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Selection of Interest and Inflation Rates for Infrastructure Investment Analyses

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ACRONYMS

Acronym	Definition
AC	Asphalt Concrete
AGC	Associated General Contractors
AM	Arithmetic Mean
BCA	Benefit-Cost Analysis
BCR	Benefit-Cost Ratio
BLS	Bureau of Labor Statistics
BPI	Bid Price Index
CCI	Construction Cost Index
CPI	Consumer Price Index
CSH	Concrete Sustainability Hub
DOT	Department of Transportation
EEA	Engineering Economic Analysis
EMA	Exponential Moving Average
EMS	Equipment Management System
FHWA	Federal Highway Administration
FOMC	Federal Open Market Committee
GAO	Government Accountability Office
GDP	Gross Domestic Product
HM	Harmonic Mean
IBCA	Incremental Benefit-Cost Analysis
LA	Liquid Asphalt
LCCA	Life Cycle Cost Analysis
MACD	Moving Average Convergence Divergence
MIT	Massachusetts Institute of Technology
NCHRP	National Cooperative Highway Research Program
NHCCI	National Highway Construction Cost Index
OMB	Office of Management and Budget
PCA	Principal Component Analysis
PCC	Portland Cement Concrete
PICS	Project Identification Coordination System
PMS	Pavement Management System
PV	Present Value
PWA	Present Worth Analysis
RAP	Reclaimed Asphalt Pavement
SDCCI	South Dakota Construction Cost Index
SDCDP	South Dakota Cash Flow Fund Duration Portfolio
SDDOT	South Dakota Department of Transportation
SDIC	South Dakota Investment Council
STD	Standard Deviation
STIP	Statewide Transportation Improvement Program
TII	Transportation Infrastructure Investment
USDOT	U.S. Department of Transportation
VE	Value Engineering

1. EXECUTIVE SUMMARY

1.1 Problem Description

The South Dakota Department of Transportation (SDDOT) uses engineering economic analyses (EEA) to support planning, design, and construction decision-making such as project programming and planning, pavement type selection, and the occasional valuing of roads transferred from the state highway system to counties and cities. Interest, inflation, and discount rates are three critical factors that significantly affect the outcome of an economic analysis.

The selection and use of appropriate interest and inflation rates for various SDDOT applications are of primary concern. The inflation rate currently used by SDDOT is calculated from the South Dakota Construction Composite Index (SDCCI). This general rate can neither differentiate between regional changes to highway construction costs nor show variation among the individual material inflation rates used to create the CCI. In addition, SDDOT generally assumes a zero interest rate which approximately equates the real discount rate to the inflation rate. The validity of this assumption needs to be verified.

Establishing and maintaining sound and equitable rates of interest, inflation, and discount is extremely important to SDDOT. Using inappropriate values for interest and inflation rates could unfairly favor certain industries and regions, jeopardize economic analyses, and weaken the credibility of SDDOT investment decisions. This study is intended to determine whether appropriate rates are being used in various applications and to establish a means of obtaining appropriate rates that can help validate, support, and enhance SDDOT's transportation investment decisions.

1.2 Literature Review

The literature review captured recent development in EEA and compared the values of interest, inflation, and discount rates in different states, as well as the criteria for conducting economic analyses. Descriptions of the three primary sources for this report follow. Office of Management and Budget (OMB) Circular No. A-94 *Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs* establishes discount rate guidelines for use in benefit-cost analysis and other types of economic analyses of federal programs. *Economic Analysis Primer* published by the Federal Highway Administration (FHWA) in 2003 describes how interest, inflation, and discount rates are to be used in economic analyses. The final report for SDDOT research project SD1996-08 *Guidelines for Using Economic Factors and Maintenance Costs in Life-Cycle Cost Analysis* represents the department's most recent endeavor to establish a consistent approach toward preparing an economic analysis.

Historical data show that interest rates change over time, and that federal and state rates are not equivalent. Federal and local interest rates may vary due to differences in issued bond yields between the federal level and state level; determining an interest rate for a project funded by both federal and state dollars may need to consider both rates. Some states do not use an interest rate in their life cycle cost analysis (LCCA), and the values of interest rates vary among states. The interest rates applied by a number of states are described by Zimmerman in the SD1996-08 final report. Of the 29 states that responded to the survey, only 12 indicated that they included the interest rate. Few among these 12 states provided an interest rate value (such as 6%, 7%, and 8%). Some states indicated that the value of their interest rate ranges from 0 to 10% or from 5% to 8%. One agency indicated that it would use an interest rate according to the prime interest rate in the future applying the forward-looking method.

The rate of inflation is usually measured by comparing the price index of groupings or "market baskets" of goods and services from the current year to that of the base year. The measuring methods vary by purpose of application (such as the Laspeyres price index, the Paasche price index, and the Fisher price index). The price indices used by different agencies and in different programs may also be different, and the items included in the price index are not necessarily the same. A number of popular indices have been widely used to calculate the inflation rate, including the consumer price index (CPI), the construction cost index (CCI), the bid price index (BPI), the gross domestic product (GDP) deflator, and the producer price index (PPI). FHWA uses the national highway construction cost index (NHCCI) calculated with the Fisher price index method to quantify changes in highway construction costs. SDDOT also uses the Fisher price index to compute SDCCI.

The best way for public agencies to forecast the life cycle costs of a project is to exclude the influence of inflation, called the real cost. Change in real cost can be measured by an escalation rate. Considering the escalation rate in LCCA, may improve the analysis because it acknowledges and differentiates changes in relative prices for different materials. The OMB Memorandum "*Interpretation of OMB Circular A-94*" suggests "Agencies should decide, based on their own professional judgment, if there is a reliable basis to assume changes in relative prices and when such assumptions would improve their analysis." Conflicting voices have been raised over the use of material-specific interest rates. While supporters consider it a more justifiable method, opponents think it may not reflect the actual price change during the life cycle of highway construction.

The same debate can be found over whether or not material-specific discount rates should be used because the discount rate is approximated by subtracting the inflation rate from the nominal interest rate. The discount rate accounts for the time value of money or opportunity cost of capital when performing an economic analysis. In EEA, the discount rate value can vary among programs with different budget time periods or between the federal and state levels. In January 2003, OMB reported a 10-year real discount rate of 2.5% and a 30-year rate of 3.2%. Nine years later, according to the report issued in January 2012, the 10-year real discount rate became 1.1% and the 30-year rate was 2.0%. FHWA stated that selection of discount rate can affect the results of an economic analysis: a higher discount rate more rapidly reduces the present value of future costs and benefits, and vice versa.

1.3 SDDOT INTERVIEWS

Interviews were conducted with SDDOT personnel to collect information on SDDOT's past and current interest and inflation rates, the procedures for determining these rates, the data sources available for developing alternatives, and expectations of future improvements. The interviews revealed that EEA has been widely used in long- and short-term SDDOT planning, project development, and management processes in areas such as pavement, bridge, vehicle fleet, or overall asset management. LCCA, Benefit-Cost Analysis (BCA), and incremental benefit-cost analysis (IBCA) have been used to determine if a project is economically justifiable or to choose the best alternative.

All SDDOT offices currently assume a zero interest rate because the state government can neither issue bonds nor save unused money. Therefore, no interest revenue is generated from savings. The inflation rates applied by different SDDOT offices vary. Overall, three inflation rates are currently used. The five-year Statewide Transportation Improvement Plan (STIP) uses a 2% inflation rate that is determined by combining weekly updated Associated General Contractor reports, historical trends, and DOT judgment. The inflation rate used in pavement management is 4.51%, which is the five-year moving average of inflation rates based on SDCCI. Bridge engineers have used a 5% discount rate since 1990. The inflation rate for fleet management is 5% and is provided by the Office of Finance.

Opinions were split among interviewees on determining the interest rate for discounting purposes when a transportation project is funded by a combination of federal and state or local funds. Some agreed that adopting a rate that reflects the composition of funding sources is appropriate, while others considered the change not worth the effort and thought using the federal rate or zero interest rate is sufficient.

The method of moving average historical inflation rates assumes future trends can be adequately represented by the average of historical data; however, a forward-looking inflation rate projects the historical trend into the future. All the interviewees seemed to agree that if the trend is clear and reliable, the forward-looking inflation rate is more appropriate than the historical average inflation rate because projects are budgeted based on (future) costs during the life cycle. When asked if the historical average value is to be used, the interviewees agreed that the five-year arithmetic mean is sufficient to reflect recent or anticipated fluctuations, while the 10-year arithmetic mean can smooth out some of the dramatic fluctuations that occurred within the five-year time period.

When discussing variations in rates among materials, projects, and regions, questions centered on information availability and project characteristics. For the three proposed methods of estimating a discount rate (region-, project-, and material-specific discount rates) a general, constant discount rate is preferred for long-term, conceptual transportation planning activities. For project- or program-level planning activities, where more information (e.g. materials quantities, unit price, etc.) becomes available, an investment- or project-type-specific index may be more defensible.

The interviews revealed current practices at SDDOT, identified existing issues, clarified user expectations for new methodologies or modifications of current methods, and collected data to evaluate, verify, and support the recommended methods.

1.4 Methodologies

1.4.1 Inflation Rate

SDDOT measures the annual inflation rate as the percentage change of SDCCI from the previous year:

$$\pi = 100\%\left(\frac{SDCCI_t - SDCCI_{t-1}}{SDCCI_{t-1}}\right) \qquad \text{Equation 1-1}$$

where π, $SDCCI_t$, and $SDCCI_{t-1}$ are the inflation rate, SDCCI of current year *t*, and SDCCI of previous year *t-1*, respectively.

SDDOT has used the Fisher price index to calculate SDCCI since 1986. The Fisher price index is expressed as:

$$F(p) = \sqrt{\frac{\sum_{j=1}^{N} \boldsymbol{p_{j,t} q_{j,0}}}{\sum_{j=1}^{N} \boldsymbol{p_{j,0} q_{j,0}}} \times \frac{\sum_{j=1}^{N} \boldsymbol{p_{j,t} q_{j,t}}}{\sum_{j=1}^{N} \boldsymbol{p_{j,0} q_{j,t}}}}, \qquad \text{Equation 1-2}$$

where

$p_{j,t}$ is the unit price of individual material or item *j* in the current year
$q_{j,t}$ is the quantity of individual material or item *j* during the current year
$p_{j,0}$ is the unit price of individual material or item *j* during the base year (2006 in this study)
$q_{j,0}$ is the quantity of individual material or item *j* during the base year.

1.4.2 Nominal Interest Rate

The nominal interest rate is the rate at which interest is paid by a borrower to use money. It reflects the opportunity cost of the capital. The SDDOT current assumption of a zero interest rate means no opportunity cost of capital is allocated to SDDOT projects. However, any public transportation funds, either from the federal highway trust fund or from the SD state transportation fund, should bear opportunity costs of a) potential displacement of private investments and b) crowd-out of private consumption. Displacement refers to the fact that public investments "siphon away any resources that could otherwise have earned private sector rates of return" and crowd-out refers to the fact that "the funds raised by taxation are, in reality, diverted mainly from consumption."

The capital allocated to SDDOT projects is usually a combination of federal and state funds. Corresponding interest rates can be estimated by a weighted sum of Treasury and state-issued bond yields if the capital consists of both federal and state funds, with the weights being the percentage contribution of the respective funding sources. The daily Treasury bond yield can be obtained from the Department of Treasury. SDDOT can choose the interest rate that matches its decision timeframe from a cross-section of bond yields with maturities ranging from one month to 30 years.

The interest rate applicable to state funding can be approximated in two ways. One is to employ the annual rate of return generated by the South Dakota Investment Council (SDIC). The other is through the rate of state or municipal bonds at the Electronic Municipal Market Access of the Municipal Securities Rulemaking Board. Although SDDOT is not authorized to issue bonds, state-issued bonds sponsored by general state revenue can provide a reliable proxy for the cost of capital applicable to SDDOT funding dollars. Although the state/municipal bond rate is more reliable than the SDCDP rate, the availability of the former may often be constrained.

1.4.3 Real Interest Rate

The real interest rate is approximated by subtracting the inflation rate from the nominal interest rate. Note that the term "real interest rate," often related to debt securities or savings accounts in general economics, is less commonly seen in engineering economics, where the equivalent term is "real discount rate" or simply "discount rate." The current nominal and real interest rates recommended by OMB Circular No. A-94 for 2013 cost-effectiveness analyses are listed in Table 1.1.

Table 1.1 Nominal vs. Real Interest Rates (OMB Circular A-94)

Interest Rate	**3-year**	**5-year**	**7-year**	**10-year**	**20-year**	**30-year**
Nominal (i)	0.5	1.1	1.5	2.0	2.7	3.0
Real (r)	-1.4	-0.8	-0.4	0.1	0.8	1.1

The very low or even negative values in Table 1.1 are specific to the current economic environment and a direct result of the low-interest-rate policy of the Federal Reserve. The negative discount rate is barely justifiable for SDDOT's long-term (more than 10 years) projects or any other investment projects, public or private. To correct negative rates, we propose the following method to determine the real interest rate for all applications. In Table 1.2, r is the calculated real interest rate, r_{omb} is from the OMB annual publication, and $r_{sd} = i - \pi$ is the real interest rate specific to SDDOT. The r_{omb} rate is essentially a floor rate for the purpose of being conservative: a higher real interest rate (or discount rate) means more penalties to future cash flows.

Table 1.2 Real Interest Rate Selection

		r_{omb}	
		< 0	>0
r_{sd}	$< r_{omb}$	$r = 0$	$r = r_{omb}$
	$> r_{omb}$	$r = r_{sd}$	$r = r_{sd}$

1.4.4 General Discount Rate

In the benefit-cost analysis, the equation of the discount rate is described as:

$$r^* = \frac{i-\pi}{1+\pi} \qquad \text{Equation 1-3}$$

where i is the nominal interest rate and π is the general inflation rate. When π is small, the discount rate can be approximated by the nominal interest rate minus the inflation rate, which is usually used in EEA.

$$r^* = i - \pi \qquad \text{Equation 1-4}$$

1.4.5 Material-specific Discount Rate

Due to the nature of raw materials, some may have a higher inflation rate than others, resulting in different discount rates among these materials. In this situation, where the material-specific discount rate may be more reasonable than the general discount rate, the equation can be formulated as follows:

$$r_j = i - \pi_j \qquad \text{Equation 1-5}$$

where i is the nominal interest rate and π_j is the inflation rate for material j.

1.5 Data Collection, Exploratory Data Analysis and Applications

Eight items are used to create SDCCI: unclassified excavation, liquid asphalt, asphalt concrete, gravel cushion, PCC pavement, class A concrete, reinforcing steel, and structural steel. In January, the unit prices and quantities of these eight items are extracted from all projects let in the previous year and input into an excel spreadsheet to collect the new SDCCI. Results of a sensitivity analysis to identify the impact of individual items on inflation rate suggest that liquid asphalt, asphalt concrete, and PCC pavement have the greatest impact on the statewide inflation rate.

Inflation rates were reviewed and analyzed by cost item and by region. Historical data show that changes in construction materials costs differ from the general inflation rate. Analysis of data from 2007-2012 reveals that the inflation rate for liquid asphalt is consistently higher than that of PCC pavement and asphalt pavement in South Dakota. Based on the same six-year data, geographic-specific inflation rates display conspicuous disparity in project costs between the East River and West River regions, suggesting the application of regional inflation rates.

The effects of mathematical method (e.g., arithmetic mean, harmonic mean and exponential moving average) and length of historical data in calculating short- and long-term inflation rates were analyzed. The results illustrate that the five-year average discount rate can be used for short-term (less than five years) programming purposes such as the STIP to account for the most recent changes. The long-term (10 years or more) average discount rate may be more appropriate for long-term projects to smooth out dramatic fluctuations. Of the three moving average methods (i.e., arithmetic mean, harmonic mean and exponential moving average), the arithmetic mean was more effective smoothing out fluctuations than the exponential moving average.

Applications included pavement LCCAs to identify the impact of discount rate on selection of pavement type. The LCCA case study compared using a general discount rate (the current methodology of SDDOT) with using material-specific discount rates (the proposed methodology). The results suggested that using different discount rates would lead to different decisions in selecting design alternatives. An SDCCI case study was also performed to determine if there is a need to expand the basket.

1.6 Summary

The work conducted in this study can be summarized as follows:

1. The current SDDOT methodologies to calculate interest, inflation, and discount rates were evaluated, and possible methodological problems were discussed.
2. A literature review and interviews of SDDOT personnel were conducted to identify current practices of using interest, inflation, and discount rates in EEAs.
3. Methodologies were proposed and developed that use a non-zero interest rate and a region- and a material-specific inflation rate instead of a general inflation rate.
4. Comparisons were made of the effects of the length of historical data on calculating the short- and long-term inflation rates as well as the corresponding mathematical methods (e.g., arithmetic mean, harmonic mean, and exponential moving average).
5. The LCCA case studies for selecting pavement types were provided to demonstrate disparity between decisions when using material-specific discount rates to select pavement type. The factors that contribute to SDCCI were examined to determine if there is a need for to revise the components in the market basket.

The findings show that:

- Using a zero interest rate either overestimates or underestimates the discount rate, which can directly impact budget preparation for future projects.
- For the inflation rate, the fluctuation of a material-specific rate differs dramatically from the overall rate, justifying the use of material-specific inflation rates. However, given the relatively brief period of analysis in this study, there may not be strong evidence to support the same relative price changes in materials in the future. This is difficult to determine given the influence advances in technology may have on material prices. Hence, the decision to apply the material-specific discount method depends on the availability of data and reliability of prediction.
- While the East River inflation rate is consistent with the statewide trend, the West River trend varies widely. Given the large disparity between east and west, the application of regional inflation rates may be reasonable. However, the question of data availability and prediction reliability remains. Can SDDOT assign a project by region (e.g., East River or West River)? Can we assume that regional differences in project costs can be extrapolated into the future? In the light of such uncertainty, the use of the region-specific rates must be carefully considered.
- Study results illustrate that as analysis time increases, the fluctuation of moving average discount rate becomes smoother. This also indicates that the five-year average discount rate can be used for short-term (five years or less) programming purposes such as STIP, while the long-term (10 or more years) average discount rate may be appropriate for long-term projects.Therefore, SDDOT can use the arithmetic mean for long-term projects to smooth out dramatic fluctuations that occur

in a brief time period, while the exponential moving average may be appropriate for short-term projects to weight the most recent changes more heavily.

- Examination of the items in the SDCCI confirms that the inflation rates calculated with the inclusion of new items differ considerably. This difference suggests that expanding the SDCCI basket may be more justifiable as the construction costs of some new items are increasingly prevalent.

1.7 Implementation Recommendations

Based on the results of this research, the following recommendations are offered.

A. Incorporating Interest Rates

Any EEA of transportation investments should incorporate interest rates to explicitly account for the time value of capital

Both the federal and state portions of SDDOT funds displace private investment and consumption. SDDOT transportation investments should earn a rate of return that of the private investment disrupted by the public investment.

B. Region-Specific Discount Rates

County information for each cost item should be kept, regional CCI calculated, and trends monitored for both East and West River.

Despite compelling evidence of the disparity between East and West River in changes to project costs, more years of data are needed to confirm the inflation rate trend, given trend volatility in both regions.

C. Material-Specific Discount Rates

Changes in inflation rate for individual materials should continue to be monitored by calculating the rates for future years.

Historical data show that some materials have consistently higher rates than general inflation and others have consistently lower rates. Although this justifies the material-specific discount method, the proper use of this rate relies on reasonable estimates of future changes in material prices. In this study, the material's specific rates were calculated for 2007-2012. The trend of the inflation rate can be revisited after five or more years as data become available.

D. Expanded Market Basket

Keep tracking expenditures for new cost items currently not included in SDCCI.

