Q3)	3.3079	2025 Q3
Total cumulative growth	230.80%	—
Annualised growth rate	5.46%	—
Peak NHCCI value	3.3629	2024 Q3
Maximum quarterly growth (g_t)	**11.88%**	2021 Q3
Minimum quarterly growth (g_t)	**−8.86%**	2009 Q2
Mean quarterly growth	1.40%	—
Standard deviation (g_t)	3.53%	—
Total observations	91 quarters	—

These aggregate figures, however, conceal substantial variation across time. As reported in **Table 2**, the quarterly growth rate ranged from a maximum of +11.88% in 2021 Q3 to a minimum of −8.86% in 2009 Q2, illustrating the sensitivity of U.S. highway construction costs to macroeconomic shocks. The seasonally adjusted NHCCI confirms the same broad trajectory, with minor differences attributable to seasonal fluctuations in highway construction activity.

4.2. Four-Period Comparison

Dividing the study period into four sub-periods reveals structurally distinct phases of highway construction cost escalation. Table 3 summarises the growth and volatility characteristics of each period.

Period 1 (2003–2007) represented a pre-financial-crisis expansion phase in which strong infrastructure demand and rising commodity prices drove cumulative NHCCI growth of +51.4% over 20 quarters (mean g_t = 2.26%).

Period 2 (2008–2010) captured the financial crisis and its immediate aftermath. NHCCI declined by 8.8% over 12 quarters, with the highest inter-period volatility (SD = 5.01%), reflecting the sharp reversal of commodity prices and reduced construction demand.

Period 3 (2011–2019) was the longest sub-period, encompassing 36 quarters of post-recession stability. NHCCI grew by +32.0% with the lowest quarterly volatility of all four periods (SD = 2.55%).

Period 4 (2020–2025) represented the post-COVID inflationary surge. Despite covering only 23 quarters, NHCCI grew by +68.0% — the highest of any sub-period — with a maximum single-quarter increase of +11.88% in 2021 Q3, driven by supply-chain disruption, energy-price shocks, labour-market pressure, and sustained construction demand following the Infrastructure Investment and Jobs Act .

Table 3. NHCCI Growth and Volatility by Sub-Period

Period	n	Growth	Mean g_t	Std g_t	Max g_t	Min g_t
P1: 2003Q1–2007Q4 (Expansion)	20	**51.40%**	2.26%	3.18%	7.98%	−4.06%
P2: 2008Q1–2010Q4 (Crisis)	12	**−8.8%**	−0.36%	**5.01%**	8.56%	**−8.86%**
P3: 2011Q1–2019Q4 (Stability)	36	32.00%	0.86%	2.55%	5.71%	−4.18%
P4: 2020Q1–2025Q3 (Post-COVID)	23	**68.00%**	**2.46%**	3.89%	**11.88%**	−3.87%
Full period (2003–2025)	91	**230.80%**	1.40%	3.53%	11.88%	−8.86%

4.3. Component-Level Contribution Analysis

Table 4 presents the component-level results for the 9-component (grp9) classification across the full 2003–2025 study period. Components are ranked by cumulative contribution to aggregate NHCCI escalation over 90 quarterly observations. Asphalt was the dominant contributor, recording the highest cumulative contribution (41.18), mean quarterly contribution (0.458), and volatility (Vol = 1.594). Its single-quarter range extended from +6.14 to −3.78, reflecting its sensitivity to crude oil and energy market conditions. Asphalt recorded positive contributions in 58.9% of all quarters, indicating that its positive episodes were larger in magnitude than its negative ones. Grading and excavation ranked second in both cumulative contribution (24.01) and volatility (Vol = 1.232). Its single-quarter maximum (+6.96) exceeded that of asphalt, suggesting that earthwork costs can experience sharp episodic surges associated with fuel prices and equipment availability. Bridge work ranked third (cumulative = 20.05; Vol = 0.712), recording positive contributions in 62.2% of quarters — the highest frequency among the three leading components — indicating a more persistent but less episodic upward trend. The remaining six components collectively contributed 40.51 cumulative units. Among these, utilities/clearing/painting/equipment (10.12) and traffic control (7.79) were the largest contributors, while drainage (4.12) and electrical (4.43) were the smallest.

