

Pavement Design and Selection

**2012 EDITION
February 9, 2012**



**CONSTRUCTION FIELD SERVICES
DIVISION**

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION	1
CHAPTER 2. PAVEMENT DESIGN	3
CHAPTER 3. PAVEMENT SELECTION PROCESS.....	7
A. Calculating the \$1 Million Threshold.....	7
B. Multiple Roadways to Be Let Together.....	7
C. Informational and Official LCCA	8
D. Corridor Projects.....	8
E. Alternate Pavement Bidding (APB)	9
F. LCCA Re-Analysis.....	9
G. LCCA Process Steps.....	9
CHAPTER 4. COMPONENTS OF A LIFE CYCLE COST ANALYSIS	16
A. Economic Analysis Approach	16
B. Initial Construction Cost.....	16
C. Initial User Costs	18
D. Future Maintenance Costs	19
E. Future User Costs for Maintenance Activities	20
CHAPTER 5. SOFTWARE	21
CHAPTER 6. PAVEMENT PRESERVATION STRATEGIES.....	22
CHAPTER 7. LCCA PROCESS, PRESERVATION STRATEGY & DATA UPDATES.....	31
A. Input for Future LCCA Process Updates	31
B. Process for Pavement Preservation Strategy Updates	32
C. Unit Prices – HMA & Concrete	33
D. Unit Prices – Common Items.....	34
E. Real Discount Rate.....	35
F. Maintenance Costs.....	35
G. CO3 Inputs	35
CHAPTER 8. DEFINITIONS.....	36
REFERENCES	38
LCCA CONTACTS IN PAVEMENT OPERATIONS.....	39
APPENDIX A: LCCA PRODUCTION RATES.....	A-1
APPENDIX B: SAMPLE SIMPLIFIED LINEAR SCHEDULES	B-1
APPENDIX C: LCCA MAINTENANCE OF TRAFFIC FLOWCHARTS	C-1

CHAPTER 1. INTRODUCTION

The Michigan Department of Transportation (MDOT) has used various formal and informal pavement selection procedures in the past. The approach, since 1985, uses the Life Cycle Cost Analysis (LCCA) method to compare costs of the pavement selection alternates. Pavement design of the alternates is performed using the AASHTO design method.

Life Cycle Cost Analysis is an objective, nationally recognized method used to quantify the cost effectiveness of various investment alternatives. Federal agencies have used this method for many years to determine long term capital investment strategies. The federal government, including the Federal Highway Administration (FHWA), recommends that all transportation agencies use an LCCA approach when evaluating various investment alternatives.

State legislation was enacted in 1997 regarding pavement selection and Life Cycle Cost Analysis. The legislation, Public Act 79, states that “the department shall develop and implement a life cycle cost analysis for each project for which total pavement costs exceed \$1,000,000.00 funded in whole, or in part, with state funds. The department shall design and award paving projects utilizing material having the lowest life cycle costs.” The legislation also states “life cycle cost shall compare equivalent designs and shall be based upon Michigan’s actual historic project maintenance, repair, and resurfacing schedules and costs as recorded by the pavement management system, and shall include estimates of user costs throughout the entire pavement life.”

The pavement selection process has been developed in cooperation with the asphalt and concrete paving industry associations, and uses MDOT’s Pavement Management System as the basis for determining pavement selection on specific projects. The department uses the Equivalent Uniform Annual Cost (EUAC) method to calculate a life cycle cost. Inputs to a life cycle cost analysis include both initial costs and maintenance costs. The costs and maintenance schedules are based on actual project history and cost, along with pavement performance data.

Initial Costs (Construction and User)

Initial construction costs may include pavement, shoulders, joints, subbase, base, underdrains, utility relocation, and traffic control. Only work items with costs that vary between alternates will be considered. Work item unit prices are determined using the department’s bid letting system. Initial user costs are based on daily and hourly traffic volumes, the method of maintaining traffic, capacity, and construction work days.

Maintaining traffic schemes are developed as part of the Temporary Traffic Control Plan (TTCP) for the project. After approval of the TTCP, it will be utilized to calculate user costs for the various alternatives being considered in the analysis. Maintaining traffic costs can also be included if they differ between alternatives.

Pavement Preservation Strategies (Future Maintenance and Future User Costs)

Maintenance costs are determined from MDOT’s actual historic maintenance data. The costs are retrieved from MDOT’s project database. Historic maintenance data is also used, when available, to determine the average pavement condition and age at which preventive maintenance actions occur for a particular fix type.

User costs for maintenance activities are determined by assuming typical maintaining traffic schemes, aging traffic volumes, and averaging the duration of maintenance activities. Life extension values for any maintenance activity, as well as initial fix life values, are determined using historical pavement condition data from the MDOT Pavement Management System.

All of this information is used to develop preservation strategies for specific rehabilitation or reconstruction fixes. These strategies (maintenance schedules) reflect the overall average maintenance approach that has been used network-wide for a specific fix based on historical records.

CHAPTER 2. PAVEMENT DESIGN

An effective pavement design is highly dependent upon performing an adequate investigation of the existing pavement structure, soils, and topographic features. A comprehensive investigation of these will ensure that the Engineer selects the proper reconstruction or rehabilitation fix. The information obtained from the investigation also will aid the designer in selecting the appropriate input values for the pavement design. The investigation should include reviewing as-built plans, reviewing and analyzing existing pavement distress condition, determining causes of pavement surface distresses, evaluating pavement ride quality, reviewing pavement remaining service life and conducting both a drainage evaluation and subgrade evaluation. A drainage evaluation can be conducted by a visual inspection along with a soil boring investigation. A subgrade evaluation can be conducted by collecting soils information and/or pavement deflection testing.

MDOT uses the *1993 AASHTO Guide for Design of Pavement Structures* and the AASHTO pavement design software DARWin Version 3.1, 2004, to determine pavement designs.

The department uses different accumulated Equivalent Single Axle Load (ESAL) values for pavement design depending on the selected pavement fix and the corresponding design life. Typical design lives are as follows:

<u>Pavement Fix</u>	<u>Design Life and Length of Accumulated ESAL's (Years)</u>
New/Reconstructed Concrete and HMA Pavements	20
HMA over Rubblized Concrete	20
Unbonded Concrete Overlay over Repaired Concrete	20
HMA on Aggregate Grade Lift	15 to 20
HMA over Crush & Shaped Base	10 to 15
HMA over Asphalt Stabilized Crack Relief Layer (ASCRL)	12 to 15
Mill & HMA Resurface on an HMA Pavement	10 to 15
Repair and HMA Resurface on an HMA Pavement	10 to 15
Repair and HMA Resurface on Composite or Concrete	10 to 12
Mill & HMA Resurface on Composite or Concrete	10 to 12

The pavement designer is to request the appropriate Design ESAL's from the Traffic Analysis and System Studies Unit, of the Bureau of Transportation Planning. This is done by submitting a Traffic Analysis Request, Form 1730, which can be found on connectMDOT. Design ESAL's are determined from traffic data that is collected at or near the site of the proposed project. The department has both Weigh-In-Motion (WIM) sites and Permanent Traffic Recorder (PTR) sites located throughout the state. Data from these sites is used to determine traffic volumes, traffic growth rates and vehicle mix at a specific location. Vehicle mix includes percentage of trucks, percentage of cars and vehicle classification data. Vehicle classification further divides truck data based on axle configuration.

Different 18 Kip axle equivalency factors are used for the designs of Flexible and Rigid pavements because each pavement type experiences a different loss of serviceability from the passage of identical vehicles. Work done at the AASHTO test road resulted in the creation of pavement design formulas that account for these differences. Proper use of these formulas requires that different ESAL's be used for Flexible and Rigid pavements, although the anticipated traffic is identical.

Soils information is also an important part of an accurate pavement design. A soils investigation should be performed to determine subgrade soil types and support characteristics. For reconstructs, the designer may also want to consider re-using existing layers such as the sand subbase. If re-use of existing materials is being considered, samples should be taken at regular intervals for testing to ensure they meet current specifications. There must also be sufficient depth of re-usable materials depending on the pavement being designed.

The soils analysis may include information from soil borings along with Falling Weight Deflectometer (FWD) data. The pavement designer should request this analysis from the Region Soils Engineer. The Region Soils Engineer is responsible for supplying all pertinent soils information for the pavement design, including a subgrade resilient modulus value to use in pavement design calculations, recommendations on re-use of existing materials, and use of geotextile separators.

Please see the Life Cycle Cost Analysis Request checklist, Form 1966, which can be found on connectMDOT, for soils information needed on projects requiring an LCCA.

The AASHTO pavement design procedure uses several other inputs to determine a proper pavement design. Recommended values are listed below:

All Pavement Types

- 1) Initial Serviceability - 4.5
- 2) Terminal Serviceability - 2.5
- 3) Reliability Level - 95%
- 4) Subgrade Resilient Modulus: There are generally two methods for determining the resilient modulus of the subgrade:
 - a. Back-calculation from FWD data. Contact Construction Field Services Division to schedule FWD testing.
 - b. Soil identification. After visual identification of the soil type from hand augering or soil borings, a resilient modulus can be assigned based on historical correlations.

HMA Pavements

- 1) Overall Standard Deviation - 0.49
- 2) Structural Coefficients:

HMA Top & Leveling Course	0.42
HMA Base Course	0.36
Cement Stabilized Base	0.26
ASCRL	0.30
Asphalt/Emulsion Stabilized Base	0.20
Crush & Shaped HMA	0.20
Rubblized Concrete	0.18
Dense-Graded Aggregate Base	0.14
Open-Graded Drainage Course	0.13
Sand Subbase	0.10

- 3) Elastic Modulus:
- | | |
|----------------------------------|-----------------------|
| HMA Top & Leveling Course | 390,000 – 410,000 psi |
| HMA Base Course | 275,000 – 320 000 psi |
| Cement Stabilized Base | 1,000,000 psi |
| ASCRL | 210,000 psi |
| Asphalt/Emulsion Stabilized Base | 160,000 psi |
| Crush & Shaped HMA | 100,000 – 150,000 psi |
| Rubblized Concrete | 45,000 – 55,000 psi |
| Dense-Graded Aggregate Base | 30,000 psi |
| Open-Graded Drainage Course | 24,000 psi |
| Sand Subbase | 13,500 psi |
- 4) Drainage Coefficient:
(See Table 2.4, page II-25, AASHTO Guide for Design of Pavement Structures)
- | | |
|------------------------------------|-----|
| HMA Top & Leveling Course | 1 |
| HMA Base Course | 1 |
| Rubblized Concrete | 1 |
| Crush & Shaped HMA | 1 |
| Aggregate Base (Dense and Open) | 1 |
| Sand Subbase | 1 |
| 16" of Open-Graded Drainage Course | 1.1 |

5) Stage Construction - 1

Concrete Pavements

- 1) 28-day mean PCC Modulus of rupture - 670 psi
- 2) 28-day mean Elastic Modulus of Slab - 4,200,000 psi
- 3) Mean Effective k-value (psi/in): Use AASHTO's chart for "Estimating Composite Modulus of Subgrade Reaction" and "Correction of Effective Modulus of Subgrade Reaction for Potential Loss of Subbase Support" (figures 3.3 and 3.6 in AASHTO's 1993 Guide for Design of Pavement Structures):
Typical Range: 100 – 200 psi/in

The term subbase used in figure 3.3 is considered a composite of all base/subbase materials under the concrete. Use modulus values listed above in (3) of the HMA Pavement inputs. For standard base/subbase combination, use 20,000 psi.

- 4) Overall Standard Deviation: Use 0.39
- 5) Load Transfer Coefficient, J: 2.7 for tied shoulder or widened lane (14')
 3.2 untied shoulders
- 6) Overall Drainage Coefficient: 1 to 1.05. Consider the overall drainage of the system including subgrade when assigning this input. When a 16" open-graded drainage course is specified, use 1.1.
- 7) Effective Existing Pavement Thickness: The Condition Survey Method in the DARWin software is used to characterize the effective structural capacity of the existing pavement. When repairing an existing concrete pavement in preparation for a rehabilitation fix, most

distressed cracks and joints are repaired. However, to account for the age of the pavement, and the certainty that it is has lost some structural value, a nominal number of the following inputs are included (on a per mile basis):

- unrepaired deteriorated joints – 20 to 40
- unrepaired deteriorated cracks – 20 to 40
- unrepaired punchouts – 5 to 10
- expansion joints, exceptionally wide joints, or HMA full depth patches – 5 to 10

While punchouts are commonly associated with continuously reinforced concrete pavements, it is possible to have them in jointed concrete pavements. If a number of the listed items remain in place (are not repaired), then include the actual count.

CHAPTER 3. PAVEMENT SELECTION PROCESS

Pavement selection is determined using the life cycle cost analysis method when the total project pavement costs exceed one million dollars, and when comparable Hot Mix Asphalt (HMA) and concrete designs are available for analysis, per this manual. Currently, HMA reconstruction is compared to concrete reconstruction, and HMA placed over rubblized concrete is compared to an unbonded concrete overlay. Certain fixes known under a different name (e.g. 'inlay') may still require an LCCA. Also, it does not matter if the project is a 3R or 4R project. Please contact Pavement Operations staff with any questions.

The following sections describe the process.

A. Calculating the \$1 Million Threshold

When pavement costs are being totaled to determine if an LCCA is required for a project, only the hard surface cost of the HMA and concrete (including transverse joints) will be included in the threshold estimate. The cost of any base and subbase materials, rubblization, embankment, HMA separator layers, etc, will not be included. The areas of pavement to include are:

- 1) Mainline through lanes, including continuous center left turn lanes
- 2) Ramps
- 3) Acceleration/deceleration lanes associated with ramps
- 4) Weave/merge lanes
- 5) Collector/distributor lanes
- 6) Service drives

Note: the above encompass both production and miscellaneous paving areas.

When performing the threshold estimate, use unit prices established by the department, or expected market prices.

If pavement costs exceed \$1 million, an LCCA is required and will be performed per this manual.

If pavement costs are below the \$1million LCCA threshold, maintain documentation in the project file for possible future reference. If the project scope increases during the design phase, the threshold estimate needs to be recalculated to determine if an LCCA is or is not required.