SDCCI needs to be reviewed periodically for construction costs associated with new items such as traffic control, environmental measures (storm water protection, erosion control), and utilities. As new cost items become increasingly prevalent, the basket should be expanded to reflect cost changes. Traffic control cost trends can be revisited after five or more years of data become available.

E. Smoothed Discount Rates

When calculating discount rates using historical data, the exponential moving average should be used for short-term transportation programming if the time interval is less than or equal to five years; the arithmetic moving average should be used for long-term project planning and comparisons of design alternatives with time intervals longer than 10 years.

The arithmetic mean is more appropriate for long-term projects because it can smooth out dramatic fluctuations that occur during a short time period. On the other hand, the exponential moving average may be appropriate for short-term projects because it heavily weights the most recent values.

1.8 Implementation and Maintenance Process

We suggest immediate implementation of recommendations A and E. We also advise establishing a tracking mechanism to monitor price changes of individual cost items and revisiting the study in five years if necessary.

2. PROBLEM DESCRIPTION

Engineering economic analyses (EEA) such as life-cycle cost analysis (LCCA), benefit-cost analysis (BCA), present worth analysis (PWA) etc. apply economic methodologies to engineering problems for decision-making support. EEA allows transportation agencies to compare the overall cost of transportation infrastructure investment alternatives. When conducting an EEA, interest, inflation, and discount rates are the three critical factors that significantly affect the outcome of an economic analysis. Whereas the rates themselves can be determined by different factors and estimated using different methodologies, it is necessary to explore the appropriate methodology to establish sound interest and inflation rates.

Interest, inflation, and discount rates have been constantly used in project programming and planning, pavement type selection, five-year Statewide Transportation Improvement Program (STIP), and sometimes valuing roads transferred from the state highway system to counties and cities by SDDOT. Using inappropriate values for interest and inflation rates could unfairly favor certain industries (such as concrete over asphalt or vice versa), jeopardize the economic analysis, and weaken the credibility of SDDOT investment decisions.

The current interest and inflation rates used by SDDOT for various planning activities may be inappropriate. The inflation rate currently used by SDDOT is a rate calculated from the South Dakota Construction Composite Index (SDCCI). This general rate can neither differentiate between South Dakota regions changes in highway construction costs nor show large variations among the individual material inflation rates used to create CCI. In addition, SDDOT generally assumes a zero interest rate, which approximately equates the real discount rate to the inflation rate. The validity of this assumption needs to be verified.

The discount rate is becoming one of the most controversial topics for any EEA because high discount rates favor design alternatives that have low initial capital cost and high future cost for maintenance or rehabilitation activities, while alternatives with high initial cost and low future cost are disfavored within the same analysis period. Is a project-specific or material-specific discount rate more justifiable than a general discount rate? The purpose of this project is to validate, support, and enhance the current transportation investment decisions at SDDOT by determining if the appropriate rates are being used in various applications and by developing methodologies to establish and maintain the sound and equitable interest and inflation rates.

3. RESEARCH OBJECTIVES

The study covered in this report was undertaken to address the following four main objectives.

3.1 Identify the Current Use of Interest, Inflation, and Discount Rates

Identify and describe SDDOT's use of interest, inflation, and discount rates and determine how critical discounting is for each application.

This research identified various uses of interest and inflation rates at SDDOT (e.g., STIP, LCCA, valuing roads transferred from the state highway systems to counties, etc.). Through the SDDOT interviews, this research helped to understand the historical and contemporary reasons behind the selected rates, as well as the sources and methodologies to generate them. We also reviewed relevant literature and guides regarding the methodologies and resources to obtain interest rates, to calculate material-specific rates, to predict future rates, and to modify CCI.

3.2 Develop Methodologies to Calculate Interest, Inflation, and Discount Rates

Examine and evaluate methods for establishing sound interest and inflation rates for infrastructure investments in South Dakota.

This research established criteria for calculating sound interest and inflation rates for infrastructure investments in South Dakota. The criteria include the project lifecycle, location, components, and type of investment. We also verified the validity of the current SDDOT practice of assuming a zero interest rate and identified the reliable sources of the proxy for SD state interest rates.

Examine the South Dakota Construction Cost Index (SDCCI) and determine if there is a need for asset or project-specific indices.

We examined the methodology to calculate SDCCI (Fisher price index) and all eight cost items included in the current format. We used the Fisher price index to identify liquid asphalt, asphalt concrete, and PCC pavement as the three most influential materials to the statewide inflation rate and calculated their respective inflation rates. We also investigated the methodology to include new items in SDCCI and illustrated with an example using traffic control items.

3.3 Develop the Methodologies to Use Interest, Inflation and Discount Rates for Different Applications

Propose a methodology to establish and maintain sound and equitable interest and inflation rates for different applications within SDDOT.

We proposed the approach for determining the interest rates, inflation rates, and discount rates that reflect the characteristics of South Dakota's Transportation Infrastructure Investment (TII) projects. We compared the proposed method with the current method using hypothetical examples as well as applications for LCCA and STIP. This approach identified the appropriate interest and inflation rates for different applications and the averaging methods for projects of different service lives.

4. TASK DESCRIPTIONS

In the following text, the tasks outlined in the proposal for research are itemized and the methods for their completion are summarized.

4.1 Project Scope and Work Plan Review

Task 1: Meet with the project's technical panel to review the project scope and work plan.

A meeting was conducted on September 5, 2012, in Pierre, South Dakota, with the technical panel members to establish the project scope and discuss the project work plan. The research team outlined the project work plan and any assistance that was required from SDDOT.

4.2 Literature Review

Task 2: Review and summarize the literature on current federal and state methods of interest, inflation, and discount rate determination and economic analysis.

We conducted a comprehensive review of published literature and contacted relevant personnel to collect and synthesize available interest, inflation, and discount rates used by other state DOTs and agencies, especially states whose transportation characteristics resemble those of South Dakota. We also reviewed the practices of other industries, such as environmental and building industries. The review emphasized data requirements and acquisition, estimation methods, and relevant assumptions or limitations. The review also described how other state DOTs justify the interest and inflation rates they use. The results of the literature search were used as the basis for developing the methodologies to calculate interest, inflation, and discount rates and were compiled in this final report.

4.3 SDDOT Interview

Task 3: Interview members of SDDOT selected by the technical panel to determine how economic analysis is performed in each office and planning stage and how interest and inflation rates are determined.

On November 13 and 14, 2012, face-to-face interviews were conducted with members of project development, finance, local transportation programs, bridge design, and other SDDOT members selected by the technical panel using a designed questionnaire. The purpose of the interviews was to obtain detailed information on SDDOT's past and current interest and inflation rates, the procedures for determining these rates, data sources available for developing new alternatives, new ideas, and expectations of future improvements.

4.4 Sensitivity Analysis

Task 4: Perform a sensitivity analysis to evaluate and compare different methods of calculating interest and inflation rates.

In this task, a sensitivity analysis was performed based on Tasks 1, 2, and 3 to identify the impact of the variability of individual factors, such as the choices of the components in South Dakota Construction Cost Index (SDCCI), indexing methods for SDCCI, and the life cycle of investments, on overall economic results. The sensitivity analysis assumes that if reasonable changes in an uncertain input variable will not change the relative ranking of project alternatives or undermine the project's economic justification, the results are considered robust. Alternatively, if a reasonable change in an uncertain input value severely undermines the project's economic justification, action will be required to minimize any negative consequences. Relevant data were collected with the assistance of SDDOT to facilitate the sensitivity analysis. The research team worked with SDDOT to identify the current data inventory and data collection activities that support the estimation of interest, inflation, and discount rates.

4.5 Propose Methodologies

Task 5: Evaluate method(s) for deriving sound and equitable interest, inflation, and discount rates based upon the results of the literature review, interviews, and sensitivity analysis and develop a worksheet focused on the ease of updating, user-friendliness, and availability of data sources.

This research task developed methodologies to calculate interest, inflation, and discount rates based on the results of the sensitivity analysis, literature review, interview summary, and data availability. Three moving average methodologies — arithmetic mean, harmonic mean, and exponential moving average— were also compared to make a smoother estimate for the discount/inflation rate.

SDDOT currently assumes a zero interest rate and applies general inflation and discount rates for all projects within South Dakota. Proposed changes to the methodologies provide a non-zero interest rate estimation method based on the treasury and state-issued bond yields, and an inflation rate calculation with regard to project location, project type, and material.

4.6 Technical Memorandum

Task 6: Submit a technical memorandum and meet with the technical panel to discuss the literature review, interviews, sensitivity analysis, and the proposed methodology.

The technical memorandum was presented to the Technical Panel for review on March 4, 2013. It contained a synthesis of current and proposed methodologies to calculate interest, inflation, and discount rates, case studies, and a sensitivity analysis. A presentation was delivered to the Technical Panel on May 10, 2013, in Pierre, SD. Comments concerning the proposed methods were documented and applied to the revisions outlined in the next task.

4.7 Revision

Task 7: Revise the methodologies based on comments from the Technical Panel.

Final comments submitted by the Technical Panel were forwarded to the research team. After careful review, a point-by-point written response addressing each concern was delivered to the Technical Panel. Revisions were made to the methodologies and the resulting changes were then presented to the panel.

4.8 Final Report

Task 8: Prepare a final report summarizing the research methodologies, findings, conclusions, and recommendations.

This task is met with this report.

4.9 Executive Presentation

Task 9: Make an executive presentation to the SDDOT Research Review Board at the conclusion of the project.

An executive presentation was made to the Research Review Board on August 20, 2013.

5. FINDINGS AND ANALYSES

5.1 Introduction

Engineering economic analyses (EEA) such as life-cycle cost analysis (LCCA), benefit-cost analysis (BCA), and present worth analysis (PWA) apply economic methodologies to engineering problems for decision-making support. EEA allows transportation agencies to compare the overall cost of transportation infrastructure investment alternatives. When conducting an EEA, interest and inflation rates are the two critical economic factors that significantly affect the outcome of an economic analysis (1). Whereas the rates themselves can be determined by various factors and estimated using different methodologies, it is necessary to explore the appropriate methodology to establish sound interest and inflation rates.

The interest rate is the rate at which money is paid by a borrower for the use of money from a lender. The inflation rate measures the value of goods and services in the future, as opposed to their current value. It can also be described as the erosion in the purchasing power of money. Inflation may result from a change in real demand or supply for goods and services, as well as the oversupply of money. The discount rate accounts for the time value of resources or an opportunity cost of resources. In other words, when resources are invested in project A, they are no longer available for other projects. Therefore, the economic return on project A (to the public) should be at least as great as the minimum return gained by the next best alternative. Interest, inflation, and discount rates have been constantly used in project programming and planning, pavement type selection, and sometimes when valuing roads transferred from the state highway system to counties and cities by the South Dakota Department of Transportation (SDDOT). Using inappropriate values for interest and inflation rates could unfairly favor certain industries, jeopardize the economic analysis, and weaken the credibility of SDDOT investment decisions.

The current interest, inflation, and discount rates used by SDDOT for various planning activities need to be reviewed for their appropriateness. At the national level, the discount rate is becoming one of the most controversial topics for any EEA because high discount rates favor design alternatives that have low initial capital cost and high future costs for maintenance or rehabilitation activities, while alternatives with high initial cost and low future cost are disfavored within the same analysis (2, 3, and 4). Is a material-specific rate more justifiable than a general rate? SDDOT is also pondering on the same matter. Additionally, SDDOT generally applies a zero interest rate for its EEA. Zero interest rate means no opportunity cost of the capital invested in the transportation projects and the opportunity cost is what you have to forgo when project A is chosen rather than project B. Is a non-zero interest rate a more proper assumption for transportation investment? The purpose of this project is to validate, support, and enhance the current transportation investment decisions within SDDOT by developing methodologies to establish and maintain the sound and equitable interest and inflation rates for different applications.

5.2 Literature Review

The interest, inflation, and discount rates in EEA are used to compare different project planning or design alternatives. In the literature review, the measurements and values of the rates used in the previous research are introduced and typical LCCA methodologies are provided.

5.2.1 Interest Rate

Interest is the amount of money paid for the use of borrowed money or debt; it is also referred to as the "rent" or debit service on a loan. An interest rate is the rate at which interest is paid by a borrower for the use of money that they borrow from a lender; it reflects the time value of money (5). In the United States, interest rates are determined by the Federal Open Market Committee (FOMC), which meets eight times a year to determine the future direction of monetary policy and interest rates (6).

Historical data of interest rates show that interest rates change over time, and that federal and state rates are not equivalent (7). Federal and local interest rates may vary due to differences in issued bond yields at the two levels; therefore, determining an interest rate for a project funded by both federal and state dollars could be a challenge. Furthermore, the interest rate can vary year to year. The lowest value of the interest rate in the United States was last reported at 0.25%. From 1971 to 2012, the average interest rate in the United States was 6.23%, although it reached 20% in March of 1980 and set a record low of 0.25% in January 2011 (7).

The interest rate is influenced by a number of variables, including the national economy, the condition of its financial system, inflation, etc. (8). Consequently, the selection and estimation of the interest rate is difficult for users who must take all these variables into account. In order to decrease the influence of variability and choose the soundest interest rate, Svensson introduced a convenient yet precise method to estimate the forward interest rate based on the Treasury bill (T-bill) and coupon bond data. Through using the extended Nelson and Siegel functional form, Svensson demonstrated that the minimization of the estimation errors of forward interest rates can be achieved (9).

According to a survey conducted by Zimmerman for SDDOT project SD1996-08, *Guidelines for Using Economic Factors and Maintenance Costs in Life-Cycle Analysis*, not all states used the interest rate on their LCCA and the values of interest rates also varied among states (10). Of the 29 states that responded to the survey, only 12 indicated that the interest rate was currently included. Among these 12 states, a few interest rate values were provided, such as 6%, 7%, and 8%. Some states indicated that the value of their interest rate ranged from 0 to 10% and some indicated that they used a narrower range, from 5% to 8% (10). The survey results reflect the states' discretion to choose their own interest rates but no further information is provided in the report to explain why such a large disparity existed.

5.2.2 Inflation Rate

The inflation rate reflects the value of goods and services in the future as opposed to today; it is the erosion in the purchasing power of money. An inflation rate is the percentage rate of change in price over time, usually one year (11). Economists usually measure the inflation rate by comparing the price index of groupings or "market baskets" of goods and services of the current year to that of the base year. The price index for individual items is constructed by dividing the price of an item in a specific year by its price in the base year, then multiplying by 100 (1). The aggregate price index of the basket can be calculated by the weighted sum of the price of individual cost items using one of the three popular price indexing methodologies: the Laspeyres price index, the Paasche price index, or the Fisher price index (12).

The price indices used for different purposes are different such as the consumer price index (CPI), the producer price index (PPI), the construction cost index (CCI); and the items included in the price index are not necessarily the same. As described in the Economic Analysis Primer, the CPI is probably the most well-known price or inflation index to the majority of Americans (1). The CPI is considered the most relevant measure from a consumer's point of view as it measures the change in prices of goods and services that directly affect one's expenses. The CPI is calculated by the U.S. Bureau of Labor Statistics (BLS) and is published on a monthly basis. The CPI is based on thousands of products that are grouped into 207 categories such as food and beverage, housing, transportation, medical care, etc. (11, 13). Another index that can be used to measure the inflation rate is the Producer Price Index (PPI). The PPI measures the cost of the same basket of goods and services as the CPI, but relates to companies rather than consumers. Because companies eventually pass their costs to consumers in terms of higher prices, changes in the PPI are often considered more useful in predicting changes in the CPI (11).

A number of other popular indices, such as the construction cost index (CCI), the bid price index (BPI), and the gross domestic product (GDP) deflator have been widely used in construction programs. The BPI is composed of six indicator items: common excavation, Portland Cement Concrete (PCC), bituminous concrete pavement, reinforcing steel, structural steel and structural concrete. The Federal Highway Administration (FHWA) previously used the BPI to quantify the changes in highway construction costs, but it adopted the national highway construction cost index (NHCCI) after the Government Accountability Office (GAO) reported that BPI data were low quality (14). Following FHWA, many states have developed a state-specific CCI, including South Dakota. Eight items are used in the current SDCCI: unclassified excavation, liquid asphalt, asphalt concrete, gravel cushion, PCC pavement, class A concrete, reinforcing steel, and structural steel (15).

The inflation rate may be different for programs and states as they serve different purposes. Zimmerman reported that among the nine states that provided typically used values for the inflation rate, one indicated a range of 3% to 4%, another listed a range of 1% to 3%, two agencies stated that they used a value of 3%, three stated that they used 4%, one used 5%, and another used 5.2% in the past few years (10). Despite the differences, each agency seems to apply a uniform inflation rate value irrespective of the purpose and time frame of programs. This practice can be questionable because the price, quantity of the materials, and time period of analysis can be very different. If prices rise more than expected, projects with large future costs may be unfairly advantaged and, on the other hand, if prices rise less than expected, projects with large future costs may be penalized.

Lindsey et al. proposed a material-specific inflation rate method to account for the considerable differences in price and quantity of materials (2). In the report, they illustrate that omitting the difference between real price changes for materials leads to missing the real project cost by an economically meaningful margin (2). In a separate study, Mack showed that "the concrete alternative has a lower LCCA (than that of Asphalt) by between 7.3% and 13.11%" for the Florida DOT rate of 3.5% and the Office of Management and Budget (OMB) rate of 2.0%, respectively, in his case studies based on the 40-year BLS data and Florida DOT's *Pavement Type Selection Manual*. After accounting for the differential price changes, he found "concrete's advantage increases to 12.9% and 19.7%" for the Florida DOT and OMB rates, respectively (3). This material-specific discount rate proposal drew strong criticism, especially from the asphalt industry. Skolnik examined the proposed material-specific inflation rates and suggested that material-specific inflation rates not be considered for LCCA (4). Skolnik argued that for the federal-aid highway construction in 2004, wages, equipment, overhead, and profits dominated the total costs of construction with 57%, while asphalt and concrete only account for less than 9% of the total costs. The use of material-specific inflation rates (asphalt and concrete) in highway construction LCCA may not reflect the actual price change of the overall highway construction activities during the life cycle (4).

Predicting future individual commodity prices based on historical price inflation information is a challenge, but a number of methods have been developed to account for future uncertainties, including simple extrapolation, time-series models, and artificial neural network (ANN) (16, 17, 18). ANN is a data mining technique that is used to discover patterns in the data and then apply these patterns to predict or classify new data. Using an ANN model with two hidden layers, 130 out of 147 CCIs for training to predict the future CCI and the rest for testing to validate the prediction accuracy, Nam et al. presented a CCI forecasting model that produced greater accuracy and higher reliability for the short-term range of future CCI (17). Wilmot et al. developed a method based on five sub-models of individual material prices to estimate the future highway construction cost in Louisiana. The method illustrated that the predicted overall construction costs, including the labor, materials, and equipment, were not significantly different from the observed costs (18). Nevertheless, estimating the future inflation rate is not always recommended. The OMB suggests that for projects or programs extending "beyond the six-year budget horizon, the inflation assumption can be extended by using the inflation rate for the sixth year of the budget forecast" (19).

Overall, inflation rate is one of the most important factors in economic analysis, and it plays an essential role in preparing the budget for an LCCA. Failing to account for inflation in project budget can undermine an agency's ability to adequately fund future projects. The Economic Analysis Primer published by FHWA in 2003 provides guidance for estimating inflation, also suggesting that inflation is very hard to predict. It suggests that the essential time to consider inflation is during the preparation of project budget, but only "after economic analysis has shown the project to be economically viable" (1).