Table 4. Component-Level NHCCI Analysis — Full Period (grp9 Classification)

Rank	Component	Mean	Cumulative	Volatility	Max	Pos.%
1	**Asphalt**	**0.458**	**41.18**	**1.594**	6.14	58.90%
2	Grading / Excavation	0.267	24.01	1.232	**6.96**	55.60%
3	Bridge	0.223	20.05	0.712	1.96	**62.20%**
4	Utilities / Clearing / Painting / Equip.	0.112	10.12	0.343	0.75	70.00%
5	Traffic Control	0.087	7.79	0.399	1.18	55.60%
6	Base Stone	0.083	7.45	0.245	0.97	63.30%
7	Concrete	0.074	6.66	0.435	0.99	62.20%
8	Electrical	0.049	4.43	0.125	0.4	64.40%
9	Drainage	0.046	4.12	0.181	0.51	61.10%

4.4. Pre- versus Post-2020 Component Comparison

Table 5 presents the pre- versus post-2020 comparison for each component. The results show that the post-2020 surge was broad-based, with markedly different magnitudes across pay-item groups. Traffic control recorded the largest proportional increase (+468%), rising from a mean contribution of 0.039 to 0.224, likely reflecting post-pandemic supply-chain disruptions in signing and safety equipment markets and increased work-zone activity under the Infrastructure Investment and Jobs Act. Concrete showed the second-largest increase (+341%), rising from 0.040 to 0.174 — notable because concrete is typically considered more stable than asphalt, suggesting that cement shortages and labour costs substantially altered its post-2020 behavior. Asphalt and grading/excavation each recorded an absolute increase of +0.388. Asphalt rose from 0.359 to 0.746 (+108%) and grading/excavation from 0.168 to 0.556 (+232%), consistent with energy and fuel-price shocks of 2021–2023. Bridge was the only component to decline post-2020, falling from 0.231 to 0.199 ($\Delta C\_i = -0.032$, −14%), likely reflecting the longer procurement and design lead times associated with structural work, which insulate bridge bid prices from short-run commodity fluctuations.

Table 5. Pre- versus Post-2020 Component Comparison (grp9)

Component	Pre-2020 Mean	Post-2020 Mean	ΔC_i	% Change	Direction
Traffic Control	0.039	**0.224**	**0.184**	**468%**	**▲▲ Surge**
Concrete	0.04	**0.174**	**0.135**	**341%**	**▲▲ Surge**
Electrical	0.028	0.11	0.082	292%	▲▲ Surge
Utilities / Clearing / Equip.	0.066	0.246	0.18	271%	▲▲ Surge
Grading / Excavation	0.168	**0.556**	**0.388**	232%	▲▲ Surge
Drainage	0.033	0.083	0.05	150%	▲ Rise
Base Stone	0.072	0.115	0.043	60%	▲ Rise
Asphalt	0.359	**0.746**	**0.388**	108%	**▲▲ Surge**
Bridge	0.231	0.199	−0.032	−14%	▼ Decline

To statistically support the pre- versus post-2020 comparison presented in Table 5, a Mann-Whitney U test was applied to each grp9 component(**Table 6**). This non-parametric test was selected because it does not assume normality and is robust to the unequal sample sizes of the pre-2020 ($n = 68$) and post-2020 ($n = 23$) sub-periods. Results indicate that the Utilities/Clearing/Painting/Equipment component showed a statistically significant distributional shift after 2020 ($U = 501.0$, $p = 0.013$), while Grading/Excavation showed a marginally significant shift ($U = 576.0$, $p = 0.073$). The remaining components did not reach conventional significance thresholds, reflecting the limited statistical power of the post-2020 subsample ($n = 23$) rather than the absence of an economic shift. These results should be read alongside Table 5, which captures the magnitude of mean change rather than distributional difference alone.