B. Multiple Roadways to Be Let Together

For multiple roadway sections that will be packaged together for a letting, the following will apply, depending on the situation:

- 1) A separate LCCA will be performed for each distinct roadway (I, US, M route, etc.) with pavement costs greater than \$1 million. In this case, each LCCA, if necessary, will stand on its own, potentially resulting in different pavement alternates being selected for the different roadways.
- 2) If a particular pavement fix type is currently not life-cycled, then it can't be included in an LCCA, even when being packaged together with a portion of a project that is life-cycled.

C. Informational and Official LCCA

Exhibit A at the end of this chapter contains a table and a flowchart to summarize the use of informational vs. official LCCA.

For new/reconstruction and major rehabilitation projects with pavement cost greater than \$1 million, the Region must determine the appropriate time to initiate the LCCA. The LCCA should be completed early enough in the design process to allow designers sufficient time to incorporate the final pavement selection. However, if the LCCA is completed too far in advance of the project's letting, the cost and other data may no longer be appropriate.

To give LCCA staff time to perform the analysis, and designers enough time to incorporate the results, it is recommended that the Regions submit LCCA requests no later than 18 months, and no earlier than 24 months, prior to letting. It is understood that there will likely be exceptions where requests will come in later, but this is recommended as a goal. LCCAs requested within 24 months of letting will be processed for official approvals.

There are a variety of reasons for a Region to request an LCCA more than 24 months before letting, such as a "shelf job" with an uncertain let date that is actively under design. In such cases, an informational LCCA will be done, but the final approved LCCA will be performed inside the 24 month period using the latest costs and following the latest processes in place. This informational LCCA may be performed at either of the following two levels of detail.

- 1) With the first, LCCA staff would informally obtain basic project level information from Region staff. Any other necessary items would be estimated to develop the initial pavement design alternatives and perform the informational LCCA.
- 2) With the second level of detail, the Region would submit all the normally required documents from which the pavement designs and informational LCCA would be developed. These initial documents could be used for the official LCCA, if they still accurately reflect what will be done on the project. Otherwise, updated documents would need to be submitted.

Regardless of the level of detail, informational LCCAs will not be sent out for industry review, nor will they go to the Engineering Operations Committee (EOC). The Region will determine how best to proceed with the design of the preliminary low cost pavement alternative.

One further note on "shelf jobs": in order to hold the Omissions and Errors Check (OEC) meeting (~95% plan completion stage), there must be an approved LCCA. Therefore if only an informational LCCA has been done, this may affect how far design can go before putting it on the shelf.

D. Corridor Projects

To prepare a cost estimate for corridor improvement studies, it may be advantageous to know the pavement type. Depending on the length of the corridor under study, multiple, more manageable and affordable projects may eventually be split out and built over a period of time. An informational LCCA could be performed for the entire corridor, thus providing an estimate of the low cost pavement design. However, a separate Official LCCA will be required for each individual project with over one million dollars in paving costs at an appropriate time in the future. This could result in the selection of different paving materials along the same corridor.

E. Alternate Pavement Bidding (APB)

If a project has been identified as a candidate for APB, then an informational LCCA will be completed to determine whether the life cycle cost difference between the two pavement design alternatives is within the specified range. Contact the Innovative Contracting Unit for information regarding the entire APB process. If the project continues under development as APB, there are additional tasks related to LCCA, including development of Equivalent Uniform Annual Cost equations.

F. LCCA Re-Analysis

Exhibit A at the end of this chapter contains a table and a flowchart to summarize circumstances requiring re-analysis of an official LCCA.

After the official LCCA has been completed, various project level changes can occur during delivery of the Five Year Program which could impact the LCCA. Under certain circumstances, a re-analysis of the LCCA will be required using the most recent data and process to ensure that the lowest cost alternative is chosen. Re-analysis will be performed if:

- 1) The project gets delayed 25 months or more from the let date specified in the official LCCA.
- 2) There are major changes in the scope of work, such as the fix type.
- 3) Changes in project length; 25 percent or 4 lane miles, whichever is less.
- 4) Major Maintenance of Traffic changes, such as number of lanes maintained, detours vs. part width, or major mainline staging.

Similar changes could also affect an informational LCCA. Re-analysis of an informational LCCA can be requested by the Region if doing so would be helpful to project development.

G. LCCA Process Steps

The process is as follows:

Step 1 - Each Region estimates pavement costs for upcoming projects in that Region. The Region requests a pavement selection using the following guidelines:

Pavement Operations in the Construction Field Services Division is responsible for preparing a pavement design and selection package for the following project types:

- a) All new/reconstruction projects with pavement costs greater than \$1 million.
- b) Major rehabilitation projects (unbonded concrete overlays & rubblized with HMA surfacing) with pavement costs greater than \$1 million.

It is suggested that the Region use some form of objective analysis to determine pavement type selection for the following project types:

- a) Rehabilitation projects (other than major rehabilitations noted above)
- b) Local roads being redesigned due to an MDOT project. Pavement designs for local roads require the concurrence of the local agency.
- c) New, reconstruction and major rehabilitation projects when the pavement cost is less than \$1 million.

Steps 2-6 pertain to projects where pavement selection is the responsibility of Pavement Operations. Otherwise, assistance will be given to the Regions on an as-needed basis.

Step 2 - The appropriate Region personnel will request, assemble and provide all necessary information for projects requiring Pavement Operations to prepare the pavement design and Life Cycle Cost Analysis. This information includes existing soils information, traffic data, approved Temporary Traffic Control Plan (TTCP), as well as other information listed on the Life Cycle Cost Analysis Request checklist, Form 1966, which can be found on connectMDOT. Please allow 3 months for completion, reviews and final approval of the LCCA.

The following provides a brief explanation for some checklist items.

Maintenance of Traffic Plans

The project's Temporary Traffic Control Plan (TTCP) will be utilized to assist in estimating initial user delay costs. Appendix C contains standard MOT flowcharts applicable to LCCA projects. For further information on the requirements of the TTCP, please refer to the Work Zone Safety and Mobility Manual (WZSMM), available on the MDOT Operations Field Services website. Examples of a standard TTCP can be obtained through the Operations Field Services Division.

The Region will submit the TTCP to the Operations Field Services Division for approval by the Safety and Mobility Peer Team (SMPT). After the TTCP has been approved, the Region will send it to the Pavement Selection Engineer of Pavement Operations, including the SMPT's approval notification.

The TTCP may be draft for use in the LCCA, but major changes to the maintenance of traffic (MOT) may require the TTCP to be re-evaluated and approved by the SMPT in order for the LCCA to be redone (see Chapter 3). All elements of a TTCP may not yet be available and may be omitted for this review if they will not affect calculation of user delay or initial MOT cost. This in no way modifies requirements of the final TTCP as specified in the WZSMM.

The TTCP submitted for use in LCCA must include at least the following. For each item, any differences between the HMA and concrete alternatives are to be identified, including cost differences. In addition, any variation of these items for different stages is to be identified.

- 1) Construction Staging – Provide a description of which portions of the pavement structure will be built in each stage. Traffic typicals are recommended to illustrate construction staging, and should be included, if available.
- 2) Traffic Control Strategies – Identify how traffic will be accommodated within the work zone. (e.g. full roadway closure, lane shifts, temporary crossovers, reversible lanes using moveable barrier, flagging, number of lanes open to traffic, etc.) For long projects utilizing flagging, note whether the work will be performed in shorter segments.
- 3) Temporary Lane Widening Requirements – Identify if temporary widening will be performed for maintaining traffic.
- 4) Traffic Volumes – Provide at a minimum the ADT for the work zone. If traffic information is available for detours or alternate routes, this data should be included, if available.

- 5) Restrictions on Operation – Identify if there will be any restrictions on operating hours. (i.e. night work only, northbound-Friday/southbound-Monday, lane closures, weekday work only, etc.)
- 6) Posted Speed Limits – Specify both the regular speed limits and any restricted speed limits that will be utilized during construction.
- 7) Detour Route – Specify whether a detour will be utilized during the project and the preferred route to direct traffic (if applicable).

Miscellaneous Paving

A description of which areas would be “miscellaneous” paving will allow specific consideration of these areas in the LCCA with respect to cost and production rates. These areas can be identified by considering where the miscellaneous concrete pay item for the concrete alternate would likely be utilized (e.g. ramps, acceleration/deceleration lanes, etc).

Major Rehabilitation with Reconstruction

Major rehabilitation projects generally have a certain amount of reconstruction for bridge touchdown points, under bridges to increase or maintain underclearance, around curves (so significant superelevation corrections aren't performed with HMA or concrete), and sometimes at locations that have failed due to weak subgrade soils. If at least 25 percent or 4 lane miles, whichever is less, of the pavement will be reconstructed, then it will be accounted for in the LCCA and the Region is to identify these areas in their LCCA request.

Reuse of Sand Subbase

Reconstruction projects that have existing reusable sand subbase, as determined by a mechanical analysis of subbase samples, should have this reflected in the LCCA calculations. If a Region determines that there is a sufficient depth of existing subbase for one or both alternatives, or that only a certain overall percentage of the existing sand subbase is deemed reusable, they are to specify this in their LCCA request. Length of project that has reusable subbase should be based on a % of soil borings meeting existing specifications.

Utility Relocation

Utility relocation costs can differ between alternates for some projects. For reconstruction projects, utilities sometimes fall within the proposed cross-section. Also, compaction to obtain density can be a concern over old utilities, because the vibration could severely damage them. If the costs are expected to differ between alternates, they can be factored into the LCCA. If a Region determines that the costs should be included in an LCCA, they are to develop the following estimates for each pavement alternative and provide them as part of their LCCA request.

- 1) Relocation cost, including both municipal and private utilities, regardless of whether the relocation would be performed during or prior to project construction, and regardless of whether MDOT bears any responsibility for the costs.
- 2) The amount of time that traffic will be affected because of utility relocation, including any pre-construction lane closures.
- 3) Any time that would be added to the project schedule because of utility relocation.

Miscellaneous

When a Region determines that pavement type will affect other design elements differently, those associated costs can be factored into the LCCA. These can include, but are not limited

to, Right of Way, drainage, access management and maintenance of traffic costs. The Region is to develop cost estimates for each pavement alternative and provide them as part of their LCCA request.

Step 3 - The pavement designer prepares multiple pavement designs to be used in the Life Cycle Cost Analysis (LCCA). The alternates considered should include both a concrete and HMA alternate with comparable design lives.

When the pavement is to be reconstructed, the Region may request evaluation of a concrete pavement with a stabilized base layer as part of the LCCA, and the pavement selection process will be completed as follows.

- 1) The appropriate initial costs, user delay costs and pavement preservation costs will be applied in preparing a draft LCCA for the two options of:
 - a. HMA pavement with an unbound base layer.
 - b. Concrete pavement with an unbound base layer.
- 2) The draft LCCA results will be used to determine remaining steps.
 - a. If the HMA option results in the lowest Equivalent Uniform Annual Cost (EUAC), proceed with the LCCA for review and approval, based on unbound base layers for each alternative.
 - b. If concrete with an unbound base results in the lowest EUAC, develop an LCCA for concrete with a stabilized base. The service life and pavement preservation strategies for concrete with an unbound base will be used for both concrete options.
 - c. If the HMA option with an unbound base layer has a lower EUAC than concrete with a stabilized base, proceed with the LCCA using concrete with an unbound base.
 - d. If concrete with a stabilized base results in a lower EUAC than the HMA with an unbound base, proceed with the LCCA using concrete with a stabilized base.

Step 4 - The pavement designer submits design alternates to the Pavement Selection Engineer, who prepares the LCCA package. The LCCA package should include:

- 1) A cover memo indicating the alternate with the lowest life cycle cost and a project summary explaining the project location, existing and proposed pavement sections, existing pavement condition (including RSL and IRI), and traffic volumes.
- 2) An appendix should also be attached which includes all of the detailed information that was used in the analysis. Items such as unit prices, production rates, soil boring logs and recommendation memos, traffic memos, maintenance of traffic information, construction scheduling analysis, pavement design information and life cycle cost calculations should all be included in the appendix.

Step 5 - The Pavement Operations Engineer along with the Pavement Selection Engineer, Lansing Pavement Design Engineer and any other necessary Lansing/Region personnel review the pavement selection package. Corrections, if necessary, are made, and an updated package is forwarded to the Engineering Operations Committee (EOC) for a preliminary review. After the LCCA package is preliminarily approved, it is sent to the paving industry associations for a two week review. Again, corrections, if any, are made, and the final package is submitted to EOC for final review and approval.

The EOC approves the pavement selection based on the alternate that has the lowest life cycle cost, in accordance with Public Act 79 of 1997.

Step 6 – The Pavement Selection Engineer notifies the appropriate Region personnel of EOC's action.