5.2.3 Discount Rate

The discount rate is a percentage rate that accounts for the time value of money when performing an economic analysis or an opportunity cost of capital (20). A higher (lower) discount rate more (less) rapidly reduces the present value of future costs and benefits (1). There are two types of discount rates in economics: nominal discount rates and real discount rates. The nominal discount rate reflects expected inflation of discounting nominal benefits and costs. A real discount rate is the discount rate adjusted to eliminate the effect of expected inflation and should be used to discount constant-dollar or real benefits and costs. The real discount rate has been widely used in EEA and can be approximated by subtracting the expected inflation rate from a nominal interest rate (19).

Concentrating on the application of the discount rate in EEA, the discount rate value can vary among programs with various budget time periods or between the federal level and state level. In January 2003, OMB reported a 10-year real discount rate of 2.5% and a 30-year rate of 3.2%. Nine years later, according to the report issued in January 2012, the 10-year real discount rate became 1.1% and the 30-year rate was 2.0%. All rates are based on current federal borrowing costs (21, 22); however, the discount rate by the U.S. Department of Transportation (USDOT) for projects with significant funding from the federal government may not be appropriate at the state level, as the opportunity cost of funds and overall project risks vary across the nation (22). According to the survey conducted by SDDOT in 1996, the discount rate used most by respondents fell within 3% to 5%. Other values provided included 2.71%, 6%, and 8%, and had a range of 0 to 10% (10). Based on a recent survey by Clemson University on the use of the LCCA's discount rate in pavement projects between 2005 and 2006, two of the 35 states that responded to the survey conducted sensitivity analyses for their discount rates, three used a probabilistic approach to account for risk and uncertainty in the prediction, and the remainder used discrete values ranging from 3% to 5.3%. Four states in the last grouping used the OMB discount rate (23).

5.2.4 Engineering Economic Analysis

Selecting appropriate discount rate values is critical because it directly affects the outcome of the economic analysis. Economic analysis is a key component of a comprehensive project or program evaluation that considers all key quantitative and qualitative impacts of highway investments; it can assist highway agencies in supporting their decision making (1). Numerous studies conducted in the past several years have researched the implementation of economic analyses in transportation. OMB Circular A-94 establishes the guidelines and rules for the use of discount rates in economic analyses (19). FHWA Economic Analysis Primer in 2003 described how the interest rate, inflation rate, discount rate, and other factors should be used in an economic analysis (1). A recent National Cooperative Highway Research Program (NCHRP) report presents the detailed methods and implementation of engineering economic analysis in highway investment through a number of projects conducted during the past few years (5). The SDDOT project SD1996-08 is SDDOT's most recent effort toward better applying economic analysis in decision-making support (10).

The economic analysis concepts and methods include, but are not limited to, LCCA, BCA, PWA, incremental benefit-cost analysis (IBCA), measures of cost-effectiveness, and cost avoidance as a concept of benefit (5). LCCA is appropriate for selecting among alternatives where benefits of the possible project alternatives are identical, and has been widely used in pavement type selection. A survey conducted by Clemson University showed that 32 of 35 states used LCCA as part of the decision-making process for pavement type selection (23). LCCA can also be used in value engineering (VE), project planning, and implementation, especially with regard to the use and timing of work zones (1).

FHWA provided several examples to show how to use benefit-cost analysis and present worth analysis to compare alternatives and introduced the tools for implementing an economic analysis. FHWA indicates that BCA can be used to help determine whether or not a project should be undertaken at all, as well as which alternative or project should be funded over others given a limited budget (1). Benefit-cost ratio (BCR) is one of the most popular parameters in benefit-cost analysis. FHWA also recommends that only the initial agency investment cost be included in the denominator of the ratio. All other BCA values, including periodic rehabilitation costs or user cost, should be included in the ratio’s numerator as positive or negative benefits.

5.3 SDDOT Interview Summary

This section summarizes the responses of SDDOT employees who participated in a face-to-face interview. The purpose of the interviews was to obtain detailed information on SDDOT’s past and current interest and inflation rates, procedures for determining these rates, data sources available for developing alternatives and new ideas, and expectations of future improvements. This summary consists of three sub-sections: current practices, methodologies, and data requirements.

5.3.1 General Application of EEA

EEA has been widely used in long- and short-term SDDOT planning, project development, and management processes in areas such as pavement, bridge, vehicle fleet, and overall asset management. Several systems using EEA at SDDOT include pavement management, bridge management, project identification coordination, and equipment management. LCCA, BCA, and incremental benefit-cost analysis (IBCA) have been used to determine whether projects are economically justifiable and choose the best alternative. Specifically, the five-year STIP uses EEA to determine project priority based on budget constraint. The bridge management system applies IBCA.

Currently, all SDDOT offices assume a zero interest rate because SDDOT can neither issue bonds nor save unused money. Therefore, no interest revenue is generated from savings. To be specific:

- State highway fund revenue sources are primarily made up of state gas tax, 3% motor vehicle excise tax, interest, sales of assets (equipment and land assets), and smaller miscellaneous revenues. SDDOT uses these revenues to match federal funds, do maintenance work, make equipment purchases, etc.
- SDDOT receives progress payments or installments for a majority of projects that have federal funding. In essence, the DOT pays the contractor and then immediately bills FHWA for the federal portion of the costs. Some projects will receive a reimbursement after they have been completed, but these are usually small-scale projects.

The inflation rates applied in different SDDOT departments or systems vary. Overall, four inflation rates are currently used:

- The five-year STIP uses a 2% inflation rate determined from a combination of weekly updated Associated General Contractor (AGC) reports, historical trends, and DOT judgment.

- The 4.51% inflation rate used in pavement management is calculated using SDCCI whose rates are computed from total (materials, wages, equipment, etc.) costs.
- Bridge engineers have used the 5% discount rate/inflation rate in the Bridge Management System (BMS) since 1990.
- The inflation rate specified by the Office of Finance for fleet management is 5%, despite the fact that the actual inflation since 2007 has been about 10% or higher every year due to the dramatic increase in equipment prices. The values of inflation rates used in different SDDOT departments are listed in Figure 5.1.

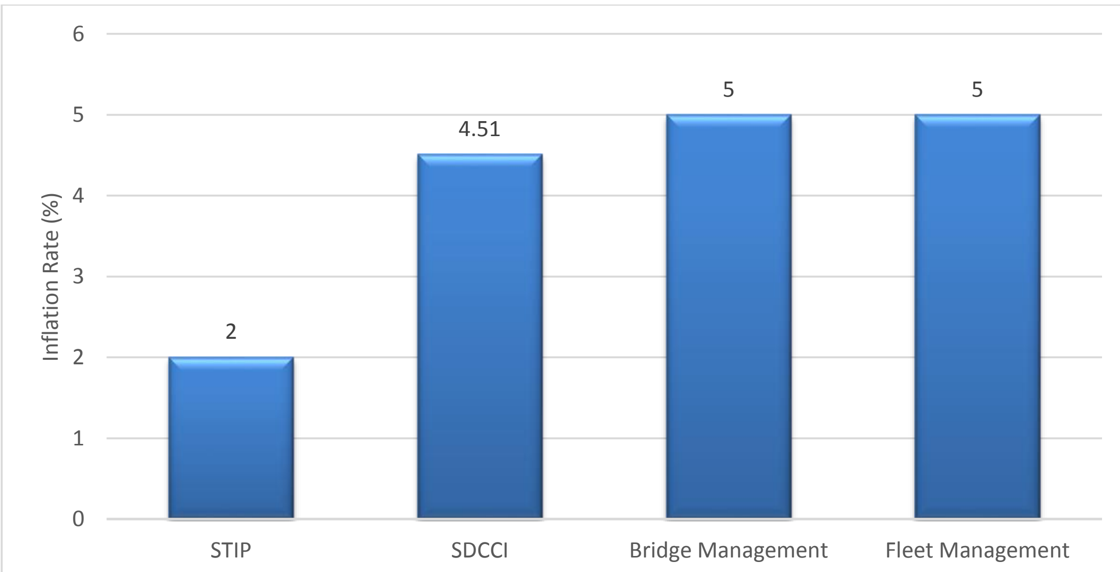


Figure 5.1 Inflation Rates Used in SDDOT

Mathematically, the discount rate approximates the difference between the interest rate and the inflation rate. SDDOT generally uses the absolute value of the difference as the discount rate when assuming a zero interest rate. First, it is incorrect to define the discount rate as the absolute difference. Second, the discount rate under such assumption is always equal to the (absolute value of) inflation rate, which lacks theoretical or empirical support. It seems that inflation rate is mistaken for discount rate. Inflation rate indicates the change of purchasing power over time while discount rate indicates the time value or opportunity cost. The discount rate normally has a positive value whether or not there is inflation in the economy.

5.3.2 Methodologies (policies, processes, and procedures)

Opinions were split among interviewees on the determination of the interest rate for the discounting purpose when a transportation project is funded by a combination of federal and state or local funds. Some agreed that adopting a rate that reflects the constitution of funding sources is appropriate, while others consider the change is not worth the effort and think using the federal rate or zero interest rate is sufficient.

In terms of using the historical average of inflation rates or a forward-looking inflation rate in the budgeting and planning stage, all seemed to agree that forward-looking is appropriate but has to be reliable, defendable, and justifiable. The interviewees also warned about small sample issues as well as the difference between short-term and long-term projections. If the historical average value is used, the five-year arithmetic mean is sufficient to reflect the recent or anticipated fluctuations, while the 10-year arithmetic mean can smooth out some of the dramatic fluctuations that occurred during that time.

Of the three originally proposed methodologies in estimating a discount rate—region-, project- and material-specific discount rates—a general discount rate with fewer fluctuations is preferred for long-term, conceptual transportation planning activities. For project or program levels of planning activities where more information (e.g., materials quantities, unit prices, etc.) becomes available, an investment- or project type-specific index may be more defensible. Regarding region-specific indices, the responses are mixed. Some interviewees mentioned that geographic cost variation is either budgeted into the project cost or considered when choosing design alternatives or materials and they thought the benefit of a region-specific rate may not be as significant as a project-type-specific rate. Others thought the geographic difference is worth investigating. All interviewees agreed that the simplicity and practicality of the method is very important.

5.3.3 Data requirements and provision

The interview established that the following data could be provided by SDDOT:

- historical SDCCI
- historical information about discount rate used in pavement management system, bridge management system, and STIP
- road swap examples
- historical statewide transportation improvement plans by year with project location information
- Cost information for new items potentially to be included in the SDCCI, such as traffic control, environmental measures (storm water protection, erosion control), and utilities

5.4 Methodologies

In this section, methodologies to calculate interest, inflation, and discount rates are introduced and procedures for conducting LCCA are presented.

5.4.1 Inflation Rate

At SDDOT, the annual inflation rate is measured as the percentage change of the SDCCI from the previous year:

$$\pi_t = 100\% \left(\frac{SDCCI_t - SDCCI_{t-1}}{SDCCI_{t-1}} \right) \qquad \text{Equation 5-1}$$

where π_t, $SDCCI_t$, and $SDCCI_{t-1}$ are the inflation rate, SDCCI of the current year *t*, and SDCCI of the previous year *t-1*, respectively. The SDCCI can be used to track price changes associated with highway construction costs and to convert current-dollar expenditures to real dollar expenditures (1). Three popular indexing methods cited by FHWA are the Laspeyres index, the Paasche index, and the Fisher price index (12):

$$\boldsymbol{L}(\boldsymbol{p}) = \frac{\sum_{j=1}^{N} p_{j,t} q_{j,0}}{\sum_{j=1}^{N} p_{j,0} q_{j,0}} \quad \text{(Laspeyres price index)} \quad \text{Equation 5-2}$$

$$\boldsymbol{P}(\boldsymbol{p}) = \frac{\sum_{j=1}^{N} p_{j,t} q_{j,t}}{\sum_{j=1}^{N} p_{j,0} q_{j,t}} \quad \text{(Paasche price index)} \quad \text{Equation 5-3}$$

$$\boldsymbol{F}(\boldsymbol{p}) = \sqrt{\frac{\sum_{j=1}^{N} p_{j,t} q_{j,0}}{\sum_{j=1}^{N} p_{j,0} q_{j,0}} \times \frac{\sum_{j=1}^{N} p_{j,t} q_{j,t}}{\sum_{j=1}^{N} p_{j,0} q_{j,t}}} \quad \text{(Fisher price index)} \quad \text{Equation 5-4}$$

where

$p_{j,t}$ is the unit price of individual material or item *j* in the current year
$q_{j,t}$ is the quantity of individual material or item *j* during the current year
$p_{j,0}$ is the unit price of individual material or item *j* during the base year (2006 in this study)
$q_{j,0}$ is the quantity of individual material or item *j* during the base year.

All three price indexes use quantities of individual items as weights to their prices in the calculation. The difference is that the Laspeyres index uses the amount of commodities at base year while the Paasche index uses the amount of commodities at current year. The Fisher index is a geometric mean of the Laspeyres and Paasche index. Despite the ease of calculation, the Laspeyres price index has the inherent limitation of overstating the impact of increase in the unit price and understating the impact of decrease in the unit price as time goes on. The reason is that the Laspeyres price index is unable to account for the consumers' reaction to the price change, i.e., they may purchase less when price increases or vice versa. In contrast, the Paasche price index usually understates the impact of unit price increase and overstates the impact of unit price decrease. Fisher index, on the other hand, overcomes this limitation by considering the quantities of both the base year and the future year. FHWA uses the Fisher price index to calculate the National Highway Construction Cost Index (NHCCI) (14) and SDDOT uses it to calculate SDCCI (Figure 5.2).

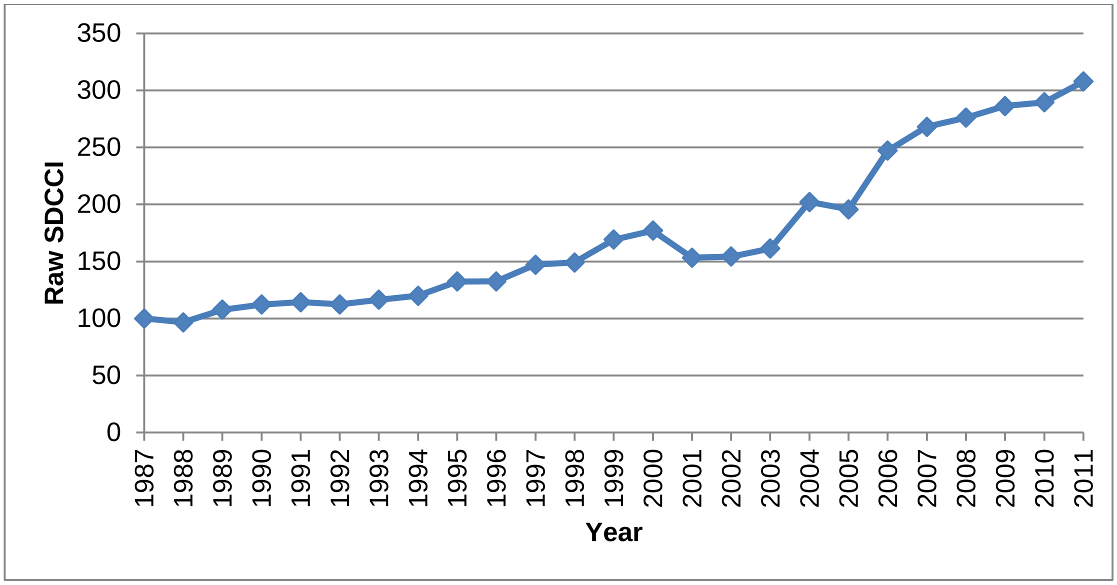


Figure 5.2 Raw Annual SDCCI

5.4.2 Interest Rate

Nominal Interest Rate

The nominal interest rate is the rate at which interest is paid by a borrower for the use of money. It reflects the opportunity cost of the capital. The capital allocated to SDDOT projects is usually a combination of federal and state funds. There is always an opportunity cost to both federal and state dollars invested in an SDDOT project; otherwise, the federal funds could be used to generate (economic or social) returns from other state DOT's projects or non-state DOT's projects. At a minimum, the state funds could be used by the state as collateral, explicitly or implicitly, to issue bonds, borrow money, or be allocated to other state departments when it is legally allowed to do so.

SDDOT currently assumes a zero interest rate. A zero interest rate assumption means no opportunity cost of capital allocated to SDDOT projects. However, any public transportation fund, either from the Federal Highway Trust Fund or from South Dakota state transportation funds, should bear opportunity costs of (a) potential displacement of private investments and (b) crowd-out of private consumption. More specifically, the displacement refers to the fact that public investments "siphon away any resources that could otherwise have earned private sector rates of return" (24). The crowd-out effect refers to "the funds raised by taxation are, in reality, diverted mainly from consumption" (24).

However, the estimation for the opportunity cost is challenging in practice. Instead, "governments typically use the rate at which they borrow money as a basis" for calculating nominal interest rates[1] (24). To correct for the potential bias of zero interest rate in terms of SDDOT transportation investments, actual interest rates can be estimated by a weighted sum of treasury and state-issued bond yields if the capital consists of both federal and state funds, with the weights being the percentage contribution of respective funding sources. The daily Treasury bond yield can be obtained from the Department of the Treasury (25). SDDOT can choose the interest rate that matches its decision timeframe from a cross section of bond yields with maturities ranging from one month to 30 years.

[1] Nominal interest rate in the context of this report is equivalent to nominal discount rate used by Berechman (2009).

The interest rate, or the reference yield, applicable to the state of South Dakota can be approximated in two ways. The first is to employ the annual rate of return generated by SDIC. The historical information up to the most recent year is available for the South Dakota Cash Flow Fund Duration Portfolio (SDCDP) on the SDIC website (26). The total return SDCDP reported therein is a reasonable proxy for the interest rate relevant to SDDOT. The second way to approximate South Dakota's reference yield is through the rate of state or municipal bonds at the Electronic Municipal Market Access of the Municipal Securities Rulemaking Board (27). Although SDDOT is not authorized to issue bonds, state-issued bonds sponsored by general state revenue provide a reliable proxy for the cost of capital applicable to SDDOT's funding dollars. The state/municipal bond rate is better than the SDCDP rate, but the availability of the former may often be constrained. For instance, the bond with CUSIP number 837549KW3 may not be available at the time of investment decision.

Example: Suppose SDDOT plans for a 30-year highway project on February 12, 2013. 80 percent funding is from federal and 20% funding is from the state. The appropriate federal rate will be a 30-year treasury-bond yield at 3.19%. If the SDCDP rate stands at 1.88% in 2012, the weighted sum of rates is 2.93% (2.93%=3.19%×80%+1.88%×20%).

If SDDOT plans for a 10-year project on February 20, 2013, the appropriate federal rate will be a 10-year treasury-note yield at 2.02%. The appropriate state interest rate will be the yield for a 10-year SD Economic Development and Finance Bond (CUSIP 837549KW3) at 3.737%, the weighted sum of rates is 2.36% (2.36%=2.02%×80%+3.737%×20%)

Real Interest Rate

Note that the interest rate (bond yield) determined above is a nominal interest rate that ignores the effects of inflation. To correct for the effects of inflation, the term "real interest rate" is commonly used in economics textbooks (11). The real interest rate is approximated by subtracting the inflation rate from the nominal interest rate.[2] As such, the real interest rate reflects the opportunity cost of capital in constant dollars while the nominal interest rate represents the opportunity cost of capital in current dollars. Note that the terminology "real interest rate" often related to debt securities or savings accounts in general economics is less commonly seen in engineering economics, in which the equivalent term is "real discount rate" or simply "discount rate."

The discount rate recommended by OMB Circular No. A-94 for cost-effectiveness analyses is the real interest rate ("For cost-effectiveness analysis, analyses that involve constant-dollar costs should use the real treasury borrowing rate on marketable securities of comparable maturity to the period of analysis" [21]). The current nominal and real interest rates for 2013 (28) are listed in Table 5.1.