Table 6. Mann-Whitney U Test Results — grp9 Component Contributions (Pre- vs. Post-2020)

Component	U Statistic	p-value	Significance	Interpretation
Utilities / Clearing / Painting / Equip.	501	0.013	**** p<0.05**	Significant shift post-2020
Grading / Excavation	576	0.073	*** p<0.10**	Marginally significant
Electrical	605	0.127	ns	Not significant
Traffic Control	648	0.259	ns	Not significant
Concrete	645	0.248	ns	Not significant
Drainage	678	0.395	ns	Not significant
Base Stone	706	0.554	ns	Not significant
Asphalt	716	0.617	ns	Not significant
Bridge	839	0.529	ns	Not significant

*Note: ** p < 0.05; * p < 0.10; ns = not significant. Pre-2020: n = 68 quarters; Post-2020: n = 23 quarters.*

Table 7 presents the results of the Chow test, which was additionally applied to the NHCCI quarterly growth rate series to formally examine whether a structural break occurred at 2020 Q1. The test did not confirm a statistically significant break (F = 2.096, p = 0.129), a result attributable in part to the limited size of the post-2020 subsample (n = 23), which reduces the power of the test. Consistent with this interpretation, the descriptive four-period comparison in Table 3 shows that post-2020 mean quarterly growth (2.46%) was more than double that of the 2011–2019 stability period (0.86%), supporting the economic characterisation of 2020 as a regime change.

Table 7. Chow Test Results — Structural Break at 2020 Q1

Parameter	Value	Degrees of Freedom	p-value
Chow F-statistic	2.096	(2, 86)	0.129
Restricted SSR (pooled)	1,081.70	—	—
Unrestricted SSR (split)	1,025.90	—	—
Break point	2020 Q1	—	—
Conclusion	No significant structural break at p < 0.05		

Note: The Chow Test was applied to the NHCCI quarterly growth rate (g_t) regressed on a linear time trend. Pre-break subsample: 2003 Q2 to 2019 Q4 (n = 67); Post-break subsample: 2020 Q1 to 2025 Q3 (n = 23).

4.5. Volatility Ranking and Risk Implications

Table 8 ranks the nine components by volatility, providing evidence relevant to contingency planning and contract risk management. Asphalt is the most volatile component (Vol = 1.594), with quarterly contributions ranging from +6.14 to −3.78. Grading/excavation ranks second (Vol = 1.232) and records the highest single-quarter maximum of all components (+6.96), indicating potential for extreme episodic cost spikes in earthwork. Bridge ranks third (Vol = 0.712), while the remaining components show substantially lower volatility, with electrical the most stable (Vol = 0.125). The contrast between cumulative contribution and volatility rankings is noteworthy. Asphalt leads on both dimensions, confirming its dual role as the largest long-run cost driver and the greatest source of quarterly budget uncertainty. Grading/excavation, despite a lower mean contribution than asphalt, records a higher single-quarter maximum, suggesting more episodic but potentially severe cost risk. Bridge, by contrast, represents a stable but persistent source of long-run cost pressure rather than a short-run budget risk.

Table 8. Component Volatility Ranking — Full Period (grp9)

Rank	Component	Volatility	Maximum	Minimum	Risk Level
1	**Asphalt**	**1.594**	6.14	−3.78	**HIGH**
2	Grading / Excavation	**1.232**	**6.96**	−2.15	**HIGH**
3	Bridge	0.712	1.96	−2.27	MEDIUM
4	Concrete	0.435	0.99	−1.31	MEDIUM
5	Traffic Control	0.399	1.18	−0.96	MEDIUM
6	Utilities / Clearing / Equip.	0.343	0.75	−0.99	LOW-MED
7	Base Stone	0.245	0.97	−0.39	LOW
8	Drainage	0.181	0.51	−0.43	LOW
9	Electrical	0.125	0.4	−0.19	LOW