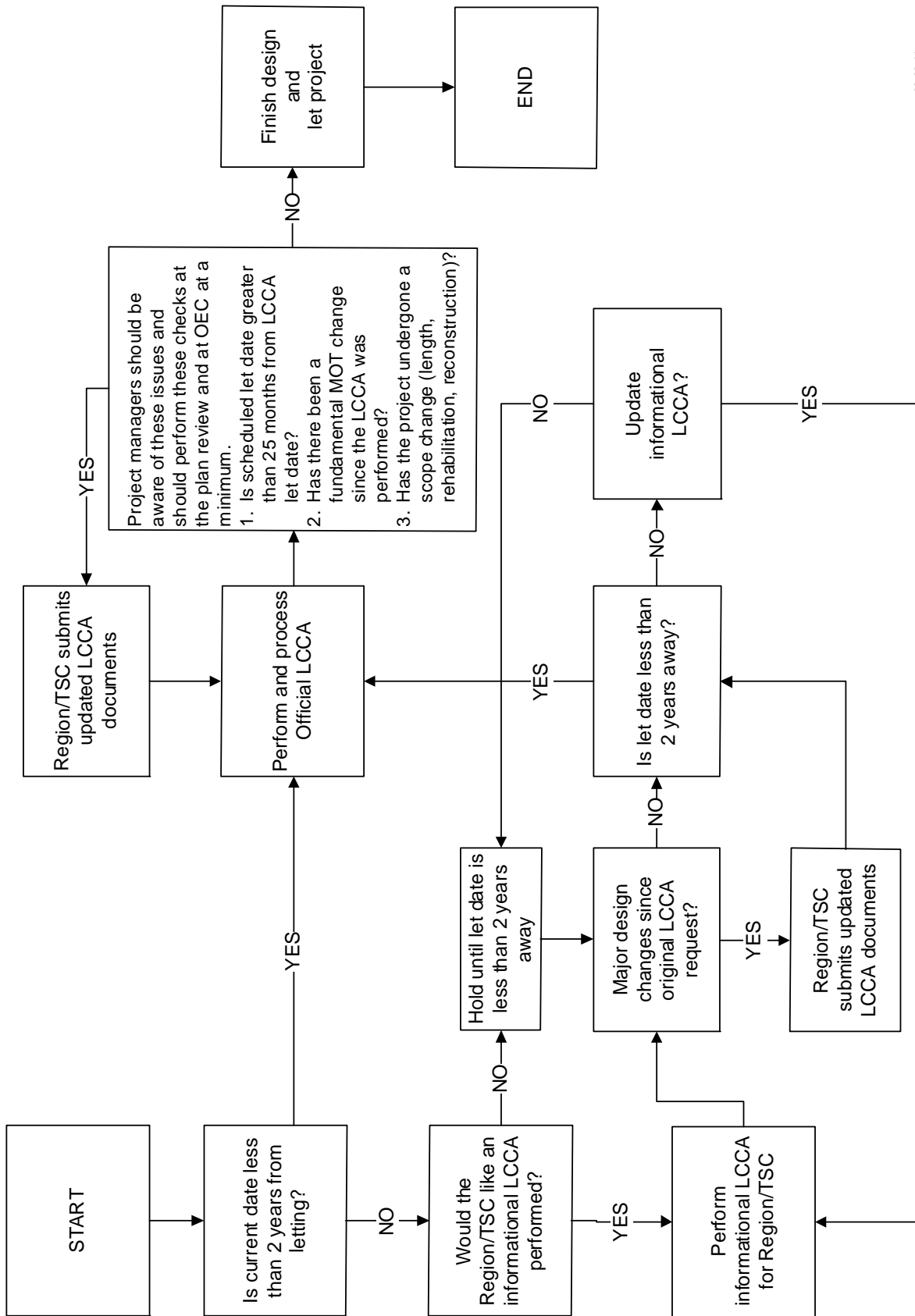
EXHIBIT A

Summary of Life Cycle Cost Analysis (LCCA) Use Cases

	Official LCCA	Informational LCCA	Corridor Projects
Use	Projects with defined scope, maintenance of traffic and letting date	Projects with scope of work but limited information on maintenance of traffic or letting date For example: Shelf Projects	For corridor scoping, an Informational LCCA can be performed for estimating pavement costs
Time Frame	Less than 24 months before Letting Date	Greater than 24 months before letting	Greater than 24 months before letting
Limitations	LCCA must be redone if: <ul style="list-style-type: none"> • Letting Date delayed 25 months or more from Letting Date (as specified in the Official LCCA) • Project Length changes by 25% or 4 lane miles* • Major Scope Change • Major Maintenance of Traffic (MOT) changes with number of lanes maintained, change in detour or number of stages. 	LCCA is for information only, when a project is defined, project will be submitted for an Official LCCA.	Individual Projects must go through an Official LCCA when project limits are defined.

* Whichever is less

Life Cycle Cost Analysis Process Schedule



CHAPTER 4. COMPONENTS OF A LIFE CYCLE COST ANALYSIS

A. Economic Analysis Approach

LCCA is used to compare the relative long term costs of different pavement alternatives. LCCA allows the Engineer to objectively evaluate costs of two or more rehabilitation and/or new/reconstruction alternatives that may have significantly different initial costs and require very different levels of future preventive maintenance expenditures.

The analysis is expressed in terms of Equivalent Uniform Annual Costs (EUAC). The Service Life for each pavement fix has been determined using actual department pavement maintenance records and condition data. A pavement's Service Life is defined as the amount of time (expressed in years) before the pavement is in need of a subsequent rehabilitation or reconstruction. Service Life values can vary significantly based on the type of original rehabilitation or reconstruction method, as well as the number and type of preventive maintenance treatments.

Historical maintenance data is also used to identify what maintenance expenditures actually occur throughout the Service Life. This data, along with Pavement Management System performance data, is used to develop Pavement Preservation Strategies (Chapter 6) that reflect average pavement performance and the associated average maintenance costs. These Pavement Preservation Strategies define the basis for the Life Cycle Cost Analysis.

Future costs are discounted to their present value and annualized over the Service Life, which allows comparison of different alternatives. Federal Highway Administration's September 1998 Interim Technical Bulletin, *Life Cycle Cost Analysis in Pavement Design*, states that "good practice suggests conducting LCCA using constant dollars and real discount rates." It goes on to say that "real discount rates reflect the true time value of money with no inflation premium and should be used in conjunction with noninflated dollar cost estimates of future investments."

All life-cycle costs will be expressed in current-year dollars. Real discount rates are used in the analysis and no correction is made for inflation. Recommended discount rates are published annually by the Federal Government's Office of Management and Budget. Cost data is based on the department's bidding records.

All costs are reported on a per mile basis for the entire roadway on bidirectional roadways (e.g. east & west-bound M-57), while costs are computed per directional mile on divided highways (e.g. one bound of I-75). If there are miscellaneous paving areas included in the calculations, costs will be computed on a per lane mile basis.

B. Initial Construction Costs

Only costs that differ between alternates are considered in the calculation. The following portions of the roadway will be included in the LCCA when present, some of which may not be included in the \$1 million threshold calculation (See Chapter 3 for calculation of the \$1 million threshold): mainline pavement, miscellaneous paving areas, ramps, weave/merge/collector/distributor lanes, continuous/contiguous parking lanes, continuous/contiguous non-motorized lanes, and shoulders. Cost items such as the following may be included: HMA and concrete pavement, joints, excavation, subbase, base, rubblization,

pavement repairs, separator layers, underdrains, traffic control, utility relocation, etc. Unit prices will be determined from past MDOT projects and will be based on the weighted average of low bid data. The procedure used for unit price determination is further explained in Chapter 7.

Miscellaneous Paving

When the LCCA will include miscellaneous paving areas, costs will be calculated on a per lane mile basis.

- 1) For the concrete alternate, the average unit price for miscellaneous concrete will be applied to areas identified as miscellaneous paving.
- 2) For the HMA alternate, the standard HMA average unit prices will be applied to those areas, as there is no separate pay item for miscellaneous HMA.
- 3) The total of all mainline and all miscellaneous paving area costs will be multiplied by their respective number of lane miles. This applies to all pay items included in initial construction costs.
- 4) The above costs will be added together, and then divided by the total number of lane miles that the project will cover. The result is a weighted average initial cost per lane mile.

Reuse of Sand Subbase

When the LCCA will account for the reuse of existing sand subbase (see Chapter 2 for additional information), either by leaving it in place or by first stockpiling then reusing it, no costs will be assessed (except as outlined below), since the amount of existing sand is the same for both alternatives. Costs will be included for additional sand subbase that needs to be brought on-site to construct the proposed pavement section.

- 1) For locations that have an insufficient depth of existing sand subbase, but can accommodate a grade raise, the cost of the additional depth of material and its placement will be included.
- 2) The following procedure will be used to address other situations, such as: locations that have an adequate depth of existing sand subbase for only part of a project; or the existing sand subbase is deemed reusable for a certain length, or an overall percentage of a project, but cannot accommodate a grade raise (i.e. reusable material is at the wrong existing elevation).
 - a. Different proposed cross-sections will be priced out, using a combination of existing and new sand subbase to reflect project conditions. When applicable, excavation costs to the bottom of the proposed cross-section will be assessed, assuming that the reusable sand subbase will be stockpiled and the unsuitable material disposed. No costs will be assessed for placement & compaction of reusable sand subbase material (assumed to be incidental).
 - b. The length of the project where each proposed cross-section applies is determined. These lengths could be different between the HMA and concrete alternatives.
 - c. The lengths of each proposed cross-section are multiplied by their respective cost, summed, and then divided by the total length, to determine a weighted average initial cost for each pavement type.

Miscellaneous

When utility relocation, Right of Way, drainage, maintenance of traffic, etc, costs are included, they will first be converted into the same units (per directional mile, per mile, or per lane mile) as the rest of the LCCA, based on whether it is a divided roadway, an undivided roadway or includes miscellaneous concrete. This cost will be added to the total Net Present Value (NPV) when calculating each pavement type's EUAC.

If the Region states that lane closures will be necessary, or that additional time will be added to the project schedule for utility relocation work, user delay costs will be calculated and added to the LCCA. All steps below are specific to information for utility relocation as provided by the Region.

- 1) A CO3 analysis will be performed to determine the daily user delay costs based on the maintenance of traffic.
- 2) User delay costs will be multiplied by the number of days the Region estimated to complete the work.
- 3) The total user delay costs will be converted into the same units (per directional mile, per mile, or per lane mile) as the other costs in the LCCA.
- 4) The converted total user delay costs will be added to the total NPV when calculating each pavement type's EUAC.

C. Initial User Costs

User costs are those that are incurred during everyday use of a roadway, but more so within construction work zones which disrupt normal traffic flow. User costs are included in an LCCA because they affect life-cycle costs. They are influenced by the length, duration, and character of capacity restriction and their effect on traffic flow, speed changes, stops, delays, and detours experienced by the roadway users. The project's Temporary Traffic Control Plan (TTCP) will be utilized to assist in estimating these costs. Pavement Operations may require further information based on the complexity of the construction work zone for any project and may contact the Region for clarification purposes.

Total user delay costs for each pavement alternative are estimated as follows. A number of estimates and simplifications are incorporated into this process and are applied to every project.

- 1) The submitted maintaining traffic scheme (TTCP) and traffic volumes are utilized in CO3 to calculate the estimated daily user delay costs.
- 2) The production rates in Appendix A and the quantities of each associated pay item are used to calculate the estimated number of construction days to perform each work activity, broken down per stage.
- 3) A simplified linear schedule is developed utilizing the number of construction days for each work activity, simplified pre-determined construction sequencing, work item relationships, and lag times. Sample simplified linear schedules are shown in Appendix B to graphically display the work item relationships and lag times described below. Work item end lag times could be longer than those shown, when the number of days to build a certain item exceeds the minimum lag time. "Float" may be included in the schedule for a particular item when the number of days to build that item needs to be extended to meet the minimums.
 - a. Work item start times
 - i. HMA or concrete paving must begin no sooner than one day after the start of the preceding work item; two days if the preceding work item is a stabilized base layer.
 - ii. Other work items must begin no sooner than one half day after the start of the preceding work item.
 - iii. If the preceding work item is full depth repair, the work item must begin no sooner than one day after the start of repair.
 - b. Work item end times
 - i. HMA or concrete paving must end no sooner than one day after the end of the preceding work item; two days if the preceding work item is a stabilized base layer.

- ii. Other work items must end no sooner than one half day after the end of the preceding work item.
 - c. A 16 inch open-graded drainage course will be placed in two lifts, with one half day lag between lifts.
 - d. For HMA paving, initial production lots (IPL) will be incorporated for each HMA mixture with at least 5,000 tons on the project. A production rate of 1000 tons per day per HMA mixture type for a duration of three days will be used for the placement and testing of initial production lots prior to the start of production paving. This duration includes one day for placement of the IPL and two days for MDOT to report test results, and presumes the paving contractor will satisfy the testing requirements to proceed to production paving in the first IPL. The IPL for each HMA mixture will start one day after start of IPL placement for the previous HMA mixture. If different mixtures are to be used for shoulders than used on mainline, the order of placement will be shown as: first course of mainline, first course of shoulders, second course of mainline, second course of shoulders, and so on. IPLs will only be utilized in the first stage of construction during which a mix is used; the lower IPL production rate will not be applied in later stages.
 - e. For concrete paving, a cure time of three days will be used to determine when the pavement can support the construction equipment needed to initiate subsequent controlling work items, such as HMA shoulder placement items. A cure time of seven days will be used to determine when the pavement is ready to be opened to vehicular traffic.
 - f. For concrete paving on non-freeways constructed part-width, an additional seven days of joint sawing/sealing and cure time per travel bound will be included in the schedule to address paving gaps and repaving for access management. Quantities necessary to pave the gapped out areas will be included in the total for concrete paving.
 - g. Other unique situations may arise, in which case assumptions will be made and reflected in the LCCA package.
- 4) The total number of construction days for the project is determined from the simplified linear schedule.
- 5) Total user delay costs are calculated by multiplying the daily costs by the total number of construction days for the project. If weekday and weekend user delay costs differ, the costs are applied accordingly utilizing the simplified approach that work will continue seven days per week until the work is completed.

To determine user delay costs associated with initial construction of the miscellaneous paving areas, the applicable production rates and maintenance of traffic scheme will be utilized in the CO3 model to calculate daily user delay costs. A weighted averaging of the total user delay costs will be calculated (similar to the initial construction cost) to determine the per lane mile initial user delay cost.

D. Future Maintenance Costs

Maintenance costs are based on MDOT maintenance records. Historical maintenance data and pavement condition data from the Pavement Management System have been used to develop maintenance cost schedules otherwise termed "Pavement Preservation Strategies" for the various pavement fixes (see Chapter 6).

Miscellaneous paving areas will follow the maintenance schedules in Chapter 6. These costs will be calculated per lane mile, consistent with the costs related to initial construction.

E. Future User Costs for Maintenance Activities

Future user delay cost calculations will be performed on a project by project basis. Project level data used in the user delay cost calculation for initial construction (AADT, number of lanes, speeds, growth rate, etc.) will be used again for each maintenance cycle.

Traffic volumes will be increased based on the growth rate (as provided by the Traffic Analysis and System Studies Unit, of the Bureau of Transportation Planning) and the number of years in the future when the average maintenance cycle occurs. The assumed maintaining traffic schemes will be as follows:

- 1) A single lane closure on divided roadways
- 2) A single lane closure on undivided roadways with three or more lanes
- 3) Flaggers on two-lane, two-way highways

With these inputs, CO3 will be utilized to calculate the average daily user delay costs.