Table 5.1 Nominal vs. Real interest Rates on Treasury Notes and Bonds of Specified Maturities (OMB Circular A-94)

Interest Rate	3-year	5-year	7-year	10-year	20-year	30-year
Nominal (*i*)	0.5	1.1	1.5	2.0	2.7	3.0
Real (*r*)	-1.4	-0.8	-0.4	0.1	0.8	1.1

[2] The more accurate way to represent the relationship between nominal and real interest rates is derived as follows: suppose that $1 is saved in a savings account that earns nominal annual interest rate i with the inflation rate π. In a year, $1 becomes (1+$i$) nominal dollars. The real interest rate r is the rate of return on the $1 investment excluding inflation. In fact, one year later, we only have (1+r) worth of real dollars which is equal to (1+i) nominal dollars deflated by inflation. The equivalence is $1 + r = \frac{1+i}{1+\pi} \Leftrightarrow r = \frac{i-\pi}{1+\pi}$.

The very low or even negative values in Table 5.2 are caused by removing expected inflation over the analysis period from nominal Treasury interest rates. Note that special care should be taken when using a negative real interest rate because the resulting negative rate is largely due to the low nominal interest rate that is artificially suppressed by the Federal Reserve for the purpose of economic stimulus during a recession. Because the inflation rate incurred by a typical SDDOT project may be higher than the overall inflation in recent years, the occurrence of negative rates is even more likely than the federal rates if we use an SDDOT-specific (hereafter state) inflation rate. The negative (state) discount rate is hardly justifiable for SDDOT's long-term (more than 10-year) projects or any other investment projects, public or private. During a federal budget shortfall (such as that we are currently in) the rates listed in Table 5.1 may underestimate the cost of borrowing. For short-term (less than 10-year) projects, it is better to assume a zero real interest rate than a negative rate.

To correct negative rates, we propose the following method to determine the real interest rate which can be applied for all applications. In Table 5.3, r is the calculated real interest rate, r_{omb} is from the OMB annual publication, and $r_{sd} = i - \pi$ is the real interest rate specific to SDDOT. The r_{omb} rate is essentially a floor rate for the purpose of being conservative: higher real interest rate (or discount rate) means more penalties to future cash flows.

Table 5.2 Real Interest Rate Selection

		r_{omb}	
		< 0	>0
r_{sd}	< r_{omb}	r = 0	r = r_{omb}
	> r_{omb}	r = r_{sd}	r = r_{sd}

Figure 5.3 illustrates how different the discount rate can be with the proposed and current methods under the assumption of a 10% (nominal) interest rate for South Dakota and a 2% 30-year OMB discount rate.

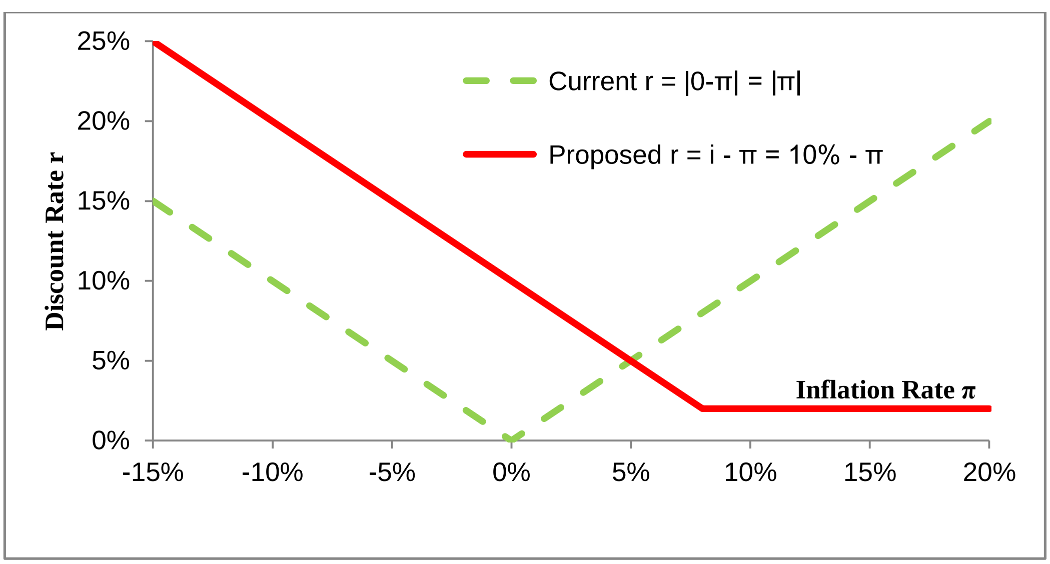


Figure 5.3 Discount Rate Methodology Comparison

5.4.3 Discount Rate

General Discount Rate

As mentioned above, both the interest and discount rates reflect opportunity cost of capital or time value of money. The discount rate policy set by OMB Circular A-94 suggests choosing the discount rate differently for the cost-effective and benefit-cost analyses.[3] In a cost-effectiveness analysis, only future real costs are discounted at the real discount rate. The real discount rate, which reflects the opportunity cost of using the highway funds, is equal to the real interest rate. Hence, both terms can be used interchangeably. In a benefit-cost analysis, both costs and benefits (often realized later than costs) of public investments should be discounted. The real discount rate should reflect the true opportunity cost of public investment that may disrupt private investment and consumption.[4] Hence, it is not necessarily equal to the real interest rate as explained in Section 5.4.2.2. Therefore, the term "discount rate" is more appropriate to use. The discount rate is formulated as (11):

$$r^{*} = \frac{i - \pi}{1 + \pi} \qquad \text{Equation 5-5}$$

where *r* is the real discount rate, *i* is the nominal interest rate and π is the general inflation rate. When π is small, the discount rate is approximately measured by the nominal interest rate minus the inflation rate usually used in EEA (11).

$$r^{*} \cong i - \pi \qquad \text{Equation 5-6}$$

---

[3] The cost-effective analysis, a common example of which is LCCA, refers to the analysis of the discounted costs of different alternative approaches to achieve the same project objectives. The benefit-cost analysis (BCA) refers to the analysis of the discounted benefits vs. costs of a project, which may "yield one or more alternative measures of a project's economic merit."(1)

[4] OMB Circular A-94 recommends a real discount rate of 7% as a baseline case.

Material-Specific Discount Rate

The prices of most goods and services rise over time; this is referred to as "general inflation." General inflation is caused mainly by the oversupply of money, or by the varying supply and demand relationship in the market; if demand is larger than supply, inflation occurs and vice versa for deflation. Due to the nature of raw materials, some may have a higher inflation rate than others, resulting in the difference of discount rates among these materials. For instance, as described by Mack, on the basis of the PPIs published by BLS from 1971, a general discount rate is a reasonable estimate of concrete while it is not a reasonable estimate for asphalt because a general discount rate underestimates the inflation rate for asphalt by approximately 2.7% (3). Hence the material-specific discount rate may be more reasonable than the general discount rate and the equation can be reformulated as follows in Equation 5-7 with subscript j representing cost item j.

$$r_j \cong i - \pi_j \qquad \text{Equation 5-7}$$

5.4.4 Moving Average Methods

The moving averaging of historical data is commonly used by decision makers as an estimate for the discount and inflation rates. The moving average method is a type of statistical analysis of time series. When the dataset contains enough observations for parameter estimation (e.g., at least 30 observations are recommended), more sophisticated models such as autoregressive moving average (ARMA) can be fitted to time series points to better predict the future. Since the discount rate is the difference between the nominal interest rate and the inflation rate, smoothing discount rate ultimately amounts to smoothing both interest and inflation rates. The same smoothing method can be applied to both rates. Three average methods, arithmetic mean, harmonic mean, and exponential moving average, are described in this section. Both the definitions and equations of the three methods are expressed in Table 5.3.

Table 5.3 Definition and Equation for Averaging Methods

Average method	Definition	Equation
Arithmetic Mean (AM)	The central tendency of a collection of numbers taken as the sum of the numbers divided by the size of the collection, with equal weight for x_1, x_2,...	$A = \frac{1}{n}\sum_{i=1}^{n} x_i$
Harmonic Mean (HM)	The reciprocal of the arithmetic mean of the reciprocals of x_1, x_2, …	$H = \left(\frac{1}{n}\sum_{i=1}^{n} x_i^{-1}\right)^{-1}$
Exponential Moving Average (EMA)	The infinite impulse response filter that applies weighting factors that decrease exponentially, creating an unequal weight for x_1, x_2, …	$S_1 = x_1$ $S_t = \alpha x_t + (1-\alpha)S_{t-1}\ (t > 1)$ Note: α is the weighting parameter.

The arithmetic mean is usually used in situations where the data are not skewed and are not dependent on each other.

The harmonic mean is usually used in situations where extreme outliers exist in the population. Unlike the arithmetic mean, the harmonic mean gives less significance to extremely large values because of the inverse effect. However, the harmonic mean may overstate the effect of negative or extremely small values.

The exponential moving average is best used in situations where all past data points are believed to be meaningful in taking the average, although older data has diminishing contribution to the average. The exponential moving average is used by Cogley (29) to predict the core inflation rate that represents the long-run trend in the price level (e.g., the core inflation rate is the yearly based inflation rate compared with the CPI based inflation rate which is the monthly based inflation rate). This method is also commonly used in stock trading as a technical indicator, such as moving average convergence/divergence (MACD) as a momentum indicator.

$$S_t = \alpha x_t + (1-\alpha)S_{t-1} = \alpha x_t + \alpha(1-\alpha)x_{t-1} + (1-\alpha)^2 S_{t-1}$$
$$= \alpha[x_t + (1-\alpha)x_{t-1} + (1-\alpha)^2 x_{t-2} + (1-\alpha)^3 x_{t-3} + \cdots] + (1-\alpha)^{t-1}x_1$$

Equation 5-8

The selection of the averaging method affects the value of the discount rate. Using the historical discount rate in Figure 5.4 (note that SDDOT uses 1987 as the base year), the five-year average for arithmetic, harmonic, and exponential moving average (with α=0.5 and an optimal value[5] over all the sample data) are calculated in **Figure** .5.

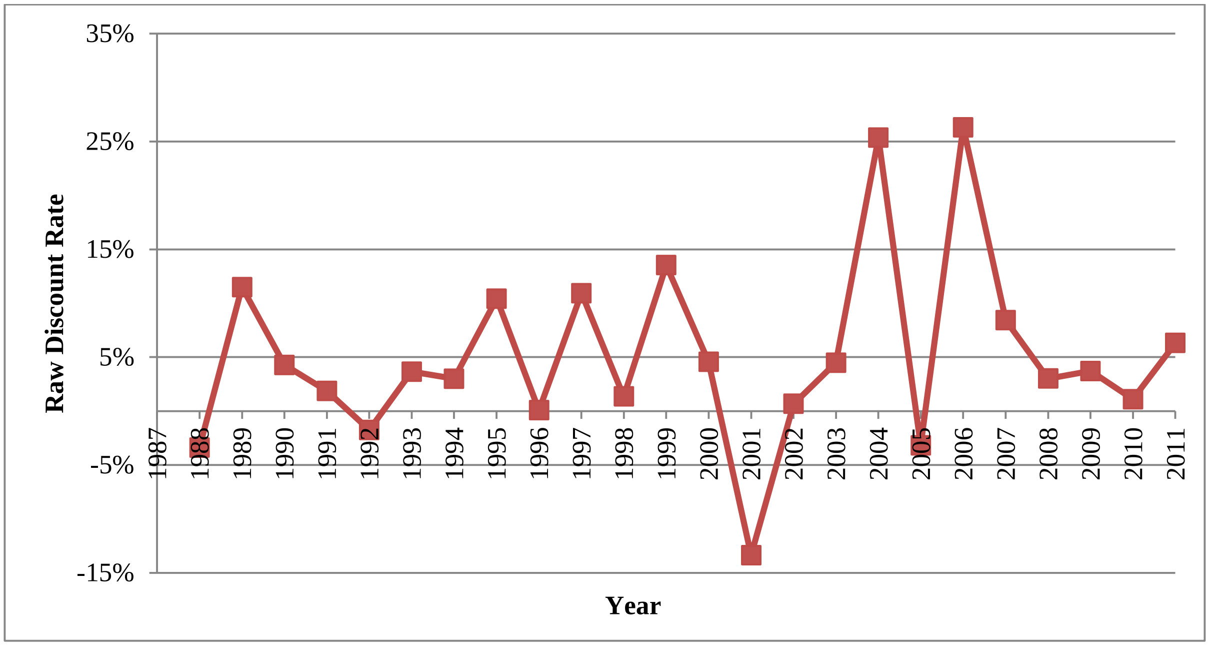


Figure 5.4 Raw Annual Discount Rate

[5] The optimal value for α is obtained by minimizing the sum of the absolute differences between the observed value and the forecasted value based on the exponential smoothing rule. The optimal value here is obtained by applying the minimization procedure to the sample discount rates from 1988 to 2011. A larger (smaller) α implies more (less) influence of most recent values. Once the value of α is established, the inflation rate based on EMA can be forecasted for the next year or several years later, depending on the planning horizon.

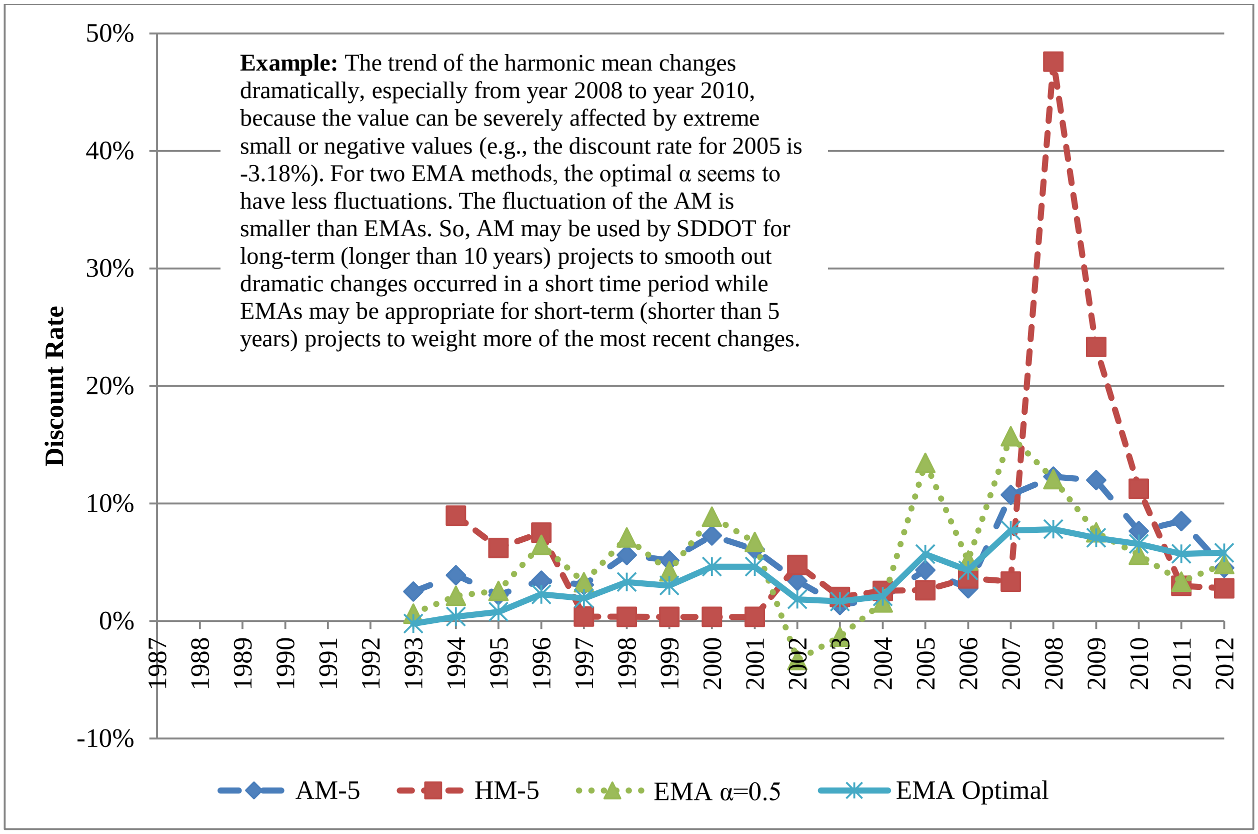


Figure 5.5 Five-Year Moving Average of Discount Rate*

*: Note: The value of HM-5 in1993 (-490.28%) is considered as an outlier and removed from the analysis.

5.4.5 Life-Cycle Cost Analysis (LCCA)

LCCA with the General Discount Rate

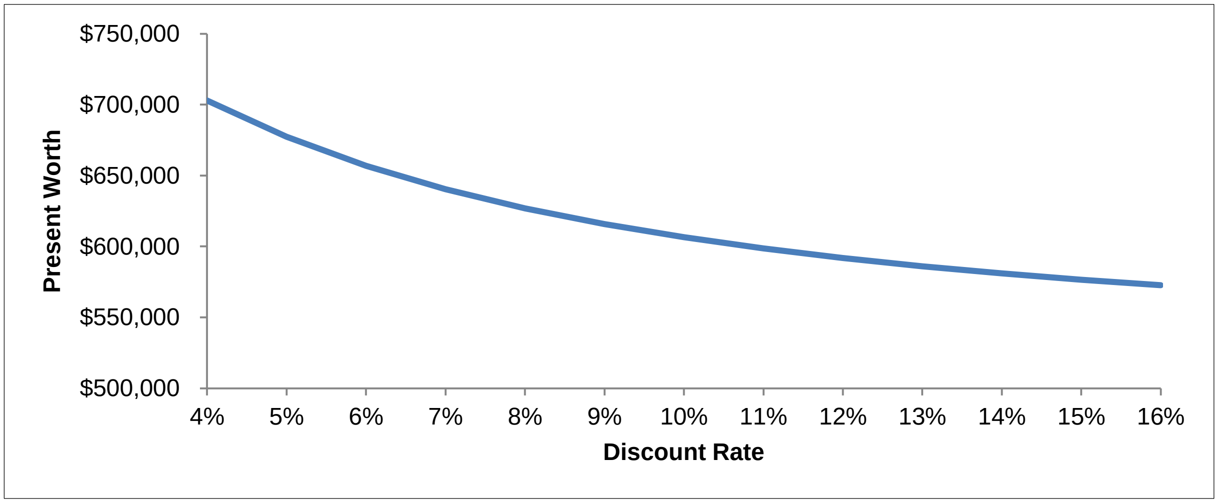
In LCCA, the discount rate can be used to discount future cash flows if the objective is to evaluate their economic value at the present time, or to compound cash flows to the future if the objective is to estimate their future value. The discounting formula for the present value (PV) is:

$$PV = \sum_{t=1}^{T} \sum_{j=1}^{N} \frac{C_{jt}^{*}}{(1+r^{*})^{t}} \qquad \text{Equation 5-9}$$

where r^* is the general discount rate and C_{jt}^* is the real cost of material j at time t.

Example: Changes in discount rate will slightly affect the net present worth, because in the project selection process, initial construction cost, which occurs in the present year, is not discounted. Only future costs like maintenance and rehabilitation are discounted to present value to allow a comparison among design alternatives. The effect of discount rate on present value depends upon the percentage of undiscounted (initial capital investment) and discounted future costs during the life cycle of a project.

For instance, assume the present worth of a project was calculated using the discount rate between 4% and 16%. The figure below shows that the present worth decreases slightly (from $700,000 to $600,000) as the discount rate increases from 4% to 16%.