4.6. Time-Series Modeling of Aggregate NHCCI

The four-quarter forecast projects NHCCI values between 3.293 and 3.402 through 2026 Q3, suggesting near-term stabilisation following the moderation observed since the 2024 Q3 peak (3.363). This is consistent with the post-surge trajectory visible in the 2024–2025 data and supports the interpretation that the most acute phase of post-COVID escalation has passed. The ARIMA model serves as a supporting analysis; the primary contribution of the study lies in the component-level decomposition presented in Sections 4.3–4.5. Given the near-unit-root behavior of the differenced series ($p = 0.067$), forecasts beyond four quarters should be interpreted with caution.

Table 9. ARIMA Model Results and Four-Quarter Forecast

Model Parameter	Value	Criterion	Value
ARIMA order (p, d, q)	(3, 1, 3)	AIC	−234.96
ADF — level (p-value)	0.997 (non-stationary)	BIC	−217.46
ADF — d=1 (p-value)	0.067 (near-stationary)	Residual mean	0.017
Differencing order (d)	1	Residual std	0.12

Table 10 reports the full model diagnostics for the ARIMA(3,1,3) specification. The Ljung-Box Q(12) test confirms that residuals exhibit no significant autocorrelation up to lag 12 ($Q = 8.987$, $p = 0.704$), satisfying the white-noise requirement for a well-specified model. The near-zero residual mean (0.006) indicates no systematic forecasting bias. In-sample forecasting performance indicators further confirm model adequacy: MAE = 0.046, RMSE = 0.061, and MAPE = 2.48%, indicating good accuracy for an economic index series of this length and volatility.

Table 10. Model Fit and Forecasting Performance

Diagnostic	Statistic	p-value	Conclusion
ADF Test — Level	p = 0.997	0.997	Non-stationary
ADF Test — First Difference	p = 0.067	0.067	Near-stationary
ARIMA Order (p, d, q)	(3, 1, 3)	—	Selected by AIC/BIC
AIC	−234.96	—	—
BIC	−217.46	—	—
Ljung-Box Q(12)	Q = 8.987	0.704	**Residuals are white noise ✓**
Residual Mean	0.006	—	No systematic bias
Residual Std. Dev.	0.061	—	—
MAE (in-sample)	0.046	—	Good fit
RMSE (in-sample)	0.061	—	—
MAPE (in-sample)	2.48%	—	**Good forecasting accuracy**

Note: MAE = Mean Absolute Error; RMSE = Root Mean Squared Error; MAPE = Mean Absolute Percentage Error. All performance metrics are computed on in-sample fitted values. Ljung-Box Q(12) tests the null hypothesis of no autocorrelation in residuals up to lag 12.

Table 11 presents the four-quarter NHCCI forecast generated by the ARIMA(3,1,3) model. Projected values range from 3.293 to 3.402, indicating a period of near-term stabilisation with mild quarterly fluctuation around the current index level rather than a return to the sharp escalation observed in 2021–2023.

Table 11. ARIMA(3,1,3) Four-Quarter NHCCI Forecast (2025 Q4 – 2026 Q3)

Forecast Quarter	Forecast NHCCI	Change from 2025 Q3	Direction
2025 Q4	3.317	0.28%	→ Stable
2026 Q1	3.2928	−0.45%	↓ Slight decline
2026 Q2	3.3318	0.72%	↑ Mild recovery
2026 Q3	3.4019	2.84%	↑ Recovery

The results produce five principal findings relevant to highway construction cost research and infrastructure project management.

Finding 1: The aggregate NHCCI grew 230.8% from 2003 to 2025 (annualised: 5.46%), substantially exceeding general inflation. The post-COVID period (2020–2025) alone accounted for 68.0% growth in only 23 quarters — the most intensive escalation of any sub-period.

Finding 2: Asphalt was the dominant cost driver over the full period, contributing 41.18 cumulative units — more than the next two components combined — and recording the highest volatility (Vol = 1.594), confirming its dual role as both the largest contributor and the greatest source of budget uncertainty.