The average number of days (or part of a single day) necessary to perform one lane mile of maintenance is shown in the Pavement Preservation Strategies in Chapter 6.

The daily user cost will then be multiplied by the duration of the maintenance cycle. This value will be the per lane mile user cost for the maintenance cycle. This may need to be converted into the same units (per directional mile or per mile) as the other costs in the LCCA and then included in the EUAC calculation.

Cost inputs into CO3 are updated annually, and consequently there will be no need to account for inflation separately. Also, it will not be necessary to inflate prices to future dollars, since they would be deflated back to present day dollars in a subsequent calculation.

For some roadways, when traffic is aged to the year of the future maintenance activity, CO3 calculations may indicate very large backups and user costs (i.e. over capacity situations). In these situations, it is very likely that maintenance would not be performed during the day, but at some off-peak time in order to meet the standards set forth in MDOT's Mobility Policy. Therefore, when calculating user delay for maintenance activities, if the output states that MDOT's Mobility Policy is being violated (i.e. greater than 10 minutes of user delay), the user delay analysis will be rerun. Night work will be assumed, applying the user costs from 9pm to 5am, with this time frame counting as one day's worth of maintenance work.

CHAPTER 5. SOFTWARE

Several tools have been developed to assist in completing a pavement design and LCCA. The tools have been developed to minimize the time required to perform an analysis and also maintain uniformity in the analysis method.

Pavement design software titled “DARWin Version 3.1” is used by the department to conduct pavement designs. This software was developed by AASHTO to compliment the 1993 version of the AASHTO Guide for Design of Pavement Structures.

User cost analysis software has been developed by the University of Michigan for MDOT to aid in performing the user cost analysis portion of an LCCA. This software titled “Construction Congestion Cost (CO3)” is based on the user cost analysis method recommended by the Federal Highway Administration (FHWA). This method is explained in FHWA’s publication titled *Life Cycle Cost Analysis in Pavement Design*.

A project costing spreadsheet has been developed by MDOT which calculates initial construction and future maintenance costs that are included in the LCCA. This spreadsheet uses stored unit price data for all applicable work items, maintenance costs, and user input data for each design alternative.

CHAPTER 6. PAVEMENT PRESERVATION STRATEGIES

Pavement preservation strategies (maintenance schedules) are shown in this chapter, and reflect the overall maintenance approach that has been used network-wide for a specific fix type. They have been developed by modeling and analyzing historical maintenance activities and costs, and pavement condition data.

The pavement preservation strategies that follow are to be used when applying the maintenance timing and costs for each alternative in a life-cycle cost analysis. The methodology used to create these strategies considered a large number of projects for each fix type and provides network/system wide historical averages that may not be indicative of business practices on any actual project.

PAVEMENT PRESERVATION STRATEGY

Fix Type: New/Reconstruction HMA Pavement

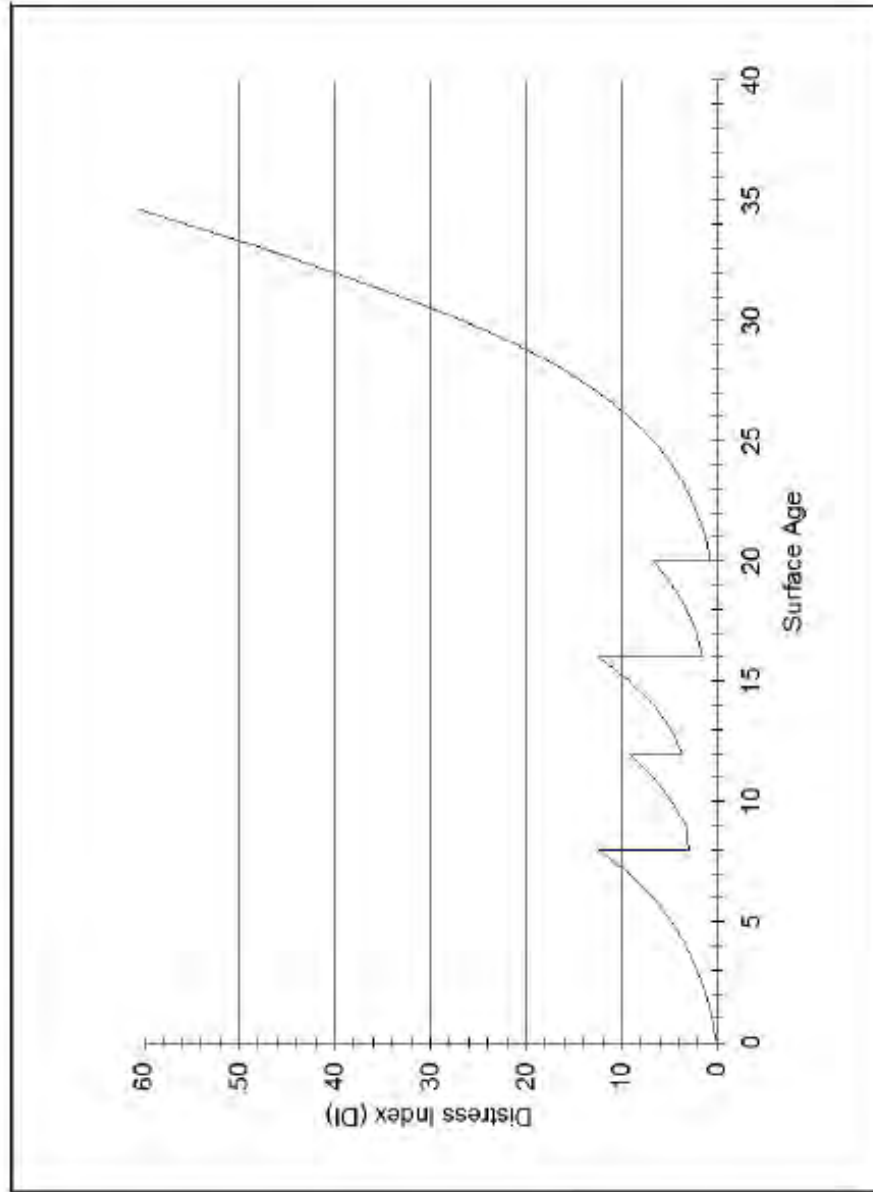
Activity	Approx. Age	Distress Index (Before)	Distress Index (After)	RSL (yrs) (Before fix)	Life (yrs) Extension	RSL (yrs) (After fix)	Cost per Lane-Mile	Time to Fix 1 Lane-Mile (In Days)
Initial Construction	0		0			14	Computed	
Prev. Maintenance	8	12	3	6	5	11	\$25,544*	0.48
Prev. Maintenance	12	9	4	7	3	10	\$36,757*	0.62
Prev. Maintenance	16	12	1	6	6	12	\$46,564*	0.90
Prev. Maintenance	20	7	1	8	5	13	\$27,350*	0.65
Rehabilitation or Reconstruction	33							

Equivalent Uniform Annual Cost (EUAC) = $NPV (i(1+i)^n) / ((1+i)^n - 1)$
 Net Present Value (NPV) = Initial Construction + SUM (Maintenance) / (1 + i)ⁿ
 i = Real Discount Rate (2012: 2.0%)

* based on actual averaged maintenance costs

PAVEMENT PRESERVATION STRATEGY

Fix Type: New/Reconstruction HMA Pavement



PAVEMENT PRESERVATION STRATEGY

Fix Type: New/Reconstruction Concrete Pavement

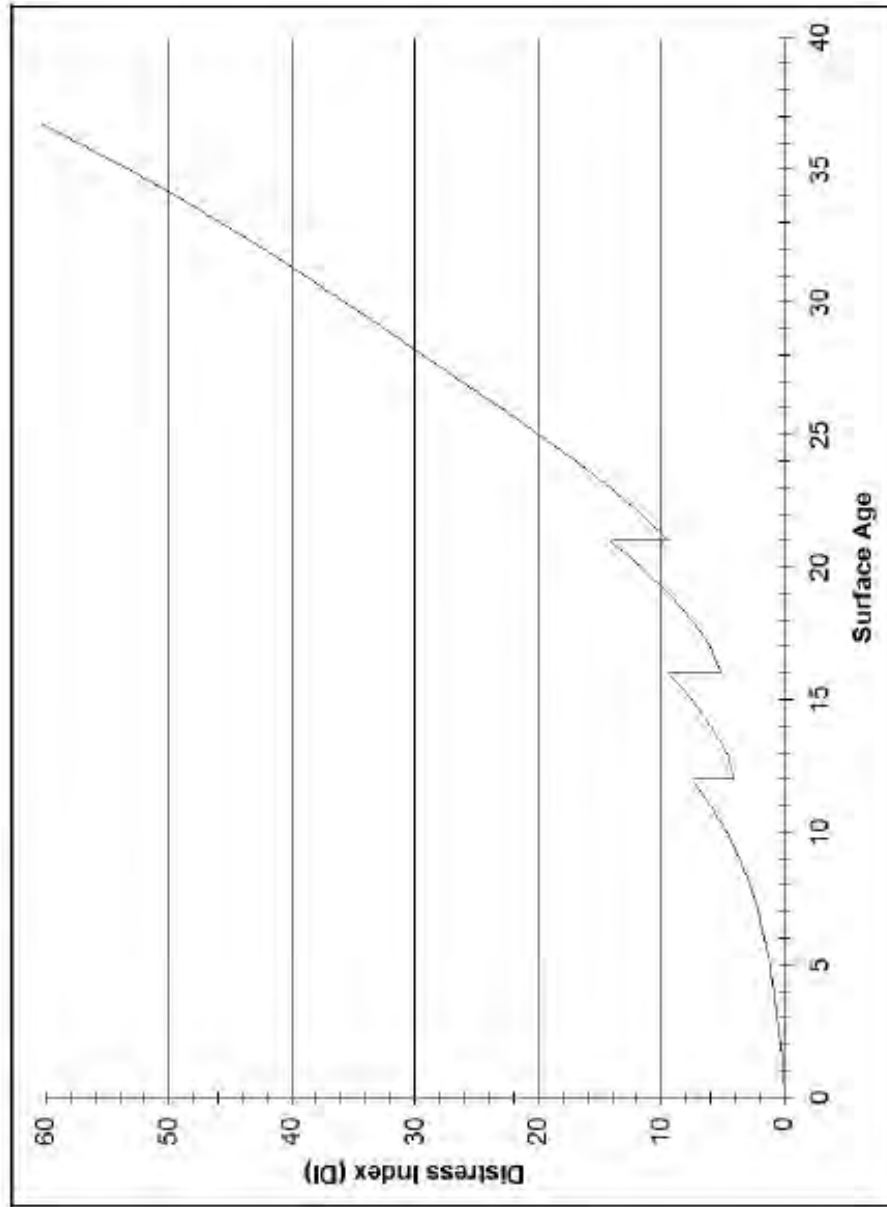
Activity	Approx. Age	Distress Index (Before)	Distress Index (After)	RSL (yrs) (Before fix)	Life (yrs) Extension	RSL (yrs) (After fix)	Cost per Lane-Mile	Time to Fix 1 Lane-Mile (In Days)
Initial Construction	0	0	0			26	Computed	
Prev. Maintenance	12	8	4	14	3	17	\$36,267*	1.34
Prev. Maintenance	16	9	5	13	3	16	\$38,720*	1.48
Prev. Maintenance	21	14	9	11	2	13	\$62,926*	1.76
Rehabilitation or Reconstruction	34							

Equivalent Uniform Annual Cost (EUAC) = $NPV(i(1+i)^n) / ((1+i)^n - 1)$
 Net Present Value (NPV) = Initial Construction + $SUM(\text{Maintenance}) / (1+i)^n$
 i = Real Discount Rate (2012: 2.0%)

* based on actual averaged maintenance costs

PAVEMENT PRESERVATION STRATEGY

Fix Type: New/Reconstruction Concrete Pavement



PAVEMENT PRESERVATION STRATEGY

Fix Type: Rehabilitation Unbonded Concrete Overlay on Repaired Concrete

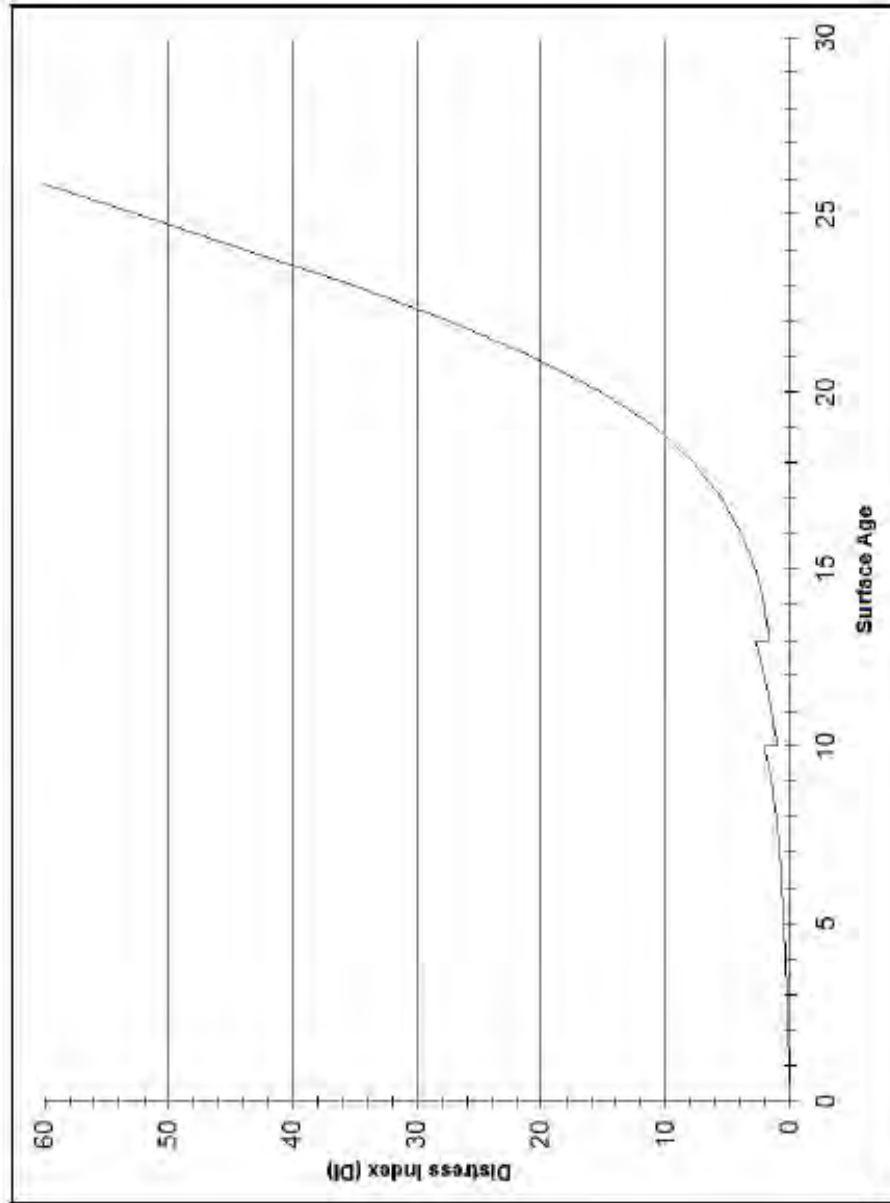
Activity	Approx. Age	Distress Index (Before)	Distress Index (After)	RSL (yrs) (Before fix)	Life (yrs) Extension	RSL (yrs) (After fix)	Cost per Lane-Mile	Time to Fix 1 Lane-Mile (In Days)
Initial Construction	0		0			21	Computed	
Prev. Maintenance	10	2	1	11	2	13	\$21,492*	1.05
Prev. Maintenance	13	3	2	10	2	12	\$35,626*	1.33
Rehabilitation or Reconstruction	25							