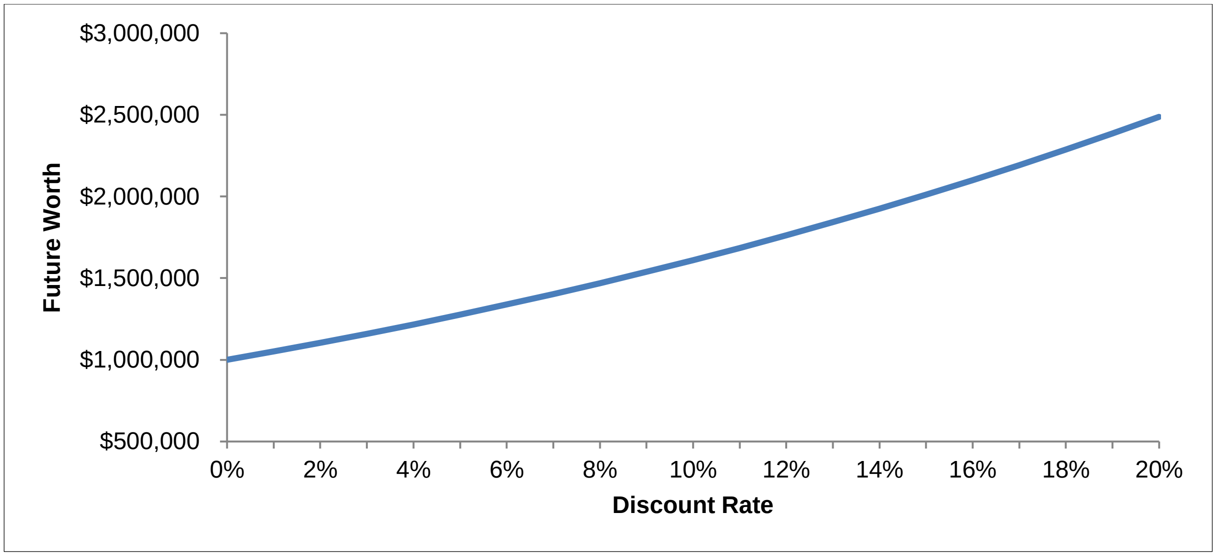


On the other hand, during the programming and planning (e.g., STIP) process when programming construction projects for future (5 or 8) years, total project cost, including initial construction cost, will be compounded to the future worth at the year of activity. The formula is calculated in Equation 5-10 (1).

$$A_t = PV \times (1 + r^*)^t \qquad \text{Equation 5-10}$$

where A is the amount of benefit or cost in year t.

Example: The following phenomenon demonstrates the impact of discount rates on project programming. Using a discount rate that is lower than reality will cause over-programming, meaning there will be more projects than the budget allows for in the future. Meanwhile, a higher discount rate will cause under-programming wherein the entire budget cannot be spent in the process of network level programming. During the time of a sufficient or surplus budget, a lower discount rate may be used in order to program more projects. For instance, assume that future worth was calculated for a fixed present worth ($1,000,000) for 5 years with different discount rates. The figure below shows that future worth significantly increases as the discount rate increases.



LCCA with the Material-specific Discount Rate

For public agencies, the best method of forecasting the life-cycle costs of a project is to exclude the influence of inflation to calculate the real cost. The change in real cost over the years can be expressed as an escalation rate. Then the real cost in the year of activity can be formulated as $C_{jt}^{*}(1+e_j)^t$ where e_j is the escalation rate for material *j*. In LCCA, the future cost needs to be discounted to the present value using a discount rate. The updated equation for the PV value is formulated as (3):

$$PV = \sum_{t=1}^{T}\sum_{j=1}^{N}\frac{C_{jt}^{*}(1+e_j)^t}{(1+r^*)^t} = \sum_{t=1}^{T}\sum_{j=1}^{N}\frac{C_{jt}^{*}}{\left(\frac{1+r^*}{1+e_j}\right)^t} \qquad \text{Equation 5-11}$$

where r^* is the general discount rate and C_{jt}^{*} is the real cost of material *j* at time *t*.

This method, referred to as the *escalation-discount method* (3), agrees with the OMB Memorandum "Interpretation of OMB Circular A-94" released on September 20, 2012 (30). The OMB Memorandum says, "Agencies should decide, based on their own professional judgment, if there is a reliable basis to assume changes in relative prices and when such assumptions would improve their analysis. Regardless of any assumptions about relative prices and costs, all alternatives being compared should be discounted with the same discount rate following the guidelines in Section 8 of Circular A-94." The first sentence in the memo suggests agencies to decide an escalation rate (e_j) for materials should be applied; and the second sentence refers to the general real discount rate (r^*), which is the same for all materials.

However, the material-specific escalation rate is usually not available because it is difficult to estimate how the real cost of each material appreciates. Fortunately, the material-specific escalation rate can be approximated by the difference between the general real discount rate (r^*) and the material-specific discount rate (r_j), which is defined as the difference between the interest rate (i) and the inflation of material j (π_j). This method is called the *material-specific discount rate method* as formulated in Equation 5-12 (2).

$$PV \approx \sum_{t=1}^{T} \sum_{j=1}^{N} \frac{C_{jt}^*}{(1+r_j)^t} \qquad \text{Equation 5-12}$$

where r_j is the discount rate for material j and $r_j = i\text{-}\pi_j$ [6]

Example: Assume that the base year for an analysis is 2013 and the discount rate for material A is 3% while the discount rate for material B is 5%. If a pavement will be built in 2033 with total cost being $1,000,000, the present worth of building a pavement with material A would be:

$$\frac{\$1{,}000{,}000}{(1+3\%)^{20}} = \$553{,}676$$

The present worth of building a pavement with material B would be:

$$\frac{\$1{,}000{,}000}{(1+5\%)^{20}} = \$376{,}889$$

5.5 SDCCI Data Collection and Analysis

This section describes the formation of the SDCCI and how its data are gathered. In the exploratory data analysis section, the inflation rates were reviewed and analyzed by region and by cost item. The sensitivity of SDCCI components in calculating the inflation rate was analyzed. The purpose of the exploratory data analysis is to assess the necessity and feasibility of an asset-specific, material-specific, or region-specific rate.

5.5.1 Data Collection Process

According to SDDOT, the process flow for the present SDCCI data is:

a) In January of each year, the Office of Finance requests data for the eight aggregated bid items in the SDCCI from the Office of Project Development.
b) The Office of Project Development uses the BID TABS software application to extract the eight aggregated items (Unclassified Excavation, Liquid Asphalt, Asphalt Concrete, Gravel Cushion, PCC Pavement, Class A Concrete, Reinforcing Steel, and Structural Steel) and mobilization. (BID TABS was implemented in 2007, and makes it possible to search through historical bid items and output those items into an Excel spreadsheet.)
c) For each project, a mobilization factor is calculated based on the total project cost and mobilization cost. A single mobilization factor is calculated and applied to all bid item categories.
d) The SDCCI Index is already set up as an Excel-based worksheet. The aggregated quantity and total cost of the eight aggregated bid items for the most recent year is inputted in the Excel-based worksheet. The mobilization factor is applied to the aggregated quantity and total cost of each of

[6] The item $\frac{1+r^*}{1+e_j}$ in Equation 5-11 is equal to $1 + \frac{r^*-e_j}{1+e_j}$ which can be approximated by $1 + r^* - e_j = 1 + i - \pi - (\pi_j - \pi)$. The right-hand side of the preceding equation can be simplified as $1 + i - \pi_j$. The material-specific discount rate (r_j) is then defined as $i - \pi_j$, hence Equation 5-12.

the eight items. (Changing the format of the worksheet or adding a new aggregated bid item would require rewriting the Excel-based worksheet for the SDCCI).

e) The SDCCI is calculated between the most recent year's data and the base year's data.
f) The new annual SDCCI is typically published on the DOT website in February.

The flow chart of the development of the present SDCCI to present is shown in Figure 5.6.

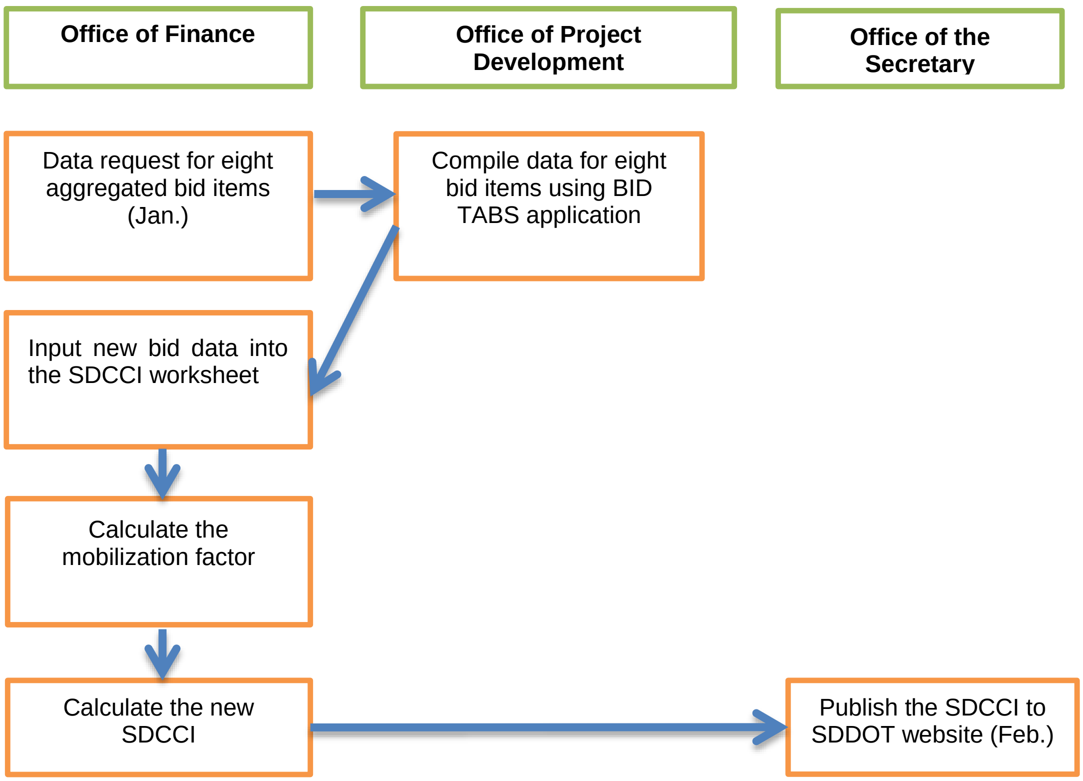


Figure 5.6 Development of the SDCCI

Prior to 2006, the cost information of all eight items had to be extracted by hand. Beginning each January, an employee of the Office of Finance looks at the abstract of bids (.pdf file only) for all projects let in the previous year. The employee then manually inputs each item within a bid category into an Excel spreadsheet and finds the total quantity and total costs of the items. Once the data set is complete, the Office of Finance would follow step "c" through "e" above to calculate the SDCCI.

5.5.2 Exploratory Data Analysis

Material/Item Cost and Cost Percentage by Year

Figure 5.7 illustrates the annual construction costs in South Dakota based on the costs of the eight items included in the SDCCI. Annual costs of materials affecting the SDCCI range between $70,000,000 and $190,000,000. Figure 5.8 shows the cost percentage of eight items from 1987 to 2012. As is depicted, Liquid Asphalt, Asphalt Concrete, and PCC Pavement are the three most consumed items/materials in SD construction activities.

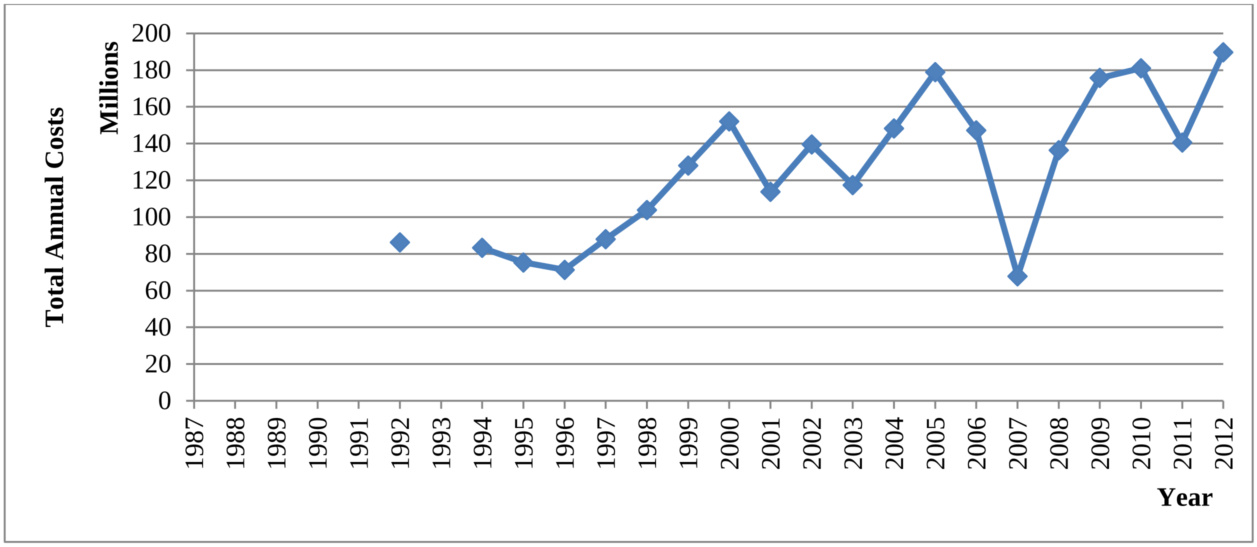


Figure 5.7 Annual Construction Costs by Year*

* Note: The original SDCCI data for year 1987-1991 and 1993 are missing.

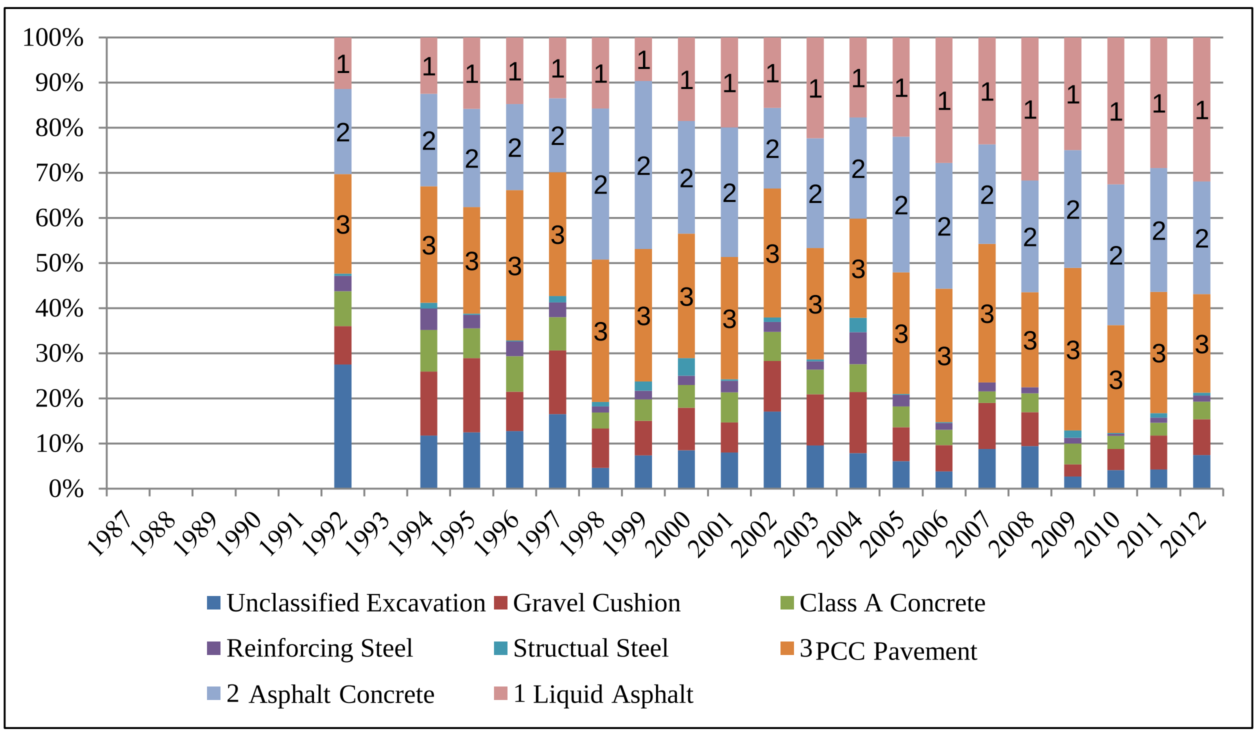


Figure 5.8 Cost Percentages of SDDCI Materials by Year

Effect of Material/Item Cost on Inflation Rate

The rest of the exploratory data analysis uses the same dataset, including project location information. The Office of Project Development has used the BID TABS software application to extract the county information since 2006 but compiling cost information earlier than 2006 is problematic.

Based on seven-year (2006-2012) SDDOT construction item unit price and quantity data, inflation rates were calculated with seven out of eight items in SDCCI and one item excluded at a time. The comparison was based on 1) the difference between the standard deviation of the inflation rate without an item and the standard deviation of the overall inflation rate, and 2) the standard deviation of the difference between the inflation rate without an item and the overall inflation rate. The item that causes the most variation when absent from the inflation rate calculation is considered to be the most influential while the item that causes relatively minor changes when absent from calculation is considered to be the least influential.

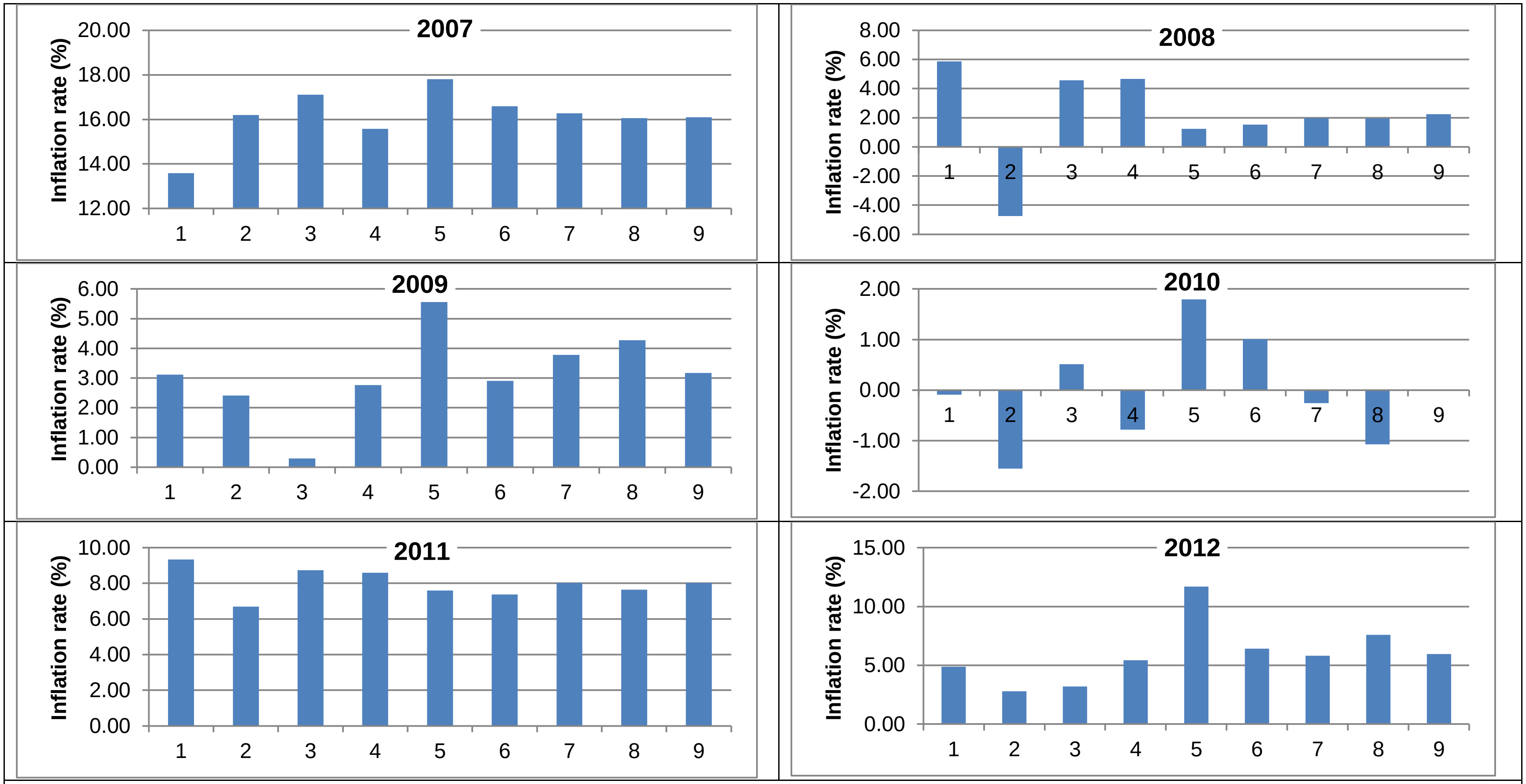
According to Table 5.4, Liquid Asphalt, Asphalt Concrete, and PCC Pavement are the three most influential materials to the statewide inflation rate.