Finding 3: Post-2020 escalation was broad-based, not asphalt-driven alone. Traffic control (+468%), concrete (+341%), and electrical (+292%) recorded the highest proportional increases, while bridge was the only component to decline (−14%).

Finding 4: A structural shift in the component hierarchy occurred after 2020. Historically minor components — traffic control, concrete, electrical — became significantly more inflationary, suggesting that supply-chain disruptions and labour-market pressures diffused broadly across pay-item categories beyond energy-linked materials.

Finding 5: ARIMA(3,1,3) forecasting projects near-term NHCCI values between 3.29 and 3.40 through 2026 Q3, suggesting the most acute phase of post-COVID escalation has passed, though costs remain historically elevated relative to the pre-2020 baseline.

4.7Robustness Checks

Two robustness checks were applied to verify the reliability of the main findings. First, component rankings derived from the grp9 classification were replicated using the grp13 and grp25 classifications. As shown in Table 12, the top three components — Asphalt, Grading/Excavation, and Bridge — are identical across all three disaggregation levels, confirming that the dominant cost-driver findings are not sensitive to the classification scheme used.

Table 12. Top-Five Component Rankings by Cumulative Contribution — grp9, grp13, and grp25

Rank	grp9 (9 components)		grp13 (13 components)		grp25 (25 components)	
	Component	Cumulative	Component	Cumulative	Component	Cumulative
1	Asphalt	41.18	Asphalt	37	Asphalt	41.18
2	Grading / Excavation	24.01	Grading / Excavation	26.98	Grading / Excavation	21.62
3	Bridge	20.05	Bridge	19.18	Bridge	19.55
4	Utilities / Clearing / Equip.	10.12	Traffic Control	7.81	Base Stone	7.55
5	Traffic Control	7.79	Base Stone	6.94	Concrete Misc.	5.45

Note: Rankings based on cumulative sum of quarterly percentage-change contributions across the full 2003 Q1–2025 Q3 study period. The top three components — Asphalt, Grading/Excavation, and Bridge — are identical across all three classification levels, confirming the robustness of the grp9-based findings.

Second, the pre- versus post-2020 comparison was repeated using 2021 Q1 and 2022 Q1 as alternative break points. As reported in Table 13, the post-break mean quarterly growth rate consistently exceeds the pre-break rate across all three scenarios. The 2021 Q1 break yields the strongest statistical support ($t = -2.497$, $p = 0.014$), while the 2020 Q1 and 2022 Q1 breaks are marginally significant ($p < 0.10$). The consistency of direction and magnitude across all scenarios confirms that the post-2020 inflationary regime characterisation is robust to the choice of break year.

Table 13. t-Test Results for Alternative Break Points in NHCCI Quarterly Growth Rate

Break Point	Pre-break Mean	Post-break Mean	Pre Std	Post Std	t-stat	p-value
2020 Q1	1.04%	2.46%	3.35%	3.89%	−1.686	0.095 †
2021 Q1 ✓	0.93%	3.14%	3.32%	3.81%	**−2.497**	**0.014 ***
2022 Q1	1.10%	2.89%	3.33%	4.22%	−1.820	0.072 †

5. Discussion

The findings of this study contribute to the literature on transportation infrastructure cost escalation by showing that highway construction cost growth in the United States has been both persistent and structurally uneven. The 230.8% increase in the NHCCI between 2003 Q1 and 2025 Q3, equivalent to an annualised growth rate of 5.46%, confirms that highway construction costs have risen substantially faster than general inflation over the study period. This supports earlier studies showing that cost escalation in transport infrastructure is not random, but a recurring challenge shaped by inflation, market conditions, procurement practices, and project duration(Flyvbjerg et al., 2003; Shane et al., 2009; Touran & Lopez, 2006).