Equivalent Uniform Annual Cost (EUAC) = $NPV (i(1+i)^n) / ((1+i)^n - 1)$
 Net Present Value (NPV) = Initial Construction + $SUM (Maintenance) / (1+i)^n$
 i = Real Discount Rate (2012: 2.0%)

* based on actual averaged maintenance costs

PAVEMENT PRESERVATION STRATEGY

Fix Type: Rehabilitation Unbonded Concrete Overlay on Repaired Concrete



PAVEMENT PRESERVATION STRATEGY

Fix Type: Rehabilitation HMA Overlay on Rubblized Concrete

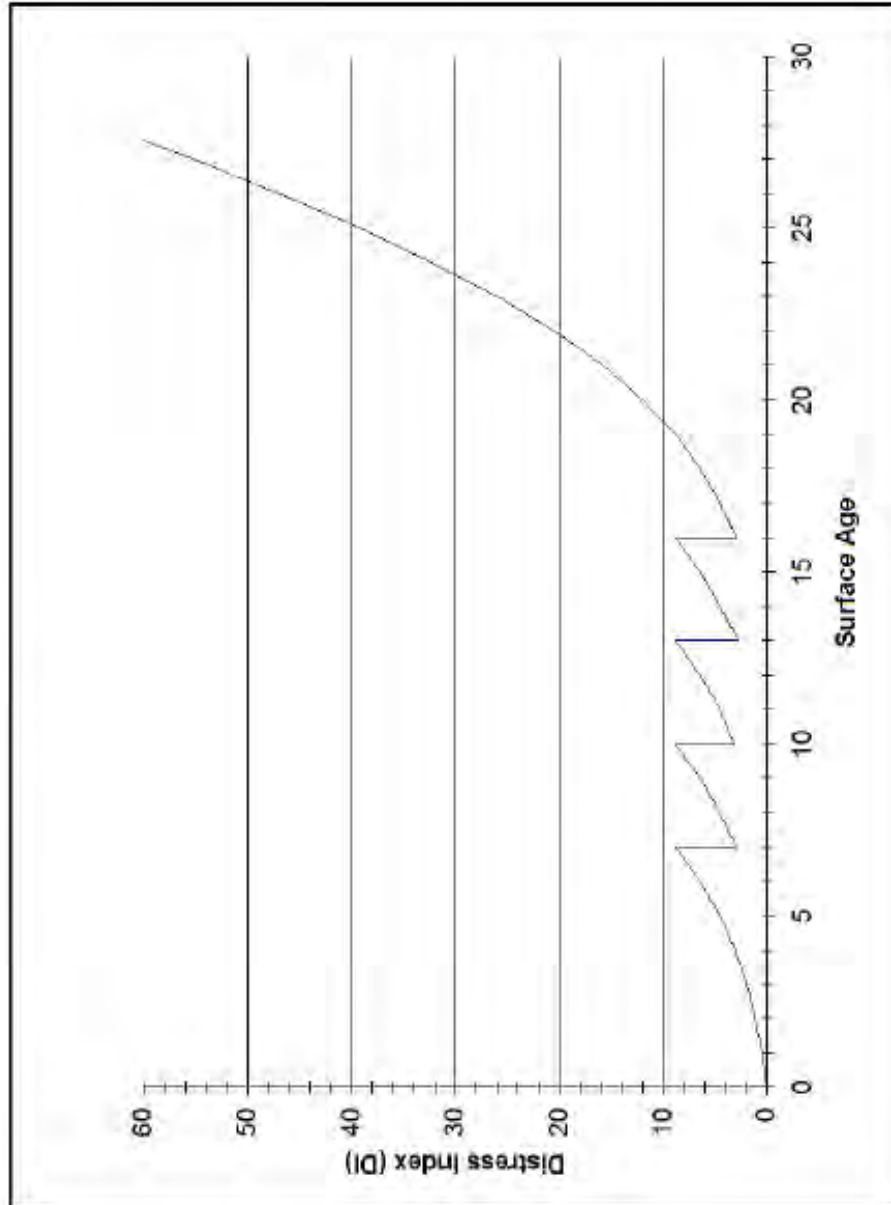
Activity	Approx. Age	Distress Index (Before)	Distress Index (After)	RSL (yrs) (Before fix)	Life (yrs) Extension	RSL (yrs) (After fix)	Cost per Lane-Mile	Time to Fix 1 Lane-Mile (In Days)
Initial Construction	0		0			14	Computed	
Prev. Maintenance	7	9	3	7	3	10	\$19,113*	0.38
Prev. Maintenance	10	9	3	7	3	10	\$45,602*	0.65
Prev. Maintenance	13	9	3	7	3	10	\$27,636*	0.53
Prev. Maintenance	16	9	3	7	3	10	\$45,069*	0.71
Rehabilitation or Reconstruction	26							

Equivalent Uniform Annual Cost (EUAC) = $NPV(i(1+i)^n) / ((1+i)^n - 1)$
 Net Present Value (NPV) = Initial Construction + $SUM(Maintenance) / (1+i)^n$
 i = Real Discount Rate (2012: 2.0%)

* based on actual averaged maintenance costs

PAVEMENT PRESERVATION STRATEGY

Fix Type: Rehabilitation HMA Overlay on Rubblized Concrete



CHAPTER 7. LCCA PROCESS, PRESERVATION STRATEGY & DATA UPDATES

A. Input for Future LCCA Process Updates

Identification and investigation of potential improvements to MDOT's LCCA process will occur according to the schedule described in this section. The schedule provides opportunity for periodic stakeholder input and for appropriate improvements to be incorporated in a timely manner. Input will be solicited from construction industry and MDOT representatives.

Since consensus among stakeholders may be difficult to reach, consensus concerning process changes is desirable but not required. MDOT will designate a small number of people with authority for final decision making. The members of this group will be determined by the Chief Operations Officer. This group, or their appointees, would decide issues including but not limited to the following:

- Which suggestions to investigate
- Investigation schedules
- Which MDOT staff will be assigned to investigations
- Level of industry participation in investigations, if any
- Which recommendations to implement
- Implementation schedules
- Schedule deviations

The group, or their appointees, will also be responsible for activities including but not limited to the following:

- Solicit stakeholder input in accordance with the established schedule
- Communicate feedback to stakeholders

Implementation is expected to require revisions to this manual, and will include inflation of published maintenance costs as described in Section F of this chapter. No new maintenance project data will be added. Some changes to the process may conflict with the existing pavement preservation strategies and thus, will not be incorporated into the manual until the pavement preservation strategies are updated per Section B of this chapter.

Since a regular schedule for process input is in place, industry review of individual LCCA packages will be limited to whether the process in place is being followed appropriately. Any comments related to the process itself should not be included and will not be considered at that time. This will eliminate expenditure of MDOT resources to respond to and investigate such comments, and will avoid related delays to LCCA decisions.

In the event that a process related issue is identified that should not wait until the next regularly scheduled cycle for input, the Chief Operations Officer may initiate a special cycle to address that issue.

Since input and investigation for the LCCA Technical Agenda was completed in 2010, the next update is expected to occur during 2014 and follow the approximate schedule shown below. Subsequent cycles will occur every four years. Items assigned to MDOT decision makers may be delegated to their appointees.

Step	Activity	Assigned To	Approximate Target Completion Date
1	Solicit input from stakeholders.	MDOT Decision Makers	February 1, 2014
2	Provide written input.	Stakeholders	February 14, 2014
3	Review previous technical agenda findings and best practices for applicability	MDOT Decision Makers	February 14, 2014
4	Solicit input from MDOT technical experts regarding which suggestions and issues should be investigated.	MDOT Decision Makers	March 1, 2014
5	Develop a detailed investigation schedule and submit to COO for approval	MDOT Decision Makers	March 10, 2014
6	Inform stakeholders of decisions from steps 3, 4 & 5.	MDOT Decision Makers	March 20, 2014
7	Perform investigations and make recommendations (including implementation estimates) to MDOT Decision Makers.	MDOT staff	August 15, 2014*
8	Accept, reject or adjust recommendations. Provide to stakeholders and establish comment period.	MDOT Decision Makers	September 15, 2014
9	Provide comments.	Stakeholders	October 15, 2014
10	Determine final changes and set implementation schedule.	MDOT Decision Makers	November 5, 2014
11	Inform stakeholders.	MDOT Decision Makers	November 20, 2014
12	Implement.	MDOT staff	Varies

* The amount of time to investigate individual items is expected to vary. For those requiring more time than provided in this schedule, the MDOT Decision Makers will determine deviations from this schedule for those items. The remaining items should continue on this schedule if appropriate.

B. Process for Pavement Preservation Strategy Updates

The pavement preservation strategies will be updated every four years, approximately two years after the overall process update. Since they will be updated in conjunction with implementation of the 2010 LCCA Technical Agenda, the next update process will occur during 2016. By early 2017, drafts are expected to be shared with MDOT management and industry representatives, with Engineering Operations Committee approval by mid 2017.

Updates will be performed in accordance with the process in place when the updates begin. In addition, data available at the time of each data “pull” will be utilized, even if additional data becomes available during the process. This will eliminate back tracking to redo steps.

Information will be shared with industry when draft updates are available. This may occur at one or more milestones during the process if MDOT deems it beneficial, but at least will occur when draft pavement preservation strategies have been developed. Their input will be focused on whether the process was followed accurately, as well as possible alternatives for decisions that were based on engineering judgment. Any suggestions for process improvements will be considered during the regularly scheduled updates for the LCCA process as a whole, not during the pavement preservation strategy update process. While industry input will be considered, MDOT retains final decision making authority and consensus is not mandatory.

C. Unit Prices – HMA & Concrete

Unit prices used in the pavement selection process to determine initial construction costs are updated based on the following procedure. There may be unique situations where these procedures do not result in an average unit price. Other methods may be utilized to estimate an average unit price, or an average unit price may not be reported for certain items.

Prices are updated on a semiannual basis. Publication of updated prices is targeted for February and August every year. The February publication will be based on price data ending with the prior December letting. The August publication will be based on price data ending with the prior June letting. Updated prices will be sent to construction industry representatives, providing one month for review and comment. However, the final decision for selected prices resides with MDOT. The updated unit prices will be used in any LCCA that has not yet been reviewed internally after the new prices are officially published.

Unit prices will be determined from past MDOT projects only, no local agency projects, and will be based on the weighted average of low bid data, when possible, following steps 1-7 listed below. Unit prices will be determined for a regional area except when steps 1-7 result in a statewide average price. There are three regional areas that are considered. The three areas are: Superior/North Regions, Grand/Bay/Southwest Regions, and University/Metro Regions. Additionally, for a given hot mix asphalt mixture, there must be a minimum of 6000 tons on a project basis in order for it to be included in the data set.

The steps listed below are the order in which price data will be queried. Steps 1-4, & 6 are on a regional area basis. Steps 5 & 7 are on a statewide basis. If a given unit price can not be obtained from the first step, the query will proceed to the second and continue through the steps until a unit price can be obtained. When unit price data is not available for a specific work item, unit prices of similar work items will be considered in unit price determination as outlined in steps 6 & 7.

In rare instances, unit prices may be encountered that are significantly lower than would reasonably be expected on future projects, and for which a similar trend for that particular item would not reasonably be expected. It is possible that such unit prices should not be included in the LCCA unit prices. This applies exclusively to prices that are significantly lower (not higher) than expected. Such unit prices will be brought to the attention of the Chief Operations Officer for review and determination on a case-by-case basis.

Steps are as follows:

- 1) 1 or more projects in the last 18 months with individual project threshold of 68,000 square yards of concrete pavement or 23,000 tons of hot mix asphalt.
- 2) 1 or more projects in the last 24 months with individual project threshold of 68,000 square yards of concrete pavement or 23,000 tons of hot mix asphalt.
- 3) 1 or more projects in the last 18 months with individual project threshold of 34,000 square yards of concrete pavement or 11,500 tons of hot mix asphalt.
- 4) 1 or more projects in the last 24 months with individual project threshold of 34,000 square yards of concrete pavement or 11,500 tons of hot mix asphalt.
- 5) Statewide weighted average of projects that meet the individual project thresholds per Steps 1-4.
- 6) Prorate the unit price for the next closest concrete thickness (using both sides of the thickness when available) within in a regional area. Calculate a unit price for the hot mix asphalt type by applying the price of a similar hot mix asphalt type within a regional area.
- 7) Prorate the unit price for the next closest concrete thickness (using both sides of the thickness when available) on a statewide basis. Calculate a unit price for the hot mix asphalt type by applying the price of a similar hot mix asphalt type on a statewide basis.