Figure 5.9 shows the change of inflation rate with one item being excluded at a time as well as the overall inflation rate over the years.

Table 5.4 Top Three Materials or Items Influencing Inflation Rate

Item excluded	Inflation rate (% change from prior year)						Results	
	2007	2008	2009	2010	2011	2012	Rank I[1]	Rank II[2]
1. Unclassified Excavation	13.59	5.87	3.12	-0.09	9.34	4.88	2	4
2. Liquid Asphalt	16.20	-4.74	2.41	-1.55	6.69	2.80	1	1
3. Asphalt Concrete	17.11	4.56	0.29	0.51	8.74	3.21	3	3
4. Gravel Cushion	15.58	4.67	2.76	-0.78	8.60	5.44	6	5
5. PCC Pavement	17.81	1.23	5.73	1.97	7.60	11.69	4	2
6. Class A Concrete	16.59	1.52	2.91	1.01	7.37	6.42	8	7
7. Reinforcing Steel	16.27	1.97	3.78	-0.26	8.02	5.81	7	8
8. Structural Steel	16.06	1.95	4.28	-1.07	7.65	7.60	5	6
9. Eight Items (overall)	16.09	2.25	3.17	0.01	8.02	5.96	-	-

[1]Ranked by the difference of the standard deviation.
[2]Ranked by the standard deviation of the difference.



Note: 1-Unclassified Excavation; 2-Liquid Asphalt; 3-Asphalt Concrete; 4-Gravel Cushion; 5-PCC Pavement; 6-Class A Concrete; 7-Reinforcing Steel; 8-Structural Steel; 9-Include Total Eight Items

Figure 5.9 Materials or Items Influencing Inflation Rate

Material-specific Inflation Rate

It is evident that the consumption of eight materials or items listed in SDCCI changes over the years. The amount, unit price, total cost, and corresponding inflation rate vary drastically from one to another. Using one general or uniform inflation rate cannot represent eight distinctive cost items. It is more appropriate to use material-specific inflation rate for construction projects with primary cost originating from a single material. For construction projects composed of multiple cost items, a general discount rate or a weighted sum of cost items is more appropriate. Table 5.5 and Figure 5.10 compare the material-specific inflation rate and the overall (eight items included) inflation rate. Apparently, material-specific inflation rates fluctuate dramatically from the overall inflation rate. This phenomenon justifies using a material-specific inflation rate.

Table 5.5 Material/Item Specific Inflation Rate

Item	**Inflation rate (% change from prior year)**					
	2007	**2008**	**2009**	**2010**	**2011**	**2012**
Liquid Asphalt	19.59	21.72	6.90	-0.09	12.27	15.47
PCC Pavement	14.53	5.16	-2.90	-8.97	8.33	-7.59
Asphalt Concrete	16.61	-4.26	12.19	-1.12	5.72	14.18
Overall (total eight items)	16.09	2.25	3.17	0.01	8.02	5.96

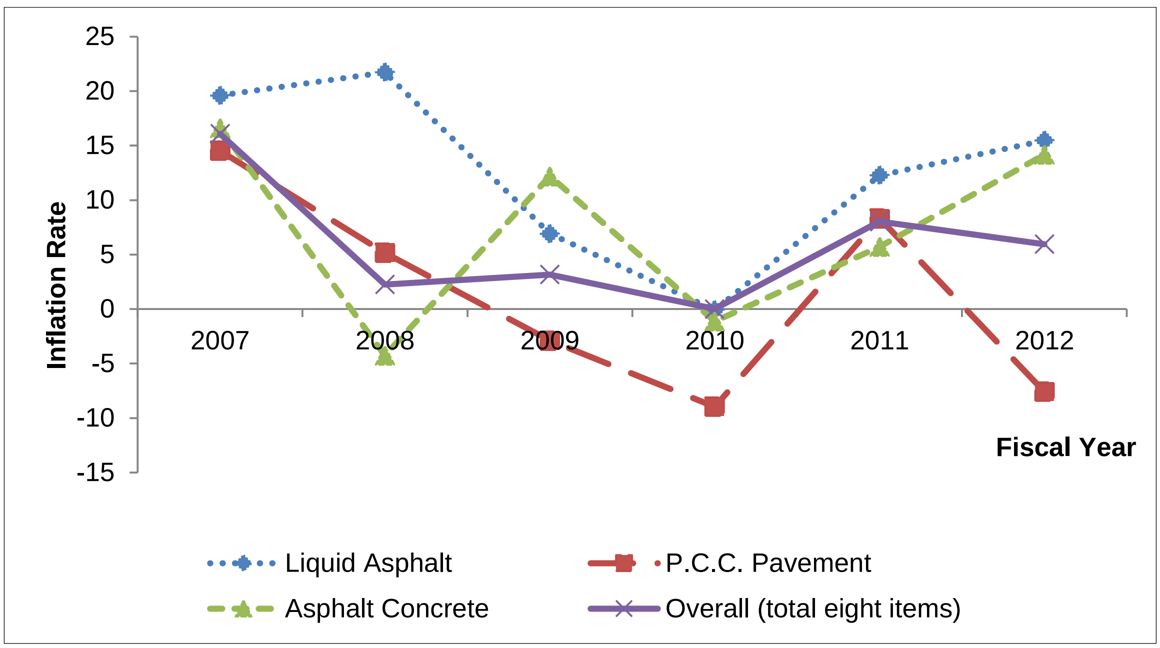


Figure 5.10 Material/Item-Specific Inflation Rate

Material Quantities by Region

Figure 5.11 shows the geographical division of East River and West River. Figure 5.12 shows the item/material quantity comparison between East River and West River. The trends between East River and West River for Liquid Asphalt, Asphalt Concrete, and Unclassified Excavation are positively correlated, while the trends for Gravel Cushion, Class A Concrete, and Reinforcing Steel are negatively correlated.

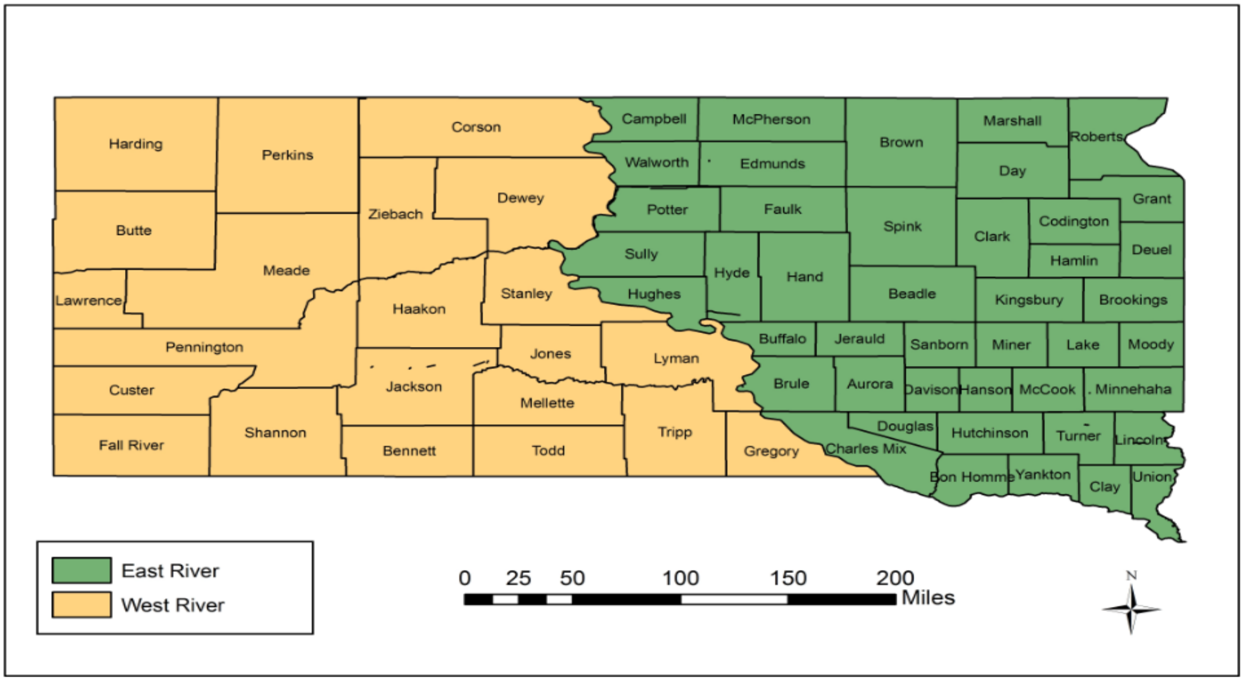


Figure 5.11 Geographical Division of East River and West River

The trends between East River and West River for both PCC Pavement and Structural Steel seem to be independent. In terms of PCC Pavement, the trend of quantity in West River is relatively flat while the trend in East River changes drastically over the years. In most years, the quantity of Structural Steel is very low, but use surged in 2009 and 2011. All the results point out the quantity differences of item/material between East River and West River. Region-specific inflation rates may be appropriate if material price changes are affected by region. For instance, concrete price change increases (or decreases) faster (or slower) in East River than that of West River. Otherwise, a specific rate for each item/material can be applied for all of South Dakota.

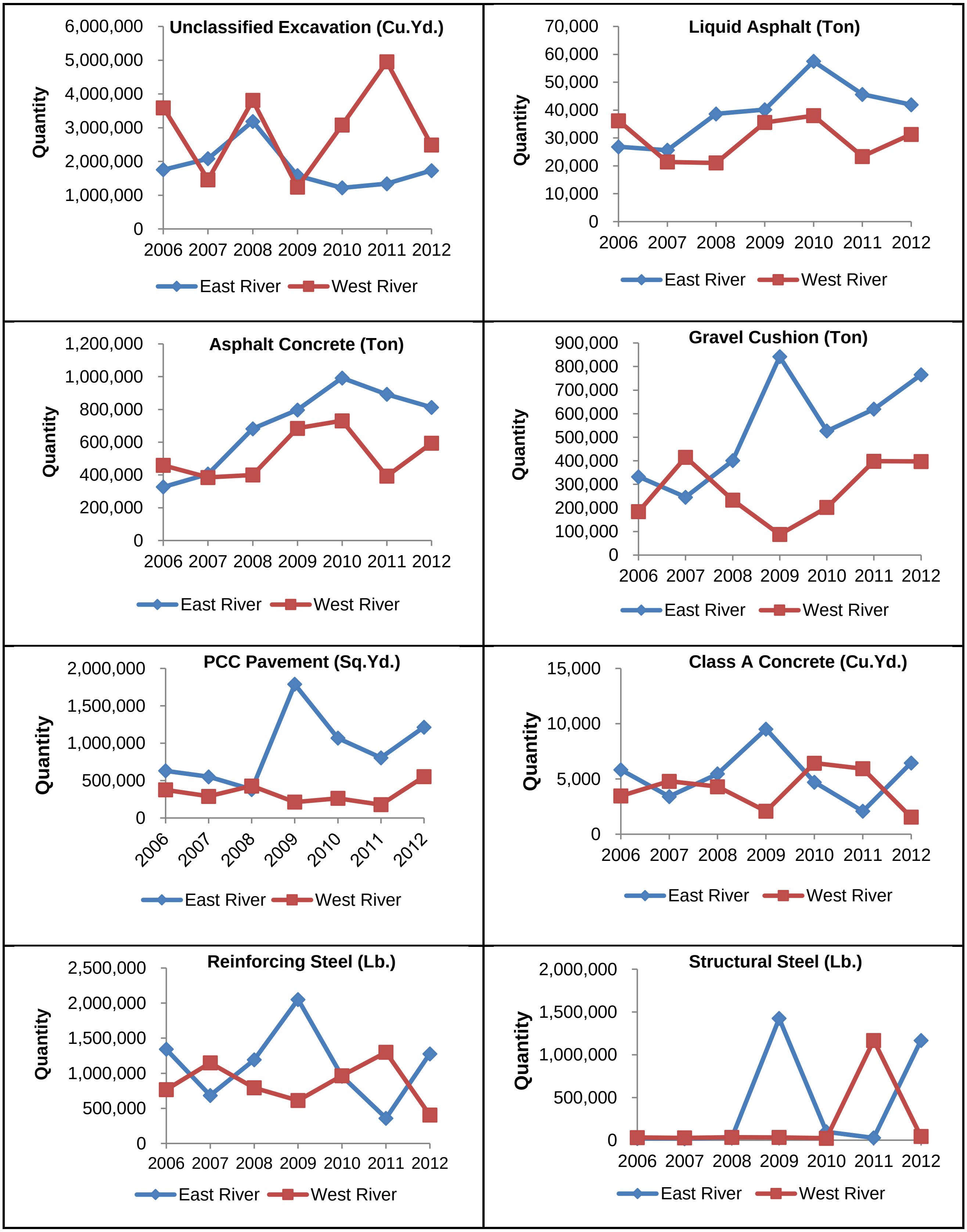


Figure 5.12 Material Quantity Comparison between East River and West River

Region-specific Inflation Rate

The previous section illustrates significant variation between East River and West River in projects, construction materials/items. The large disparity suggests the development of region-specific inflation rates. Table 5.6 and Figure 5.13 display the calculated inflation rates of the West River region, the East River region, and the state of South Dakota by using the data provided by SDDOT. Overall, all three rates are highly variable but the trend in the East River region is more consistent with the state. The rate in West River varies widely, especially in 2008 and 2010. Given the large disparity of the inflation rates between East River and West River, the application of regional inflation rates may be reasonable in order to differentiate the inherent differences between East River and West River (e.g., the type of highway projects, the quantities of various construction materials, and the excavation and mobilization costs). Because the values of the four factors $p_{j,t}$, $q_{j,t}$, $p_{j,0}$, and $q_{j,0}$ (Equation 5-4) in the overall SDCCI are not weighted by the values of either East River or West River, the inflation rate of South Dakota overall does not necessarily lie between the inflation rates of the two regions.

Table 5.6 Region-Specific Inflation Rates

Location	Inflation rate (% change from prior year)					
	2007	**2008**	**2009**	**2010**	**2011**	**2012**
East River	26.44	8.94	5.84	-2.14	4.97	8.47
West River	36.42	-8.44	14.71	-7.59	9.12	6.00
Overall (SD)	16.09	2.25	3.17	0.01	8.02	5.96

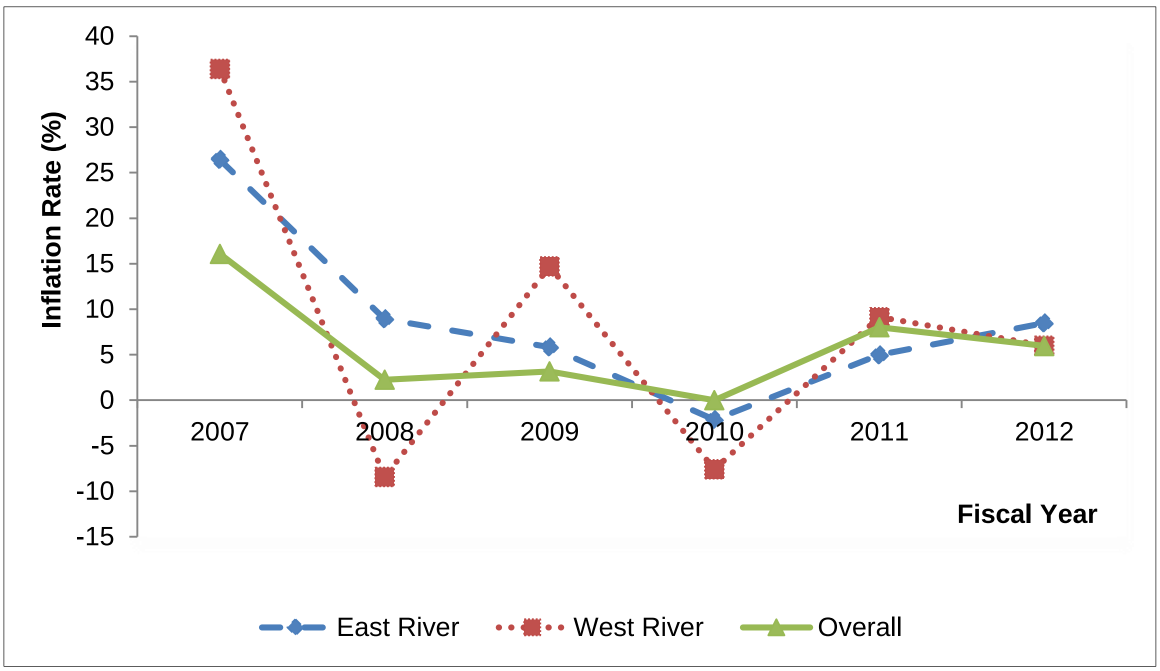


Figure 5.13 Region-Specific Inflation Rate

Historical Average of SDDOT Discount Rates

Highway projects have different service lives. The comparison between short-term (less than five years) and long-term (longer than 10 years) moving averages was conducted using the discount rate provided by SDDOT from 1987 to 2011. Figure 5.14 shows the 5-, 10-, and 20-year historical average (arithmetic mean) discount rates provided by SDDOT. As the analysis time period increases, the fluctuation becomes more smoothed. The five-year average discount rate can be used for short-term programming purposes such as STIP to sufficiently account for the most recent changes. A 10-year, 20-year, or longer average discount rate may be appropriate for the long-term projects to smooth out dramatic fluctuations.