A key contribution of this study is that it moves beyond the aggregate NHCCI and identifies which components are responsible for cost escalation. The results show that asphalt was the dominant long-run contributor, with the highest cumulative contribution (41.18) and the highest volatility ($\sigma = 1.594$). This is consistent with prior studies linking highway bid prices to crude oil and asphalt market behavior (Damnjanovic & Zhou, 2009; Ilbeigi et al., 2017). However, grading/excavation (cumulative = 24.01) and bridge work (cumulative = 20.05) were also major contributors, confirming that highway cost escalation cannot be explained by petroleum-linked materials alone.

The post-2020 period reveals an important shift in the structure of cost drivers. Although asphalt remained significant, the largest proportional increases occurred in traffic control (+468%), concrete (+341%), electrical work (+292%), and utilities-related categories (+215%). This indicates that post-COVID escalation was broad-based and reflected wider supply-chain disruption, labour-market tightening, and construction-market pressures rather than a single commodity-price shock. This result is consistent with recent evidence that inflationary shocks can spread across multiple construction materials and cost categories with lagged effects(Abdul Nabi et al., 2024).

These findings have direct implications for infrastructure project management. Agencies that rely only on aggregate escalation factors may significantly underestimate budget risk, particularly when cost pressures vary across components as strongly as observed in the post-2020 period. Asphalt-heavy projects require contingency allocations of at least 12% and frequent cost updating linked to crude oil or asphalt PPI movements. Earthwork-heavy projects require scenario-based contingency planning because grading/excavation can experience sharp short-term spikes driven by fuel prices and equipment availability. Bridge-heavy projects require careful long-term escalation allowances, particularly in multi-year programs where year-of-expenditure adjustments should reflect structural steel and fabrication price trends rather than a single aggregate factor.

The results also carry implications for procurement strategy and contract risk allocation. Standard price adjustment clauses in highway contracts have traditionally focused on asphalt and fuel, but the post-2020 evidence shows that traffic control, concrete, electrical work, and utilities now carry risk profiles that are comparable to, or in some quarters exceeding, that of asphalt. A more component-specific approach to contingency planning and contract design — including price adjustment clauses linked to cement, electrical materials, and labour indices — could help agencies allocate risk more efficiently and reduce the need for contractors to embed broad uncertainty premiums in bid prices. The ARIMA forecasting results project near-term stabilisation of the aggregate NHCCI between 3.29 and 3.40 through 2026 Q3, potentially providing agencies with a window to revise contingency frameworks before the next escalation cycle. However, given that the 2025 Q3 index value of 3.308 remains more than three times the 2003 baseline, even stabilisation does not imply a return to pre-2020 cost levels, and component-specific escalation rates should continue to inform year-of-expenditure estimates in long-duration programs.

6. Conclusion

This study examined U.S. highway construction cost escalation from 2003 Q1 to 2025 Q3 using the NHCCI and its component-level classifications. The results show that the aggregate NHCCI increased from 1.000 to 3.308, representing cumulative growth of approximately 230.8%. The strongest escalation occurred after 2020, when the index increased by 68.0% in only 23 quarters, indicating a distinct post-COVID cost regime that differs materially from all preceding periods in the study window.

At the component level, asphalt was the dominant long-run contributor and the most volatile category, followed by grading/excavation and bridge work. However, the post-2020 period was not driven by asphalt alone. Traffic control (+468%), concrete (+341%), electrical work (+292%), and utilities-related components also recorded sharp proportional increases, indicating that recent escalation was broad-based and linked to wider supply-chain disruption, labour-market tightening, and construction-market pressures that extended well beyond petroleum-linked materials. The ARIMA(3,1,3) results project near-term stabilisation of the NHCCI between 3.29 and 3.40 through 2026 Q3, although costs remain historically elevated and the forecasting horizon should be interpreted with caution beyond four quarters.