Note: When querying hot mix asphalt mixes in Steps 1-4 above, the query will be for individual mix types on a project; for example, the summation of E10 mixes will be separate from the summation of E03 mixes, even if both are present on the same project.

Those projects which meet the criteria set forth in Steps 1-4 are compiled into a “qualified project list” for later use.

D. Unit Prices – Common Items

Common items are those items that are neither an HMA mixture nor a mainline concrete pavement, but they are vital for successful pavement performance. Examples of common items would be all granular base/subbase materials, underdrains, pavement joints, and miscellaneous concrete.

To calculate a unit price for common items, first a “qualified project list” must be built based upon completing the previous steps for concrete pavements and HMA mixtures. The only common item prices that may be used in a weighted average price are those that are included in a project on the “qualified project list.”

- A regional weighted average unit price for projects in the last 18 months is determined first.
- If prices are not available for the last 18 months, unit prices in the last 24 months are used.
- If a regional price cannot be determined, a weighted statewide average price is calculated.
- Finally, items with no bids in the last 24 months are prorated, and when applicable, averaged using both sides of the thickness (for example), first on a regional basis, then on a statewide basis.

When a unit price without a bid history (e.g. stabilized bases) is required in order to complete an LCCA, MDOT reserves the right to use current market prices to estimate a unit price. Once actual bid history is established, the preceding steps will be followed to estimate a unit price for use in future LCCAs.

E. Real Discount Rate

The 30 year real discount rate is used in LCCA calculations and is obtained from the Federal Office of Management and Budget Circular A-94. It is updated yearly, usually in February. For information on the current rate see:

<http://www.whitehouse.gov/omb/circulars/default>

F. Maintenance Costs

Published maintenance costs will be inflated using the annual Producer Price Index (PPI), and by performing the following procedure, explained via an example.

- Assume that the latest published maintenance costs were all in 2007 dollars, and are to be inflated to 2009 dollars.
- The annual PPI for 2007 was 195.5, and 205.2 for 2009.
- The percent increase is calculated by: $(205.2/195.5) - 1 * 100\% = 4.96\%$.
- All published maintenance costs would be inflated by 4.96%.

If the index decreased, costs would be deflated accordingly.

The PPI for “material and supply inputs to highway and street construction” was utilized until 2010 when it was discontinued. The Bureau of Labor Statistics has replaced it with the “other non residential construction index”. Both indices must be utilized in combination for future updates. The new index will be correlated with the old index in order to properly inflate maintenance costs to present day dollars.

Published maintenance costs will be inflated in conjunction with LCCA process updates described in section A of this chapter. In years when the pavement preservation strategies are updated, inflation of costs will be included as part of the process to incorporate new data.

G. CO3 Inputs

The user costs per hour for cars and trucks are updated following the method presented in Federal Highway Administration publication number FHWA-SA-98-079, titled *Life-Cycle Cost Analysis in Pavement Design*. Yearly updates of these costs are performed by MDOT, by using the latest yearly Consumer Price Index (CPI), which is usually published in mid-January by the United States Department of Labor, Bureau of Labor Statistics.

The user cost per mile for cars (also vans, pickups and panel trucks) is the Internal Revenue Service (IRS) standard mileage rate for business travel. Normally this value is updated once per year, but depending on the stability of fuel prices, the IRS may update this value anytime throughout the year, in which case CO3 would be updated as well.

For tractor-trailer trucks, an operating cost per mile was calculated from the 2003 Motor Carrier Annual Report (the latest available data), and is annually indexed into present day dollars using the CPI.

CHAPTER 8. DEFINITIONS

Capital Preventive Maintenance – “Preventive maintenance is a planned strategy of cost-effective treatments to an existing roadway system and its appurtenances that preserves, retards future deterioration and maintains or improves the functional condition of the system without (significantly) increasing structural capacity.” Preventive maintenance is applied to pavements having a remaining service life of three years or greater. Examples of capital preventive maintenance include HMA crack sealing, chip sealing, micro-surfacing, concrete joint resealing, concrete crack sealing, thin HMA overlays, diamond grinding, full depth concrete repairs, and dowel bar retrofit.

Composite Pavement – A pavement with an HMA surface that is placed on a concrete pavement.

Concrete Pavement – A pavement with a portland cement concrete surface that is placed on either a granular, aggregate or stabilized base.

Design Life – The anticipated life of the pavement section at the time of initial construction. Design life, as fix life, does not include any additional life estimates provided by anticipated future preventive maintenance. This term is also used to define the number of years for which design Equivalent Single Axle Loads are calculated as an input parameter for formal pavement design calculations.

Distress Index (DI) – An index that quantifies the level of surface distress that exists on a pavement section based on 1/10 mile increments. The scale starts at zero and increases numerically as distress level increases (pavement condition worsens).

Equivalent Single Axle Load (ESAL) – Standard form of measurement used in pavement design to describe the damage caused by one pass of an 18,000 pound load.

Fix Life – The anticipated pavement life provided by the fix, excluding any future preventive maintenance treatments.

HMA Pavement – A pavement with a Hot Mix Asphalt surface that is placed on either a granular, aggregate or stabilized base.

International Roughness Index (IRI) – A statistic used to estimate the amount of roughness in a measured longitudinal profile (for the pavement surface). IRI is computed from a single longitudinal profile using standardized simulation of a passenger vehicle's suspension motion (The Golden Car). IRI is commonly reported with units of in/mi or m/km, with a value of 0 equaling perfection.

Life Cycle Cost Analysis (LCCA) – An economic analysis method that evaluates the long term costs of an investment alternative. The method can be used to compare the relative costs of various investment alternatives.

Poor Pavement – A pavement with an RSL of 0 to 2 years and/or an IRI of 170 or greater.

Reconstruction – Typically removes and replaces the entire pavement structure. Sometimes the sand subbase may be left in place and incorporated in the new pavement structure.

Reconstruction projects have a design life of twenty years or more. This fix is typically applied to pavements with a remaining service life of two years or less.

Rehabilitation – A fix that has an estimated design or fix life of ten to twenty years. Rehabilitation fixes are typically applied to pavements with a remaining service life of two years or less. These fixes include: two or three course HMA overlays, concrete patching & diamond grinding, crush & shape with HMA overlay, rubblize & multiple course HMA overlay, and unbonded concrete overlays.

Remaining Service Life (RSL) – The estimated number of years, from a specified date in time, until a pavement section is projected to reach a DI of 50. RSL is a function of project history and projected growth of pavement surface distress.

Service Life (Analysis Period) – The anticipated life of a rehabilitation or new/reconstruction, including additional pavement life provided by anticipated future preventive maintenance. This term is used to describe the number of years from the initial new construction, reconstruction or rehabilitation of a pavement to a subsequent rehabilitation or reconstruction. Analysis period is the term typically used to describe the time used in a life cycle cost analysis, over which all costs are evaluated.

REFERENCES

Life Cycle Cost Analysis in Pavement Design, Federal Highway Administration Publication No. FHWA-SA-98-079, 1998.

AASHTO Guide for Design of Pavement Structures, American Association of State Highway and Transportation Officials, 1993.

DARWin Version 3.01, American Association of State Highway and Transportation Officials, 1997.

Construction Congestion Cost (CO3), Robert I. Carr, University of Michigan 1997.

OMB Circular Number A-94, Federal Office of Management and Budget, 1999.

LCCA CONTACTS IN PAVEMENT OPERATIONS

<u>Title</u>	<u>Phone Number</u>
Pavement Management Engineer	517-322-1766
Pavement Design Engineer	517-322-3474
Pavement Selection Engineer	517-322-6855
Pavement Analyst	517-322-5732

APPENDIX A: LCCA PRODUCTION RATES

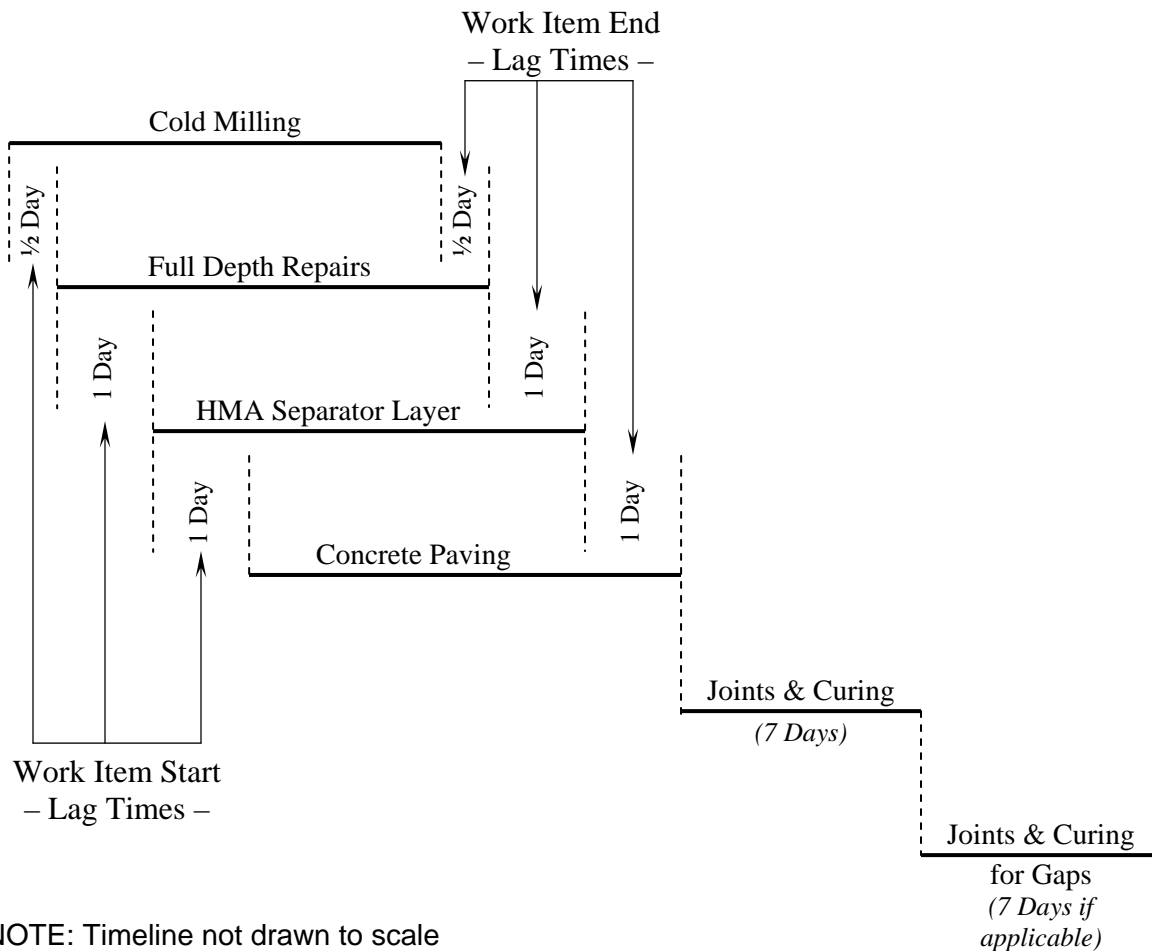
Life Cycle Cost Analysis (LCCA) Production Rates				
Work Items	Units	Freeway LCCA Rates	Non-Freeway LCCA Rates with a Detour	Non-Freeway LCCA Rates Constructed Part-width
Embankment, CIP Embankment, LM Excavation, Earth Granular Material, CI II Granular Material, CI III Subbase, CIP	Cyd/day	3000	2700	2300
Subgrade Undercutting	Cyd/day	2000	1800	1500
Aggregate Base Open-Graded Drainage Cse Stabilized Bases	Syd/day	5200	4700	3900
Aggregate Base Conditioning	Syd/day	7900	7100	5900
Geotextile Separator	Syd/day	6100	5500	4600
Rubblized Pavt Operation	Syd/day	7100	6400	5300
HMA Base Crushing and Shaping	Syd/day	12000	10800	9000
Underdrain Installation	Ft/day	4900	4400	3700
Cold Milling HMA Surface	Syd/day	8500	7600	6400
Pavt Joint and Crack Repr, Det 7 and Det 8	Ft/day	700	600	500
Hand Patching	Tons/day	700	600	500
HMA Separator Layer	Syd/day	30900	27300	23600
HMA Paving	Tons/day	1700	1500	1300
Concrete Paving	Syd/day	5600	5000	4200
Conc Pavt, Ovly, Furnishing and Placing	Cyd/day	1700	1500	1300
Pavt Repr Operation	Ea/day	100	90	75

Note: HMA and concrete paving production rates will be reduced by 50% in areas of miscellaneous paving.