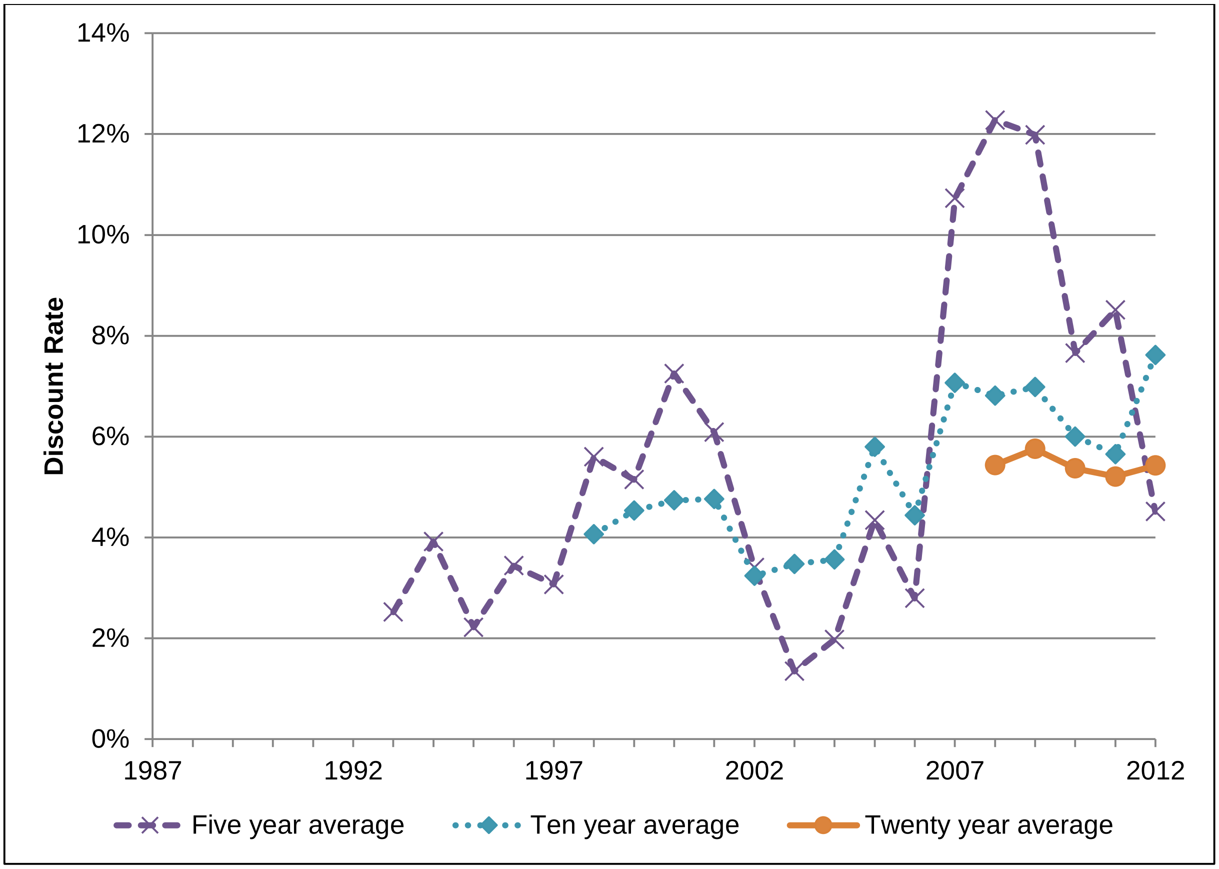


Figure 5.14 Historical Average of SDDOT Discount Rates

5.6 Applications

In this section, several case studies of applying discount rates in pavement type selection LCCAs, applying inflation rates in STIP and modifying SDCCI by adding new cost items are conducted.

5.6.1 LCCA Case Studies

This case study compares pavement type selection decisions made with a general discount rate and material-specific discount rates. The initial capital costs for alternative 2 are assumed to be higher than those of alternative 1 but there will be more future costs on alternative 1, including maintenance, rehabilitation, as well as salvage and removal costs.

Only future costs for activities such as maintenance and rehabilitation are discounted to the present value in order to compare between design alternatives. The effect of the discount rate on the present value depends on the undiscounted and discounted portions during the life cycle cost of a project. Figure 5.15 shows that the selection of discount rate significantly impacts the costs of alternative 1 with a substantial future cost. When the general discount rate of 7.1% is applied, alternative 1 is recommended for its lower PV LCC. If the general discount rate reduces from 7.1% to 5.6% (not shown in Figure 5.15), alternative 2 will have a lower PV PCC.

LIFE-CYCLE COST ESTIMATING WORKSHEET									
Initial Analysis Year	2009	Project Id							
Analysis Period	40	County							
Annual Discount rate, %	7.1	PCEMS							
						Alternative 1		Alternative 2	
						Projet Description		Projet Description	
Initial Costs									
Item	Item Description	Analysis Year	Calendar Year			Estimated Cost	Present Worth	Estimated Cost	Present Worth
Alternative 1		3	2012			$491,194	$491,194		
Alternative 2		5	2014					$572,300	$572,300
			Total Present Worth of Initial Costs						
Perodic Costs									
Item	Item Description	Analysis Year	Calendar Year			Estimated Cost	Present Worth	Estimated Cost	Present Worth
Activity 1		8	2012			$100,000	57768		
Activity 2		10	2014			$1,500	755		
Activity 3		18	2027			$120,000	34912		
Activity 4		20	2029			$1,500	380		
Activity 5		33	2042			$140,000	14557		
Activity 6		35	2044			$1,500	136		
Activity 7									
Activity 8		18	2027					$25,000	7273
Activity 9		25	2034					$80,000	14400
Activity 10		32	2041					$100,000	11136
Activity 11									
			Total Present Worth of Periodic Costs				108508		32809
Annual Costs		First Yr. of Ann. Costs		Last Yr. of Ann. Costs		Estimated		Estimated	
Item	Item Description	Analysis Yr.	Cal. Yr.	Analysis Yr.	Cal. Yr.	Annual Cost	Present Worth	Annual Cost	Present Worth
Activity 1		1	2010	40	2049	$1,156	15234		
Activity 2		1	2010	40	2049			$1,562	20585
Activity 3									
			Total Present Worth of Annual Costs				15234		20585
Replacement/Salvage Value									
Item	Item Description	Analysis Year	Calendar Year			Estimated Value	Present Worth	Estimated Value	Present Worth
Activity 1									
			Total Present Worth of Replacement/Salvage Value				$0		$0
			TOTAL LCC			Alternative 1		Alternative 2	
			Present Worth LCC			$614,937		$625,694	
			Equivalent Uniform Annual LCC			$43,569		$44,331	
			Lowest Uniform Annual LCC			Alternative 1			
			PW Cost Difference From Lowest LCC Alternative			$0		$10,757	
			% Differnece From Lowest LCC Alternative			0		2	

Figure 5.15 SD Pavement Selection Project: Using General Discount Rate

In reality, different price changes of individual materials lead to different discount rates. The discount rate of material 1 in alternative 1 may be lower (higher) than that of alternative 2, because the inflation rate of material in alternative 1 may be higher (lower) than that of alternative 2. The case study in Figure 5.16 uses 5% discount rate for material 1 in alternative 1 and 7% discount rate for material 2 in alternative 2 (other parameters such as interest rate and inflation rate are also provided in Figure 5.16). The 5% discount rate is calculated by subtracting the 5% inflation rate from the 10% nominal interest rate. The 7% discount rate is calculated by subtracting the 3% inflation rate from the 10% nominal interest rate.

LIFE-CYCLE COST ESTIMATING WORKSHEET											
Initial Analysis Year	2009	Project Id									
Analysis Period	40	County									
Annual Discount rate, %	General:7.1; *Alternative 1* : 5; *Alternative 2* : 7	PCEMS									
Annual Inflation rate, %	General:2.9; *Alternative 1* : 5; *Alternative 2* : 3					Alternative 1			Alternative 2		
Nomial interest rate, %	10					Projet Description			Projet Description		
Initial Costs											
Item	Item Description	Analysis Year	Calendar Year			Estimated Real Cost	Inflation rate	Present Worth	Estimated Real Cost	Inflation rate	Present Worth
Activity 1		3	2012			$491,194		$491,194			
Activity 2		5	2014						$572,300		$572,300
Total Present Worth of Initial Costs											
Perodic Costs											
Item	Item Description	Analysis Year	Calendar Year			Estimated Real Cost	Inflation rate	Present Worth	Estimated Real Cost	Inflation rate	Present Worth
Activity 1		8	2012			$100,000	Material 1	68217			
Activity 2		10	2014			$1,500	General	1013			
Activity 3		18	2027			$120,000	Material 1	50750			
Activity 4		20	2029			$1,500	General	685			
Activity 5		33	2042			$140,000	Material 1	28902			
Activity 6		35	2044			$1,500	General	380			
Activity 7											
Activity 8		18	2027						$25,000	General	12341
Activity 9		25	2034						$80,000	Material 2	14764
Activity 10		32	2041						$100,000	Material 2	11498
Activity 11											
Total Present Worth of Periodic Costs								149946			38603
Annual Costs		First Yr. of Ann. Costs		Last Yr. of Ann. Costs		Estimated			Estimated		
Item	Item Description	Analysis Yr.	Cal. Yr.	Analysis Yr.	Cal. Yr.	Annual Real Cost	Inflation rate	Total Present Worth	Annual Real Cost	Inflation rate	Total Present Worth
Activity 1		1	2010	40	2049	$1,156	General	16316			
Activity 2		1	2010	40	2049				$1,562	General	22046
Activity 3											
Total Present Worth of Annual Costs								16316			22046
Replacement/Salvage Value											
Item	Item Description	Analysis Year	Calendar Year			Estimated Value	Inflation rate	Present Worth	Estimated Value	Inflation rate	Present Worth
Activity 1											
Total Present Worth of Replacement/Salvage Value								$0			$0
TOTAL LCC						Alternative 1			Alternative 2		
Present Worth LCC								$657,456			$632,949
Equivalent Uniform Annual LCC								$31,939			$30,749
Lowest Uniform Annual LCC									Alternative 2		
PW Cost Difference From Lowest LCC Alternative						$24,507			$0		
% Differnece From Lowest LCC Alternative						4			0		

Figure 5.16 Pavement Type Selection ─ Material-Specific Discount Rate (Eq. 5-11)

Figure 5.16 shows the result based on Equation 5-11 and Figure 5.17 shows the result based on Equation 5-12. Both results suggest that alternative 2 should be selected. The difference between the two methods is negligible. Compared with alternative 2, the present worth of costs for alternative 1 in this example is considerably higher. The material-specific discount rates may be more reasonable in pavement type selection LCCA because the discount rates for different pavement materials are different (3).

LIFE-CYCLE COST ESTIMATING WORKSHEET									
Initial Analysis Year	2009	Project Id							
Analysis Period	40	County							
Annual Discount rate, %	General:7.1; *Alternative 1 : 5; Alternative 2 : 7*	PCEMS							
				Alternative 1			Alternative 2		
				Projet Description			Projet Description		
Initial Costs									
Item	Item Description	Analysis Year	Calendar Year	Estimated Real Cost	Inflation rate	Present Worth	Estimated Real Cost	Inflation rate	Present Worth
Activity 1		3	2012	$491,194		$491,194			
Activity 2		5	2014				$572,300		$572,300
		Total Present Worth of Initial Costs							
Perodic Costs									
Item	Item Description	Analysis Year	Calendar Year	Estimated Real Cost	Inflation rate	Present Worth	Estimated Real Cost	Inflation rate	Present Worth
Activity 1		8	2012	$100,000	Material 1	67684			
Activity 2		10	2014	$1,500	General	755			
Activity 3		18	2027	$120,000	Material 1	49862			
Activity 4		20	2029	$1,500	General	380			
Activity 5		33	2042	$140,000	Material 1	27982			
Activity 6		35	2044	$1,500	General	136			
Activity 7									
Activity 8		18	2027				$25,000	General	7273
Activity 9		25	2034				$80,000	Material 2	14740
Activity 10		32	2041				$100,000	Material 2	11474
Activity 11									
		Total Present Worth of Periodic Costs				146800			33487
Annual Costs		First Yr. of Ann. Costs	Last Yr. of Ann. Costs	Estimated			Estimated		
Item	Item Description	Analysis Yr. Cal. Yr.	Analysis Yr. Cal. Yr.	Annual Real Cost	Inflation rate	Total Present Worth	Annual Real Cost	Inflation rate	Total Present Worth
Activity 1		1 2010	40 2049	$1,156	General	16316			
Activity 2		1 2010	40 2049				$1,562	General	22046
Activity 3									
		Total Present Worth of Annual Costs				16316			22046
Replacement/Salvage Value									
Item	Item Description	Analysis Year	Calendar Year	Estimated Value	Inflation rate	Present Worth	Estimated Value	Inflation rate	Present Worth
Activity 1									
		Total Present Worth of Replacement/Salvage Value				$0			$0
		TOTAL LCC		Alternative 1			Alternative 2		
		Present Worth LCC				$654,310			$627,834
		Equivalent Uniform Annual LCC				$31,787			$30,500
		Lowest Uniform Annual LCC					Alternative 2		
		PW Cost Difference From Lowest LCC Alternative		$26,477			$0		
		% Differnece From Lowest LCC Alternative		4			0		

Figure 5.17 Pavement Type Selection ─ Material-Specific Discount Rate (Eq. 5-12)

This example is intended to illustrate the correct process to account for inflation rates and the potential impact on results. The key consideration is that because the escalation rates are used, the expected future costs of each alternative are more accurately adjusted to represent the agency's most likely expenditures based on the investment decisions. Of course, the choice of future rehabilitation and maintenance strategies (e.g., frequency, cost, technologies, etc.) as well as the removal and salvage costs directly affect the result of LCCA as they constitute the future costs.

5.6.2 STIP

This section uses the Statewide Transportation Improvement Program (STIP) to demonstrate the moving average algorithm and the length of analysis time period. The STIP is a five-year plan that identifies capital improvements to preserve, renovate, and enhance South Dakota's transportation system. It is anticipated that the five-year plan may be extended to an eight-year plan to allow more time for project planning, design, environmental studies, and right-of-way acquisition. The following example illustrates the changes in average inflation rate by the length of the historical data and the algorithm applied.

Figure 5.18 displays the STIP for fiscal year 2012 through fiscal year 2016. The estimated costs are based on the 2010 average unit costs adjusted for 2% inflation rate, which is calculated by CPI. (The purpose of this example is to illustrate the different rates calculated by EMA (for short-term, e.g., five-year) and AM (for long-term, e.g., eight-year).

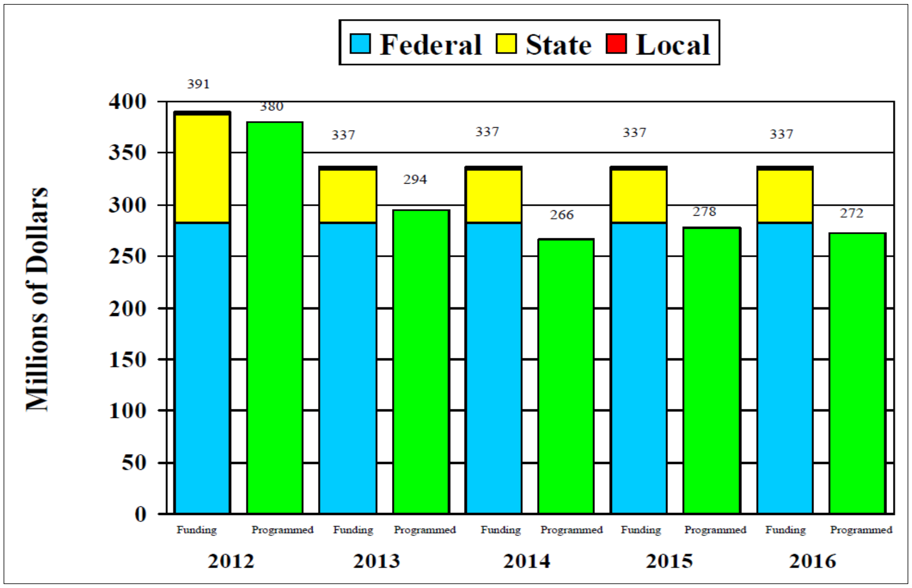


Figure 5.18 STIP Funding Use by Year (source: SDDOT 2012-2016 STIP)

Based on the historical data (31), the values of CPI-based inflation rate from 2002 to 2009 are 1.6%, 2.3%, 2.7%, 3.4%, 3.2%, 2.9%, 3.8%, and -0.4%. The five-year EMA of inflation rates used for 2010 is 2.92% and the eight-year AM of inflation rates used for 2010 is 2.44%. The numbers in Figure 5.18 are re-created in Figure 5.19 with the EMA-based and AM-based inflation rates. The EMA-based inflation rate suggests a slightly larger amount of funding than the AM-based inflation rate, with the difference being between $1 million and $7 million.

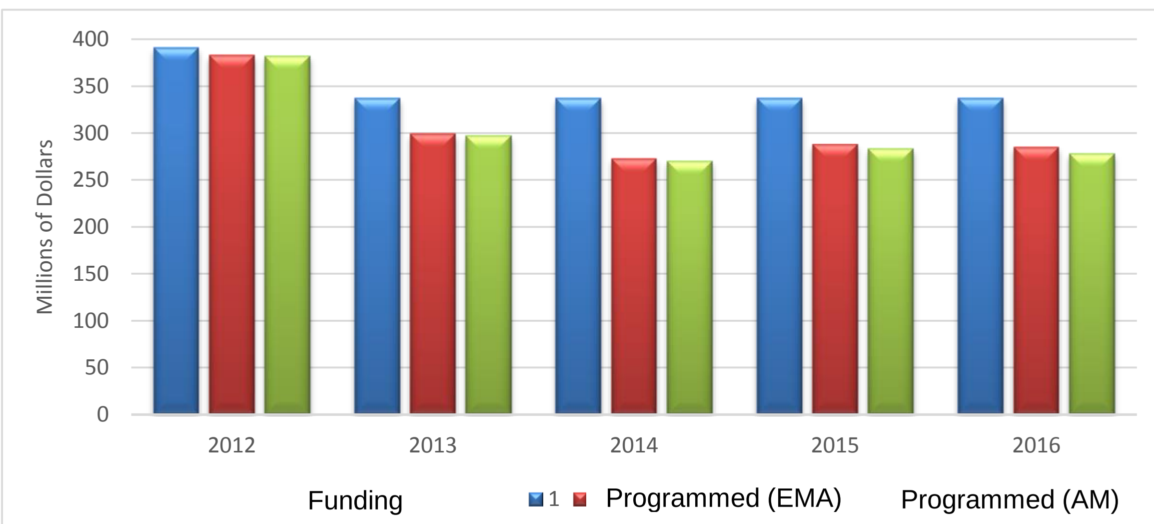


Figure 5.19 STIP Projects Programmed for EMA and AM of Inflation Rates

5.6.3 SDCCI

Over the years, construction materials, technologies, and other cost items change as travel needs change. Is it necessary to adjust the components in SDCCI to better reflect the changes in construction costs? What will happen if the new cost items such as traffic control, environmental measures (storm water protection, erosion control), and utilities are added to the current SDCCI? The historical data in recent years provide insight into what has actually occurred in the category of traffic control.

Fluctuating between 4.92% and 7.03% from 2006 to 2012, as shown in Table 5.7, the costs of traffic control items cannot be overlooked.

Table 5.7 Construction Costs of Traffic Control Items

Year	Total Annual Costs			
	Original Eight Items	**Percent**	**Traffic Control**	**Percent**
2006	\$147,138,632	95.08%	\$7,614,612	4.92%
2007	\$105,672,824	93.67%	\$7,140,906	6.33%
2008	\$136,289,167	95.17%	\$6,911,802	4.83%
2009	\$175,699,035	94.76%	\$9,705,985	5.24%
2010	\$181,034,153	93.30%	\$12,991,575	6.70%
2011	\$140,597,930	92.97%	\$10,638,487	7.03%
2012	\$189,727,360	93.75%	\$12,656,688	6.25%

Including the traffic control data in SDCCI can be a complicated process because more than 70 items are classified as traffic control and, moreover, they have different units of measurement and unit costs. We propose an approach to calculate the new SDCCI with traffic control items in Figure 5.20.

Step 1: Form a basket of traffic control items by aggregating all items across sample years

Year (*j*)	Item (*i*)			
	1	2	……	74
2006	$Q_{1,2006}$	$Q_{2,2006}$	……	$Q_{74,2006}$
2007	$Q_{1,2007}$	$Q_{2,2007}$	……	$Q_{74,2007}$
2008	.	.	.	.
2009	.	.	.	.
2010	.	.	.	.
2011	.	.	.	.
2012	$Q_{1,2012}$	$Q_{2,2012}$	……	$Q_{74,2012}$
Total*	Q_1	Q_2	……	Q_{74}

Notes: $Q_{i,j}$ is the quantity of item *i* in year *j*. $Q_i = \sum_{j=2006}^{2012} Q_{i,j}$. Q_1 through Q_{74} represent the basket of traffic control items.
* All historical years (2006-2012) are used for aggregation for simplicity. Employing a window of the most recent five years, for instance 2008-2012 for 2013 calculation, could be done if recent trends are of interest.