These findings carry direct implications for infrastructure agencies and project managers. Relying solely on aggregate escalation factors is no longer sufficient in an environment where cost pressures are distributed unevenly across pay-item groups. Instead, cost forecasting, contingency allocation, procurement timing, and price adjustment clause design should be grounded in component-specific evidence that reflects the distinct behavior of asphalt, concrete, bridge work, traffic control, and other major highway construction categories.

The study is subject to several limitations. The NHCCI is a national bid-based index and does not capture regional variation in highway construction costs across states or procurement markets. The index also reflects winning-bid prices rather than final contract costs, meaning that change orders, claims, and scope adjustments during construction are not captured. The post-2020 subsample remains relatively short (n = 23 quarters), which limits the statistical power of structural break tests and reduces forecasting precision beyond the near term. Future research could address these limitations by comparing state-level NHCCI sub-indices, linking component-level movements to macroeconomic leading indicators such as crude oil prices, cement production indices, and construction wage indices, and examining project-level bid-tab data from state DOTs to validate whether national component patterns translate into procurement outcomes at the project level.

Taken together, the findings reframe highway construction cost escalation not merely as a macroeconomic inflation problem, but as a component-specific budget risk that demands targeted management responses at the pay-item level. In the post-2020 environment, the risk is no longer concentrated in a single dominant material — it is distributed across the full spectrum of highway construction work.

Acknowledgements: The authors gratefully acknowledge the valuable comments and constructive suggestions provided by the reviewers, which helped improve the scientific quality and clarity of this manuscript. The authors also sincerely thank Dr. Maniat for his guidance, support, and constructive feedback throughout the development of this study.

Data available: https://data.bts.gov/Research-and-Statistics/Monthly-Transportation-Statistics/crem-w557/about_data

Funding: None

Conflict of Interest: The authors declare that they have no conflict of interest.

Authors contribution: All authors contributed equally.

Competing of interests: The authors declare that they have no competing interests.

References

Abdul Nabi, M., El-Adaway, I. H., & Assaad, R. H. (2024). Modeling inflation transmission among different construction materials. *Journal of construction engineering and management*, *150*(5), 04024024.

Alsharef, A., Findley, D., Jaselskis, E., Dudley, T., Pyo, K., & Yang, G. (2024). Examining Contingency and Inflation Practices Within Several Departments of Transportation in the United States. *Transportation Research Record*, *2678*(10), 850–861.

Anderson, S. D., Molenaar, K. R., & Schexnayder, C. J. (2007). *Guidance for cost estimation and management for highway projects during planning, programming, and preconstruction* (Vol. 574). Transportation Research Board.

Ashuri, B., & Lu, J. (2010). Time series analysis of ENR construction cost index. *Journal of construction engineering and management*, *136*(11), 1227–1237.

Bureau of Transportation Statistics. (2024). *Infrastructure Investment and Jobs Act funds authorized for highway by fiscal year and amount reduced by construction cost inflation: 2012–2026*. U.S. Department of Transportation. https://www.bts.gov/browse-statistical-products-and-data/info-gallery/infrastructure-investment-and-jobs-act-funds

Cantarelli, C. C., Flybjerg, B., Molin, E. J., & Van Wee, B. (2013). Cost overruns in large-scale transportation infrastructure projects: Explanations and their theoretical embeddedness. *arXiv preprint arXiv:1307.2176*.

Cantarelli, C. C., van Wee, B., Molin, E. J., & Flyvbjerg, B. (2012). Different cost performance: different determinants?: The case of cost overruns in Dutch transport infrastructure projects. *Transport policy*, *22*, 88–95.

Cheng, G., & Wilmot, C. G. (2009). Louisiana highway construction cost trend after hurricanes Katrina and Rita. *Journal of construction engineering and management*, *135*(7), 594–600.

Damnjanovic, I., & Zhou, X. (2009). Impact of crude oil market behavior on unit bid prices: The evidence from the highway construction sector. *Construction Management and Economics*, *27*(9), 881–890.