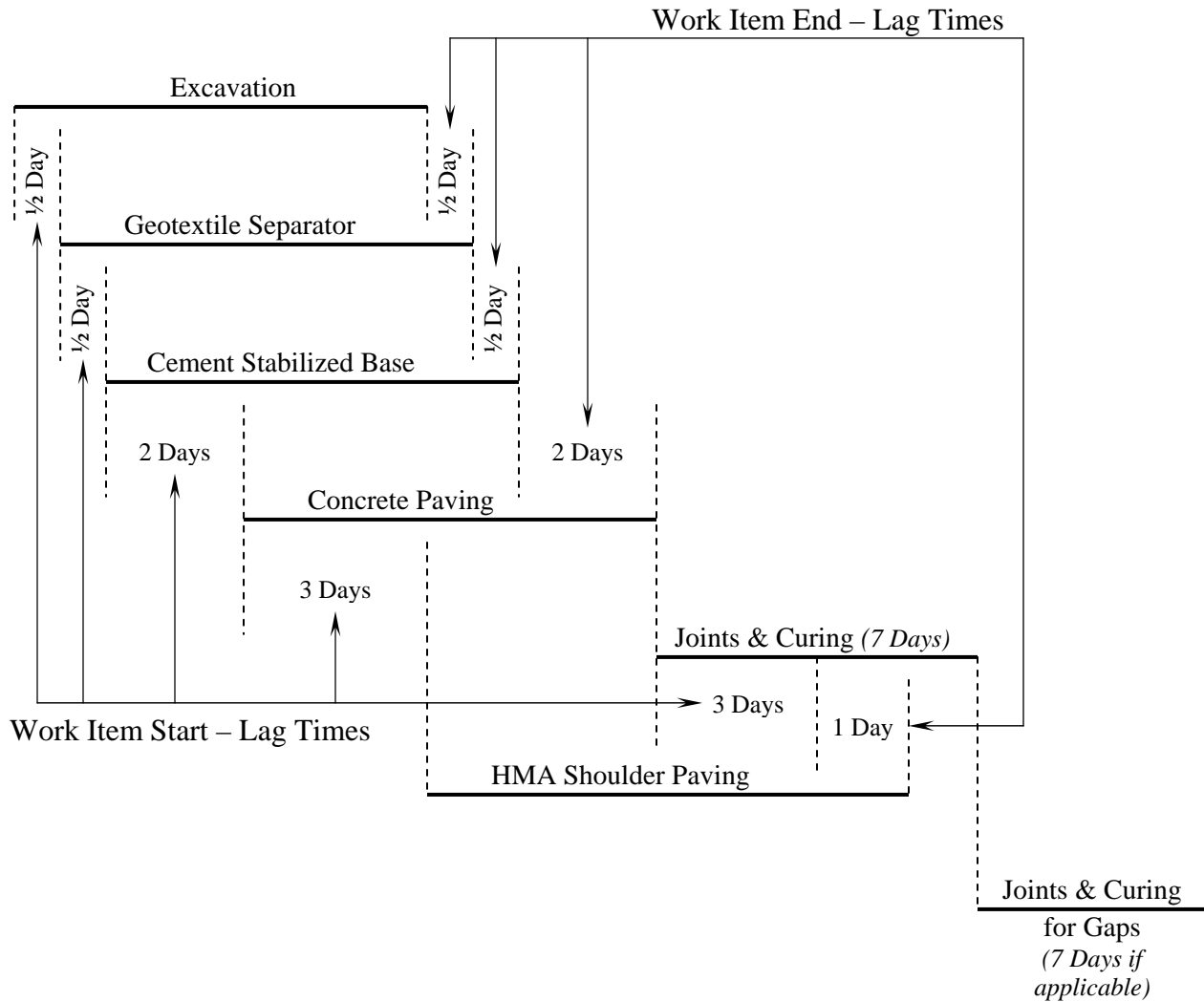
APPENDIX B: SAMPLE SIMPLIFIED LINEAR SCHEDULES

The following are examples to demonstrate the work item relationships and lag times as described in the manual, and are meant to cover only the main ideas, not every situation. Work item end lag times could be longer than those shown, when the number of days to build a certain item exceeds the minimum lag time shown. In practice, the number of days to build a certain item may need to be extended to meet the minimums, which means there will be a certain amount of “float” for that particular item in the schedule. Finally, for concrete paving on non-freeways constructed part-width, an additional seven days of joint sawing/sealing and cure time per travel bound to address paving gaps and repaving for access management will be included in the simplified linear schedule.

Example 1: Unbonded concrete overlay example: starting with cold-milling of the existing composite pavement, followed by full depth repairs, etc.

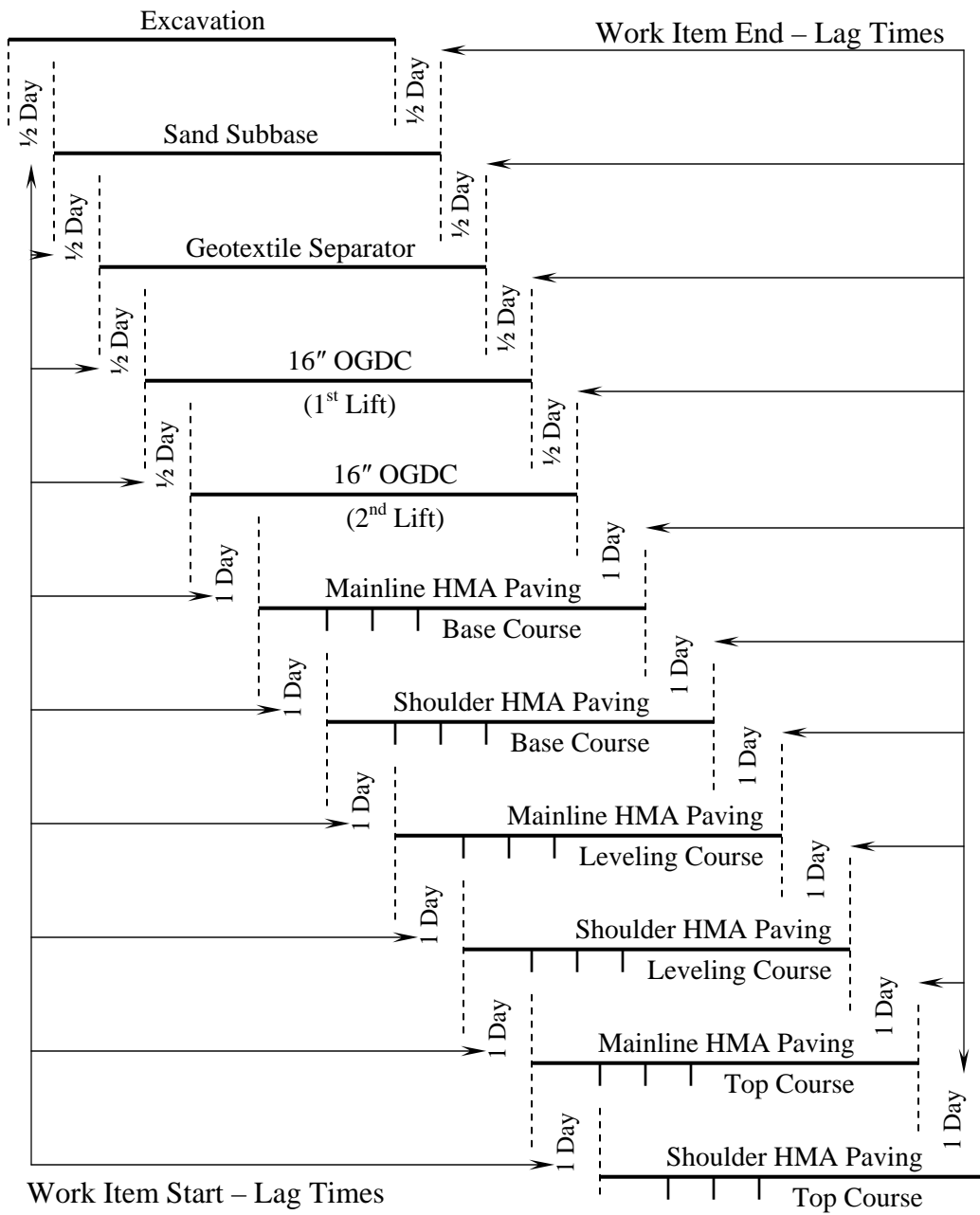


Example 2: Concrete reconstruction on a stabilized base example: re-using the existing sand subbase and placing HMA shoulders.



NOTE: Timeline not drawn to scale

Example 3: HMA reconstruction in Metro example: placement of 16" of OGDC, plus paving of the Initial Production Lots for six HMA mixes.



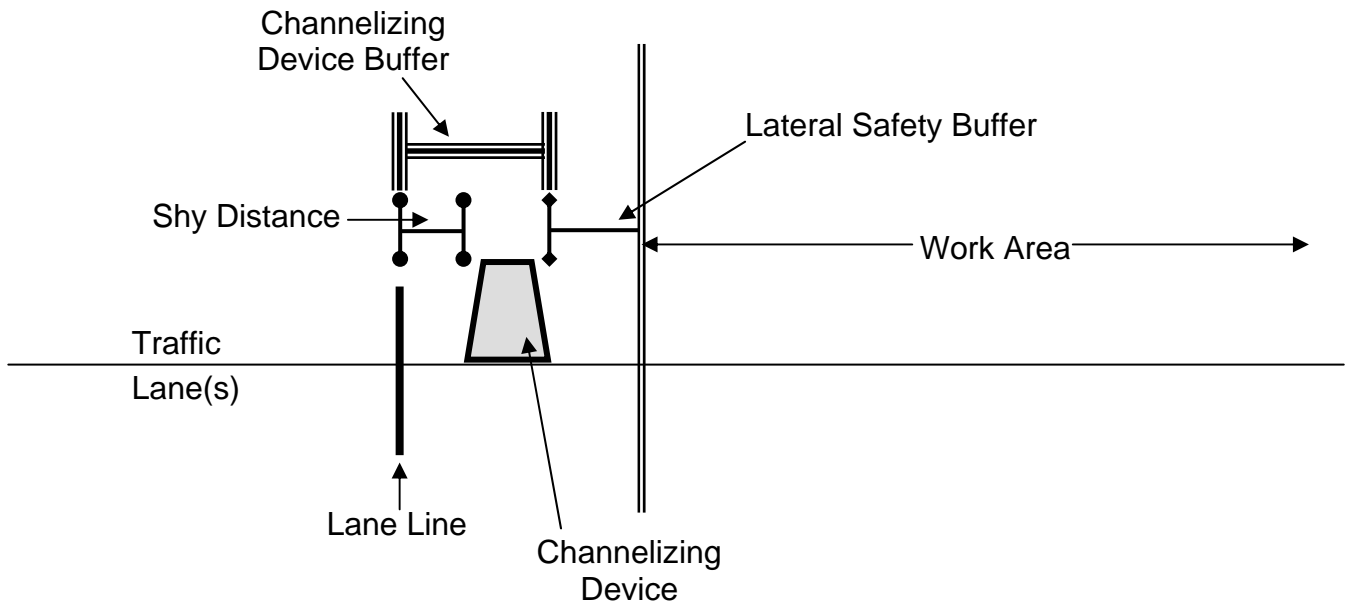
NOTE: Timeline not drawn to scale

IPL placement and testing:
1000 tons per day, for first
3 days of paving for each
mix, then full production.

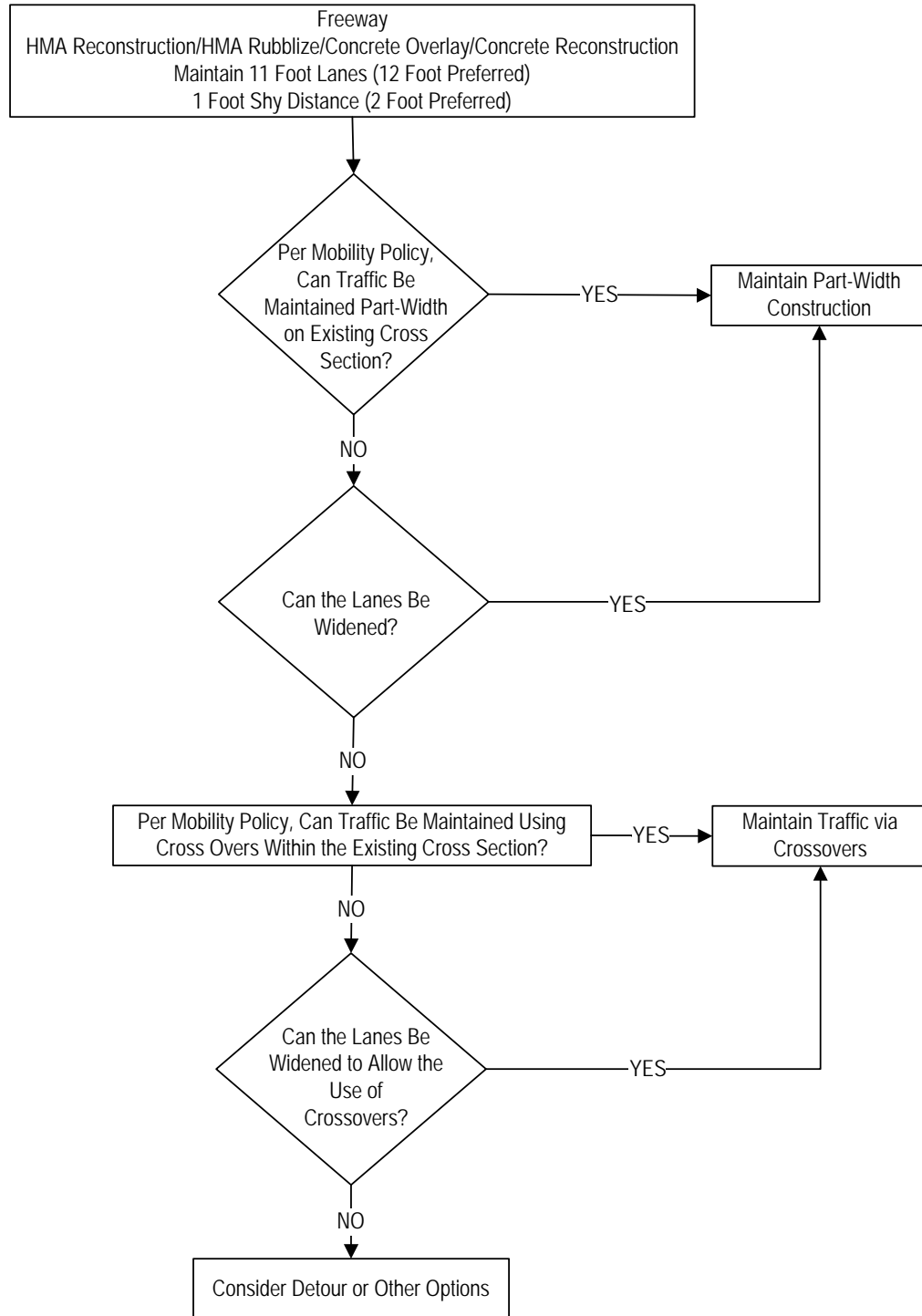
APPENDIX C: LCCA MAINTENANCE OF TRAFFIC FLOWCHARTS

The following flowcharts provide guidelines for maintaining traffic and are to be utilized with projects requiring an LCCA. A Nomenclature diagram is provided to assist in defining some terminology found in the flowcharts.