Step 2: Calculate an average unit price of traffic control annually

The unit price of traffic control for each year is computed as: $p_j = \sum_{i=1}^{74} p_{i,j} \times \frac{Q_i}{(Q_1+Q_2+\cdots+Q_{74})}$,
where p_j is the unit price of traffic control in year *j*, $p_{i,j}$ is the weighted average unit price of item *i* in year *j*.

Step 3: Calculate the quantity of traffic control annually

The quantity of traffic control for each year is computed as: $q_j = \frac{C_j}{p_j}$,
where q_j is the quantity of traffic control in year *j*, C_j is the total cost of traffic control in year *j*.

Figure 5.20 Flow Chart of Calculating the New SDCCI with Traffic Control Items

Table 5.8 shows the unit price and quantity of the traffic control based on the method in Figure 5.20.

Table 5.8 Unit Price and Quantity of Traffic Control

Year	Traffic Control		
	Unit Price	**Quantity**	**Total Cost**
2006	$6.67	1,141,621	$7,614,612
2007	$5.14	1,389,281	$7,140,906
2008	$5.83	1,185,558	$6,911,802
2009	$9.23	1,051,569	$9,705,985
2010	$10.79	1,204,038	$12,991,575
2011	$10.64	999,858	$10,638,487
2012	$10.79	1,173,002	$12,656,688

To add new items into the CCI, the following sequential statistical tests are recommended by the FHWA to improve CCI data quality (32):

1. Delete the pay items that have the same pay item number but have different pay item descriptions (or units of measures) from project to project.
2. Delete the pay items with unit of measure being "1" or "lump sum."
3. Delete the pay items that are generally related to the project type, location, and size, such as mobilization, time, and bonuses.
4. Delete the items that do not have a lagged observation (the observation for next year).
5. Delete the items for which the adjusted R-square is greater than 0.6 from a regression of the log change in price on the log change in quantity.
6. Delete the items for which the maximum observed price is more than 16 times the minimum observed price.
7. Delete the items for which the coefficient of variation of 100 times the log change in price is greater than 42.

For the data processing, test 2 recommends that the pay items with unit of measure being "1" or "lump sum (L.S.)" should be deleted. However, for the traffic control data provided by SDDOT, the cost of "miscellaneous" with L.S. units is very high, especially after 2010. Deleting this item will influence the representation of traffic control cost. The cost percentage of traffic control from 2006 to 2012 is shown in Table 5.9.

Table 5.9 Cost Percentage of Traffic Control

Year	Original Eight Items	Percent	Traffic Control				Percent of Miscellaneous in Traffic Control Costs
			Miscellaneous (L.S.)	Percent	Other Types	Percent	
2006	$147,138,632	95.08%	$2,177,105	1.41%	$5,437,507	3.51%	28.66%
2007	$105,672,824	93.67%	$1,775,762	1.57%	$5,365,144	4.76%	24.80%
2008	$136,289,167	95.18%	$1,782,666	1.24%	$5,129,136	3.58%	25.73%
2009	$175,699,035	94.76%	$2,593,036	1.40%	$7,112,949	3.84%	26.72%
2010	$181,034,153	93.31%	$4,370,558	2.25%	$8,621,017	4.44%	33.63%
2011	$140,597,930	92.96%	$3,654,324	2.42%	$6,984,163	4.62%	34.38%
2012	$189,727,360	93.74%	$4,891,202	2.42%	$7,765,486	3.84%	38.66%

Regarding FHWA criteria 5 to 7, the R-square[7] from a regression of the log change in price on the log change in quantity for the traffic control is 0.11. The maximum observed price is 2.1 times the minimum observed price. The coefficient of variation[8] of 100 times the log change in price is 3.7. Hence, the traffic control satisfies the FHWA requirements and can be added into the SDCCI.

Table 5.10 and Figure 5.21 illustrate the inflation rate comparison between the current method and the new method including traffic control, along with four related PPI-based inflation rates published by BLS. The purpose is to figure out which of the two sets of inflation rates based on the current and proposed methods, respectively, is more comparable to the general inflation rates. PPI-based inflation rates, especially PPI for finished goods, are often cited in the headline news as a reference of general inflation for producers. The results show that the CCI-based inflation rates based on the methods with and without traffic control differ significantly in the years 2007 and 2010, but their trends over the six-year time period are similar. The inclusion of traffic control costs reduces the variation over the years compared with the one without traffic control costs. Furthermore, the disparity between the inflation rates generated by the new method and each PPI-based inflation rate is smaller than that of the current method. Hence, including traffic control costs seems to produce a smoother estimate for inflation rate and lends support to revising the SDCCI basket by including additional cost items.

Table 5.10 Inflation Rate Comparison Based on SDCCI with and without Traffic Control and PPI

Method	Inflation rate (% change from prior year)					
	2007	2008	2009	2010	2011	2012
Current SDCCI (eight items)	16.09	2.25	3.17	0.01	8.02	5.96
Proposed SDCCI (with traffic control)	12.70	3.97	4.77	3.09	7.35	3.79
PPI (finished goods)	6.16	-0.94	4.27	3.75	4.65	1.36
PPI (materials and components for construction)	2.00	7.50	-2.84	2.48	3.48	2.66
PPI (industrial commodities)	6.99	-4.65	4.70	6.04	4.86	-0.10
PPI (all commodities)	7.85	-4.30	4.21	6.50	5.32	0.85

Note: The four PPI-based inflation rates are obtained from the Bureau of Labor Statistics website http://www.bls.gov/ppi/data.htm. They are calculated based on different items, which are listed in parentheses.

[7] In statistics, the R-square is referred to as the coefficient of determination; $R-square = \frac{sum\ square\ of\ regression}{sum\ square\ of\ total}$

[8] In probability theory and statistics, the coefficient of variation (CV) is a normalized measure of dispersion of a probability distribution or frequency distribution; $CV = \frac{standard\ deviation}{mean}$

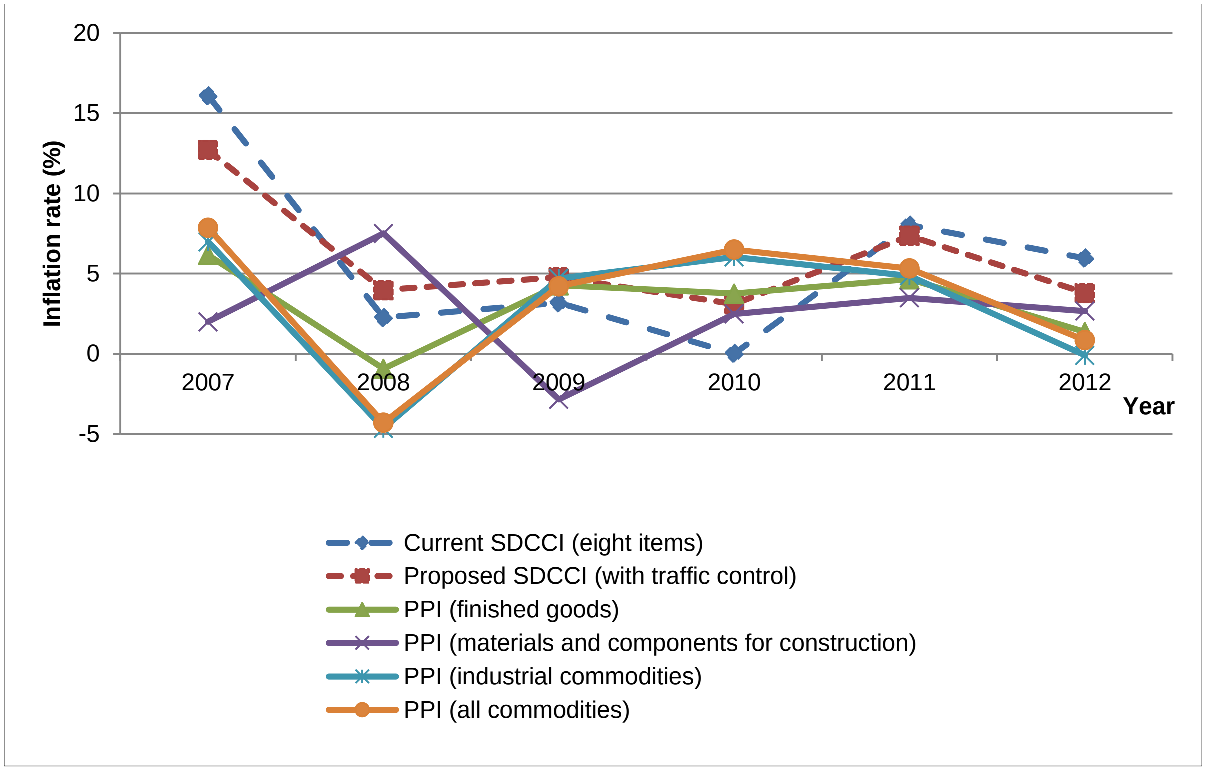


Figure 5.21 Inflation Rate Comparison Based on SDCCI with and without Traffic Control and PPI

6. CONCLUSIONS

This project discusses the current use of interest, inflation, and discount rates, and describes the resources and methodologies to calculate them. Two primary questions answered in this report are:

1. Is the zero-interest rate a valid assumption in calculating the discount rate?
2. Is a material-specific discount rate more justifiable than a general rate for project selection?

Other relevant questions discussed in the report include the regional impact on discount rate calculation, the (moving average) method to estimate the discount rate, and the inclusion of new cost item(s) in SDCCI to better reflect construction costs in South Dakota.

SDDOT generally assumes a zero interest rate. This assumption means that no opportunity cost of capital is allocated to SDDOT projects. However, any public transportation funds, either from the federal Highway Trust Fund or from the South Dakota State Transportation Fund, should bear opportunity costs of a) potential displacement of private investments and b) crowd-out of private consumption. Here, displacement refers to the fact that public investments "siphon away any resources that could otherwise have earned private sector rates of return" and crowd-out refers to the fact that "the funds raised by taxation are, in reality, diverted mainly from consumption" (24). There is always an opportunity cost to both federal and state dollars invested in an SDDOT project, because these federal funds could be used to generate economic or social returns from other investments. The state could use the funds as collateral (either explicitly or implicitly), to issue bonds, borrow money, or allocate it to other state departments.

While prices for construction materials change over time, they may not change at the same pace as the general inflation rate. When material prices rise more than the expected general inflation rate, projects with higher future costs will be unfairly favored over projects with lower future costs. On the other hand, when material prices rise less than expected, projects with larger future costs will be unfairly penalized. For example, asphalt pavement usually has lower initial construction costs but more frequent rehabilitation activities and overall higher future costs compared with concrete pavement. A study of 40-year (1971-2011) BLS data concluded that "history shows that asphalt's inflation rate has been consistently higher than that of cement and concrete. Overall, the inflation for asphalt paving is consistently higher than that for read-mix concrete (67% of the time) with the average difference being 1.81%" (3). In South Dakota, as shown in Table 5.5 and Figure 5.10, the inflation rate for liquid asphalt was consistently higher than that of PCC pavement and asphalt pavement between 2007 and 2012. When the inflation rate of concrete is consistent with the overall rate, asphalt or asphalt materials can be awarded larger discounts than they actually have if a general rate is used. The material-specific discount method is more defensible and justifiable in theory; its practicality, however, depends on a reasonable basis for estimating changes in relative prices. If there is neither strong evidence to support the assumption of different escalation rates for materials in the future nor a reasonable basis for predicting future changes, analysis will not be improved by using the material-specific rate. Therefore, the decision to apply the material-specific discount method depends on data availability and prediction reliability.

Inflation rates also vary spatially and temporally. Geographic-specific inflation rates display conspicuous disparity in project costs between the East River and West River regions, possibly due to project type and size. The large disparity of inflation rates between East and West River depicted in Figure 5.13 suggests the application of regional inflation rates may be a reasonable means of differentiating the inherent regional differences. However, data availability and prediction reliability are questionable. Can SDDOT categorize a project by region (e.g., East River or West River)? Does SDDOT believe prior regional differences in changes to projects costs can be extrapolated into the future? If the answers are uncertain, the use of the region-specific rate should be carefully weighted.

All rates are time-dependent measures and should be smoothed over time. The average will be determined by the period of analysis as well as the moving average method. As depicted in Figures 5.14, 5.18, and 5.19, the five-year average discount rate is considered for short-term (five years or less) programming purposes such as STIP in order to sufficiently account for the most recent changes. The long-term (10 years or more) average discount rate is more appropriate for long-range projects to smooth out dramatic fluctuations. Among the three moving average methods (arithmetic mean, harmonic mean, and exponential moving average), the arithmetic mean is more appropriate for long-term projects because it can smooth out dramatic fluctuations that occur during a brief time period. The exponential moving average may be appropriate for short-term projects because it heavily weights the most recent values.

The percentage and costs of individual services and materials among total construction costs in South Dakota change over time. As a gauge of cost variations in the transportation construction industries, the composition of SDCCI has barely changed. In the past six years, traffic control expenditures (currently not included in SDCCI) have been steadily growing, surpassing expenditures for class A concrete, reinforcing steel, structural steel, and unclassified excavation, all of which are cost items in the current SDCCI. To accommodate the diversity of traffic control costs, a method has been developed to estimate unit price and quantities. Although noticeable changes in the inflation rate were observed after including traffic control, the overall variation of inflation rate was reduced, suggesting that it may be necessary to review and revise the SDCCI basket as construction cost items change over time.

Although the project results demonstrate that using region- or material-specific discount rates as well as expanding the SDCCI basket may benefit South Dakota transportation infrastructure investment decisions, implementing these changes can be a challenge. Updating methodologies requires additional work to extract the needed information that is not currently available. For example, when calculating the region-specific discount rate, information for project location is needed to group construction costs for materials or items by region (e.g., East or West River). The SDCCI index spreadsheet needs to be altered to calculate inflation rate for individual cost items as well as the overall inflation rate. LCCA worksheet should also be modified to allow the input of material-specific rates. Each future activity in LCCA must be categorized by material or by a general rate if material information is unclear. For any addition to the SDCCI basket, the unit prices and quantities should be calculated annually based on the process laid out in **Figure** . If the new aggregated bidding item contains a large number of miscellaneous components such as traffic control, the calculation could be complicated and the workload may increase substantially.

7. IMPLEMENTATION RECOMMENDATIONS

This study examined the current method of calculating the discount rate and introduced a new methodology. Changes were proposed to allow for a more reasonable analysis with regard to project location and type. Different moving average methodologies were presented and compared for the needs of both short- and long-term projects.

Based on the results of this research, the following recommendations are offered.

7.1 Incorporating Interest Rates

Any EEA of transportation investments should incorporate interest rates to explicitly account for the time value of capital.

Both the federal and state portions of SDDOT funds displace private investment and consumption. SDDOT transportation investments should earn a rate of return that matches that of the private investment disrupted by the public investment. The lack of reliable data makes it impractical to estimate the cost of economic displacement. Instead, one should approximate the cost of SDDOT funds and estimate the “nominal interest rate.” Any engineering economic analysis should incorporate interest rate to explicitly account for the time value of capital. This study proposes estimation of the nominal interest rate by taking a weighted average of federal Treasury bond yield and South Dakota state bond yield (or SDIC SDCDP investment return), with the weight being the percentage of funding source. As long as the funding percentage can be determined, this method of estimating interest rates can be applied at the project, regional, or state level.

7.2 Region-Specific Discount Rates

County information for each cost item should be kept, regional CCI calculated, and trends monitored for both East and West River.

Data from 2006 to 2012 reveal a great deal of variation between the East and West River regions in quantity of construction cost items (e.g., unclassified excavation, liquid asphalt, asphalt concrete, gravel cushion, PCC pavement, class A concrete, reinforcing steel and structural steel). As a result, there is a large disparity in regional inflation rates. Although the evidence is compelling, more years of data are needed to confirm the trend of the inflation rate, given trend volatility in both regions. The premise in using the region-specific discount rate method is that the two regions have inherent differences in inflation rate, and future changes in regional project costs can be reliably predicted. The latter requires a discernible trend from both regions.

7.3 Material-Specific Discount Rates

Changes in inflation rate for individual materials should continue to be monitored by calculating the rates for future years.

Using the general rate is sufficient if price changes for individual materials are similar to the general inflation rate. However, historical data show that some materials have consistently higher rates than the general inflation and others have consistently lower rates. While this justifies the material-specific discount method, applying this rate depends on reasonable estimates of future changes in relative material prices. Should these conditions not be met, the material-specific method will be compromised. In this study, the materials specific rates were calculated for 2007-2012. The trend of the inflation rate can be revisited after five or more years of data become available. The feasibility of modifying the current LCCA spreadsheet to allow the input of material-specific rates should be investigated because each future activity within LCCA is required to be categorized either by a specific material or by a general rate for non-material costs.

7.4 Expanded Market Basket

Keep tracking expenditure for new cost items currently not included in SDCCI.

The unit price for traffic control has been steadily increasing since 2006. Traffic control expenditures, which are not considered in the current SDCCI, have surpassed expenditures for class A concrete, reinforcing steel, structural steel, and unclassified excavation. SDCCI needs to be reviewed periodically for the construction costs associated with new items such as traffic control, environmental measures (storm water protection, erosion control), and utilities. As the new cost items increase in prevalence, the components in the basket should be revised to reflect cost changes. In this study, traffic control cost was calculated for 2007-2012. The trend of traffic control cost can be revisited after five or more years of data become available.

7.5 Smoothed Discount Rates

When calculating discount rates using historical data, the exponential moving average should be used for short-term transportation programming if the time interval is less than or equal to five years; the arithmetic moving average should be used for long-term project planning and comparisons of design alternatives with time intervals longer than 10 years.

The long-term (10 years or more) average discount rate is more appropriate for long-range projects to smooth out dramatic fluctuations. The arithmetic mean is more appropriate for long-term projects because it can smooth out dramatic fluctuations that occur during a brief time period. The exponential moving average may be appropriate for short-term projects because it heavily weights the most recent values.

7.6 Implementation and Maintenance Process

We suggest immediate implementation of recommendations 7.1 and 7.5. We also advise establishing a tracking mechanism to monitor price changes of individual cost items and revisiting the study in five years, if necessary.

8. RESEARCH BENEFITS

This research project examined SDDOT's current methodologies to calculate the discount rate, and proposed new methodologies to account for possible problems.

The study identified concerns with the current practice of assuming a zero interest rate for SDDOT projects, and recommended immediate incorporation of interest rate to explicitly account for the time value of SDDOT capital investments. Reliable sources for retrieving the federal and state interest rates have been provided to facilitate the calculation of the nominal interest rate.

This project proposed different ways to average historical rates for both long-term and short-term projects. The arithmetic mean is more appropriate for long-term projects because it can smooth out dramatic fluctuations that occur during a brief time period. The exponential moving average is appropriate for short-term projects because it heavily weights the most recent values.

This study investigated material-specific and region-specific rates. The findings presented individual historical inflation rates by material in contrast to one general inflation rate based on SDCCI and historical inflation rates by region (e.g., East and West River) in contrast to one general rate for the state. Differences between disaggregate rates and aggregate (or general) rate justify the use of material- or region-specific rates to accurately estimate real project costs. However, accuracy will be compromised without a reliable prediction. The findings prompt future data collection and analysis to increase prediction reliability.

This research proposed an approach to expanding the SDCCI market basket with new cost items such as traffic control. The inclusion of new prominent cost items in the SDCCI basket may improve the accuracy of tracking change of construction costs.

Overall, this study helped to increase the credibility of SDDOT programming decisions and identified future steps to further enhance the decision-making process.

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