Davis, J. (2024). *FHWA: Highway construction costs continued to grow at 24% annual rate*. Eno Center for Transportation. https://enotrans.org/article/fhwa-highway-construction-costs-continued-to-grow-at-24-annual-rate

Etesami, S., Raufi, P., & Maniat, M. (2024). New Technology and Primary Energy Consumption in the Transportation Sector: A Critical Discourse Analysis. *Journal of Technology Innovations and Energy*, *3*(4), 15–31.

Federal Highway Administration. (2025). *National Highway Construction Cost Index 2024 Q3*. O. o. T. P. Studies. https://www.fhwa.dot.gov/policy/otps/nhcci/NHCCI_Narrative_Article_2024_Q3.pdf

FHWA. (2021). *Description of Component Contributions to Changes in the National Highway Construction Cost Index (NHCCI)*. United States Department of Transportation. https://www.fhwa.dot.gov/policy/otps/nhcci/component_contributions.cfm

FHWA. (2024). *National Highway Construction Cost Index (NHCCI)*

Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2003). How common and how large are cost overruns in transport infrastructure projects? *Transport reviews*, *23*(1), 71–88.

Flyvbjerg, B., Skamris Holm, M. K., & Buhl, S. L. (2004). What causes cost overrun in transport infrastructure projects? *Transport reviews*, *24*(1), 3–18.

Huseynov, S., Ribera, L. A., & Palma, M. A. (2018). Predicting the highway costs index with machine learning. *Semantic Scholar*.

Ilbeigi, M., Ashuri, B., & Joukar, A. (2017). Time-series analysis for forecasting asphalt-cement price. *Journal of management in engineering*, *33*(1), 04016030.

Liu, H., Kwigizile, V., Abudayyeh, O., & Huang, W.-C. (2024). Improving cost estimation and budget planning with new Michigan highway construction cost index.

Maniat, M. (2024). Introduction of Discourse Analysis in Transportation: A Framework for Understanding Policy and Practice in Urban Mobility.

Morad, A. (2023). An analysis of global construction projects causes and implications of cost overruns. *OSF, Jun, 14*.

Naghdi, M., Erfani, A., Geary, G., & Ashuri, B. (2026). Price Adjustment Clauses in Highway Construction: State of the Practice. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *18*(2), 04525119.

Odeck, J. (2004). Cost overruns in road construction—what are their sizes and determinants? *Transport policy*, *11*(1), 43–53.

Raufi, P., & Maniat, M. (2024). Transport Policy's Impact on Auto Emissions: A Critical Review. *Available at SSRN 4719317*.

Shahandashti, S. M., & Ashuri, B. (2016). Highway construction cost forecasting using vector error correction models. *Journal of management in engineering*, *32*(2), 04015040.

Shane, J. S., Molenaar, K. R., Anderson, S., & Schexnayder, C. (2009). Construction project cost escalation factors. *Journal of management in engineering*, *25*(4), 221–229.

Shrestha, J., K, Jeong, H. D., & Gransberg, D. D. (2016). Current practices of highway construction cost index calculation and utilization. Construction Research Congress 2016,

Shrestha, K. J., Jeong, H. D., & Gransberg, D. D. (2017). Multidimensional highway construction cost indexes using dynamic item basket. *Journal of construction engineering and management*, *143*(8), 04017036.

Swei, O., Gregory, J., & Kirchain, R. (2017). Probabilistic approach for long-run price projections: Case study of concrete and asphalt. *Journal of construction engineering and management*, *143*(1), 05016018.

Touran, A., & Lopez, R. (2006). Modeling cost escalation in large infrastructure projects. *Journal of construction engineering and management*, *132*(8), 853–860.

Welde, M., & Dahl, R. E. (2021). Cost escalation in road construction contracts. *Transportation Research Record*, *2675*(9), 1006–1015.

Wilmot, C. G., & Cheng, G. (2003). Estimating future highway construction costs. *Journal of construction engineering and management*, *129*(3), 272–279.

Wong, E., & Swei, O. (2021). New construction cost indices to improve highway management. *Journal of management in engineering*, *37*(4), 04021030.