NOMENCLATURE (not to scale)



Maintaining Traffic for Freeways

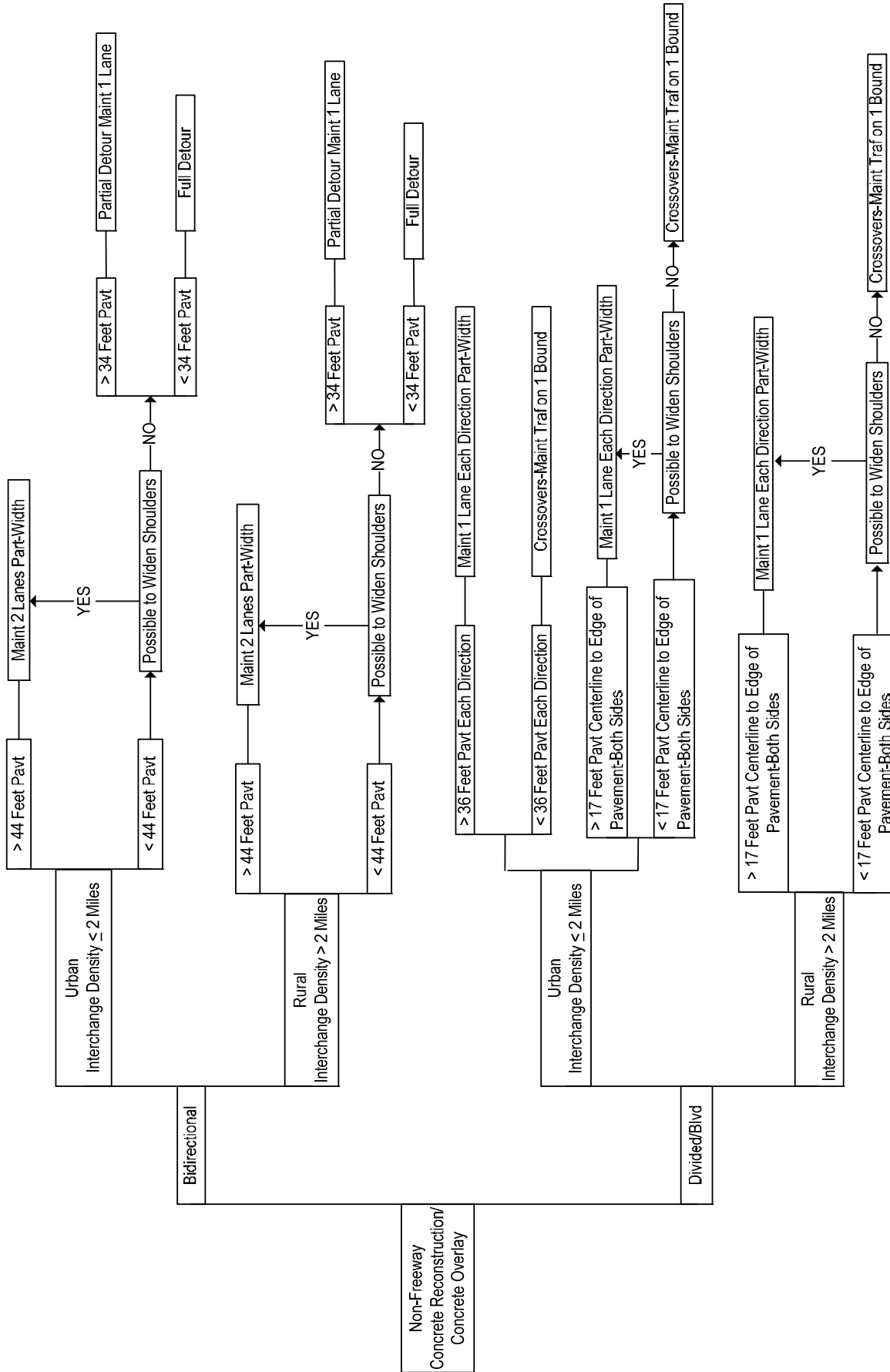


Maintaining Traffic Criteria:

- 1) Traffic will be maintained on 11 foot wide lanes.
- 2) Four-foot wide channelizing device buffer includes 1 foot of shy distance from the edge of the travel lanes to channelizing devices plus the width of the channelizing devices.
- 3) 12+ inches of edge drop requires channelizing devices, refer to page 17-5 of the Work Zone Safety and Mobility Manual for guidance.
- 4) Construction joints will match lane lines (longitudinal paint lines).
- 5) Maintain a 4-foot wide lateral safety buffer. For HMA rubblize with ADT < 20,000, this lateral safety buffer shall be a minimum of 1 foot.

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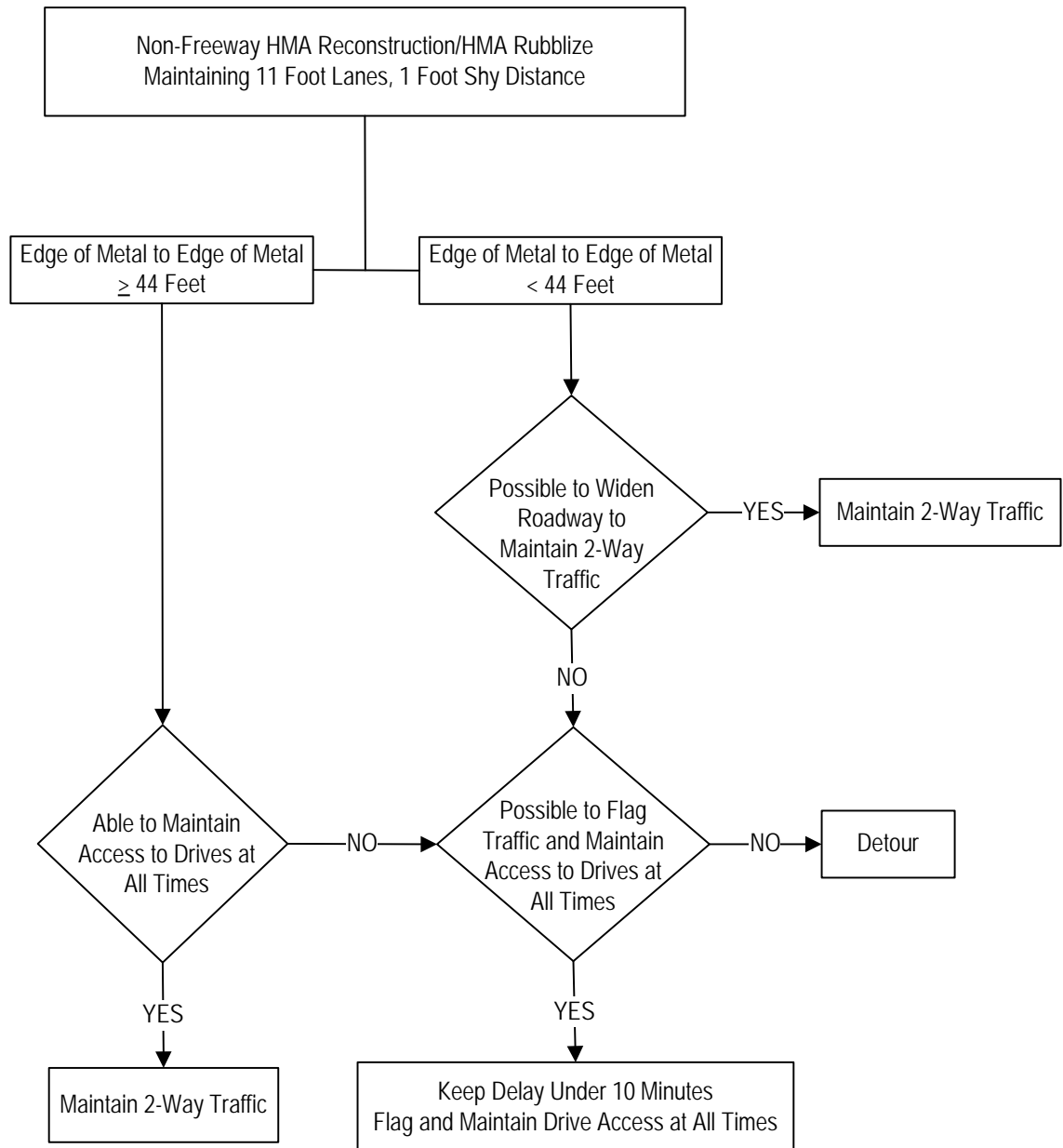
Maintaining Traffic for Non-Freeway Concrete Reconstruction/Concrete Overlay



Maintaining Traffic Criteria:

- 1) Traffic will be maintained on 11-foot wide lanes and 1-foot shy distance.
- 2) Maintain 4-foot wide channelizing device buffer, which includes 1 foot of shy distance from the edge of the travel lanes to channelizing devices plus the width of the channelizing devices.
- 3) 12+ inches of edge drop requires channelizing devices, refer to page 17-5 of the Work Zone Safety and Mobility Manual for guidance.
- 4) Construction joints will match lane lines.
- 5) Maintain lateral safety buffer of 4 feet minimum.

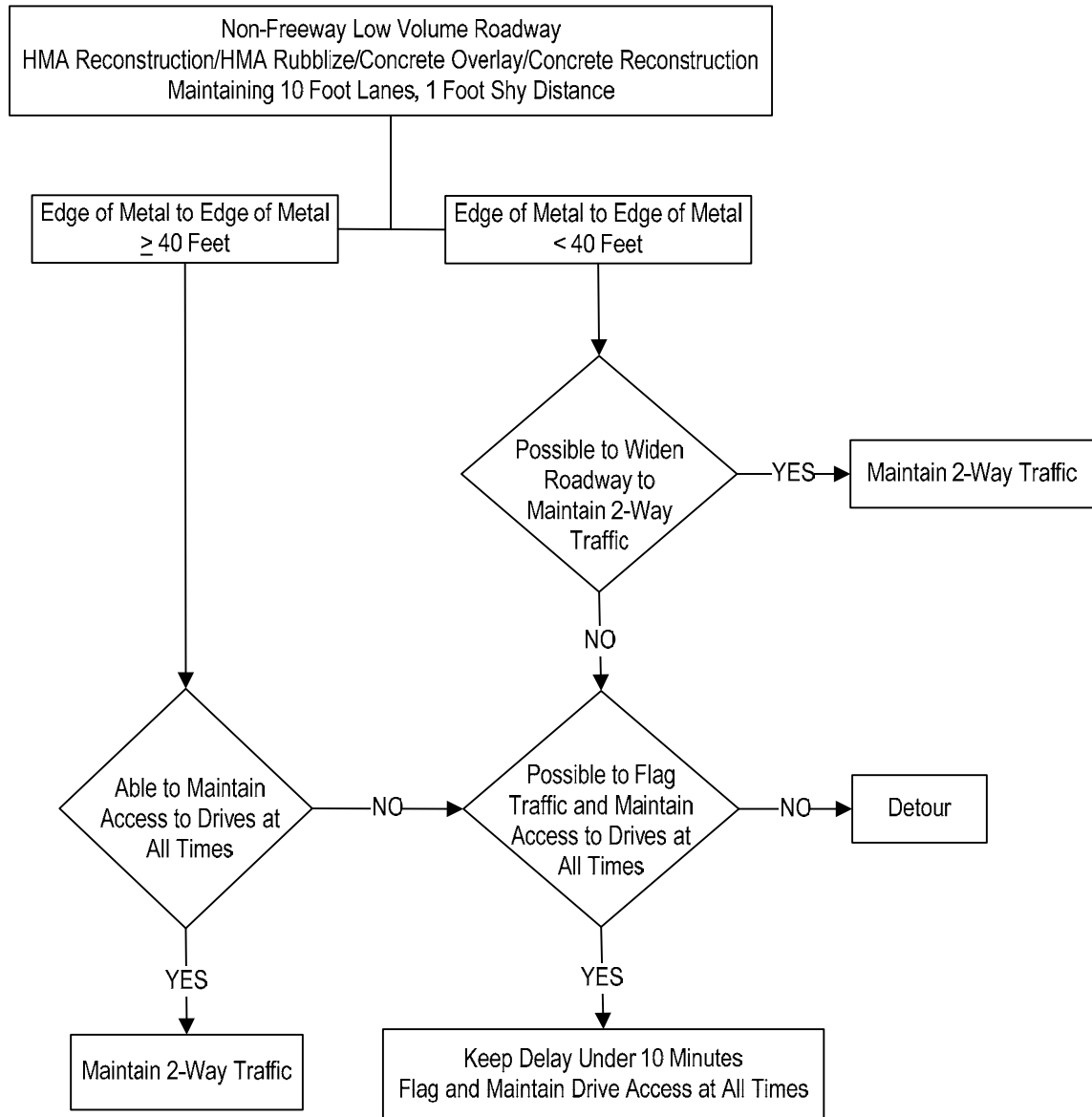
Maintaining Traffic for Non-Freeway HMA Reconstruction/HMA Rubblize



Maintaining Traffic Criteria:

- 1) Traffic will be maintained on 11 foot wide lanes.
- 2) Four-foot wide channelizing device buffer includes 1 foot of shy distance from the edge of the travel lanes to channelizing devices plus the width of the channelizing devices.
- 3) 12+ inches of edge drop requires channelizing devices, refer to page 17-5 of the Work Zone Safety and Mobility Manual for guidance.
- 4) Construction joints will match lane lines (longitudinal paint lines).
- 5) Maintain a 4-foot wide lateral safety buffer.

**Maintaining Traffic for Non-Freeway Low Volume Roadway (< 20,000 ADT)
HMA Reconstruction/HMA Rubblize/Concrete Overlay/Concrete Reconstruction**



Maintaining Traffic Criteria:

- 1) Traffic will be maintained on 10 foot wide lanes.
- 2) Maintain a 4-foot wide channelizing device buffer, which includes 1 foot of shy distance from the edge of the travel lanes to channelizing devices plus the width of the channelizing devices.
- 3) 12+ inches of edge drop requires channelizing devices, refer to page 17-5 of the Work Zone Safety and Mobility Manual for guidance.
- 4) Construction joints will match lane lines (longitudinal paint lines).
- 5) Maintain a 4-foot wide lateral safety buffer. For HMA rubblize, this lateral safety buffer shall be a minimum of 1 foot.