Pavement Selection Manual

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MDOT
Michigan Department of Transportation

CONSTRUCTION FIELD SERVICES DIVISION

Engineering Preamble

This manual provides guidance to administrative, engineering, and technical staff. Engineering practice requires that professionals use a combination of technical skills and judgment in decision making. Engineering judgment is necessary to allow decisions to account for unique site-specific conditions and considerations to provide high quality products, within budget, and to protect the public health, safety, and welfare. This manual provides the general operational guidelines; however, it is understood that adaptation, adjustments, and deviations are sometimes necessary. Innovation is a key foundational element to advance the state of engineering practice and develop more effective and efficient engineering solutions and materials. As such, it is essential that our engineering manuals provide a vehicle to promote, pilot, or implement technologies or practices that provide efficiencies and quality products, while maintaining the safety, health, and welfare of the public. It is expected when making significant or impactful deviations from the technical information from these guidance materials, that reasonable consultations with experts, technical committees, and/or policy setting bodies occur prior to actions within the timeframes allowed. It is also expected that these consultations will eliminate any potential conflicts of interest, perceived or otherwise. MDOT Leadership is committed to a culture of innovation to optimize engineering solutions.

The National Society of Professional Engineers Code of Ethics for Engineering is founded on six fundamental canons. Those canons are provided below.

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform Services only in areas of their competence.
3. Issue public statement only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, reasonably, ethically and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

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CHAPTER 1. INTRODUCTION

The Michigan Department of Transportation (MDOT) has used various formal and informal pavement selection procedures in the past. The primary procedure that MDOT has used since 1985 is the Life Cycle Cost Analysis (LCCA) method. This method compares costs of the pavement selection alternates to determine the most cost-effective option. Pavement design of the alternates is performed using a combination of the AASHTO 1993 and Mechanistic-Empirical (ME) design methods. Pavement design guidelines can be found in the *Michigan DOT User Guide For Mechanistic-Empirical Pavement Design*:

- https://www.michigan.gov/documents/mdot/MDOT_Mechanistic_Empirical_Pavement_Design_User_Guide_483676_7.pdf

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 estimated total pavement costs exceed $1,500,000.00 funded in whole or in part with state funds. The department shall design and award paving projects utilizing material having the lowest life cycle cost.” 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 initial construction costs, future maintenance costs, and user delay costs for both initial construction and future maintenance activities. 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 from current values, and averaging the duration of actual historic 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 SELECTION PROCESS

Pavement selection is determined using the Life Cycle Cost Analysis method or LCCA, when the total project pavement costs exceed 1.5 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. Only pavements on MDOT trunkline are life-cycled. Please contact Pavement Management Section staff with any questions.

The following sections describe the process.

A. Calculating the $1.5 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. Only the portions of a project with fix-types containing a pavement preservation strategy in Chapter 5 will be included. 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 the LCCA unit prices established by MDOT Pavement Management Section, which can be found in ProjectWise in the following subfolder: (include description here). Expected market prices can be used for items without a bid history.

If pavement costs exceed $1.5 million, an LCCA is required and will be performed per this manual.

If pavement costs are below the $1.5 million LCCA threshold, maintain cost estimate documentation in the project file for possible future reference. If the project scope increases or changes 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

If a project contains 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 $1.5 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 (does not have a pavement preservation strategy in Chapter 5), then it cannot 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 $1.5 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 not be appropriate.

To give designers enough time to incorporate the results, it is recommended that the Regions submit LCCA requests no later than 18 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. Official LCCAs will only be performed within 30 months of a project's letting date. Any requests for the official LCCA to be performed more than 30 months in advance of the scheduled letting date requires approval from MDOT's Engineering Operations Committee (EOC).

There are a variety of reasons for a Region to request an LCCA more than 30 months before letting, such as a "shelf job" which is a project 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 30-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 EOC. The Region will determine how best to proceed with the design of the preliminary low-cost pavement alternative until the final alternative is determined with the official LCCA.

* 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 and will require a reevaluation when an official LCCA is conducted.

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 1.5 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, Pavement Management staff will conduct additional tasks related to LCCA, including development of Equivalent Uniform Annual Cost equations following the LCCA process in place at the time. If the project does not proceed as an APB, the normal LCCA process will continue.

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 prior to letting 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 24 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.

It is the Region’s responsibility to request a re-analysis if any the above project changes occur.

G. LCCA Process Steps

The process is as follows:

STEP 1 - Each Region estimates pavement costs for upcoming projects in that Region using guidance provided in section A above. The Region requests a pavement selection using the following guidelines:

MDOT Pavement Management staff 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 $1.5 million.
b) Major rehabilitation projects (unbonded concrete overlays & rubblized with HMA surfacing) with pavement costs greater than $1.5 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 $1.5 million.

Steps 2-6 pertain to projects where pavement selection is the responsibility of Pavement Management Staff (where LCCA is needed). 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 Management 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 MDOT's intranet site. Please allow up to 3 months for completion, reviews, and final EOC approval of the LCCA.

The following provides a brief explanation for some checklist items. Additionally, see Chapter 3 for details on how the following will be used in the LCCA.

<u>Maintenance of Traffic Plans</u>

The project's Temporary Traffic Control Plan (TTCP) will be utilized to assist in estimating initial user delay costs. Appendix C contains standard maintenance of traffic (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 website. Examples of a standard TTCP can be obtained through the Construction Field Services Division.

If the TTCP will be different between the two alternatives, then the Region will submit the TTCP to the Construction Field Services Division, Traffic Incident and Work Zone Management Unit, for approval by the Statewide Peer Review Team (SPRT), using Form 5615, Temporary Traffic Control Plan for Life Cycle Cost Analysis Request checklist, which can be found on MDOT's intranet site. Examples of differences that warrant submission of the TTCP to the SPRT include: one alternative will be maintained by closing one direction of a divided route while the other alternative will be built part-width, different amounts of temporary pavement or temporary shoulder will be needed, etc. After the TTCP has been approved, the Region will send it to the Pavement Selection Engineer of Pavement Management, including the SPRT's approval notification.

If the TTCP will be the same for both alternatives, then a memo describing the traffic control plan can be submitted to the Pavement Selection Engineer of the Pavement Management Section.

The TTCP may be draft for use in the LCCA, but major changes to the MOT may require the TTCP to be re-evaluated and approved by the SPRT (if applicable) in order for the LCCA to be revised (see Section F above). 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 and/or TMP as specified in the WZSMM.

The TTCP submitted for use in LCCA must include at least the following, using Form 5615 and any separate attachments. 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) <u>Construction Staging</u> – Provide a description of which portions of the pavement structure will be built in each stage. Provide cross section typicals of the existing roadway and the work zone, specifically detailing lane and shoulder widths, shy distances, and work space.

2) <u>Traffic Control Strategies</u> – 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. Note if other MOT alternatives were considered, what they were, and why they were not selected. Refer to Appendix C for guidelines on shy distance and buffer widths, providing reasons when guidelines cannot be met.

3) <u>Temporary Lane Widening Requirements</u> – Identify if temporary widening will be performed for maintaining traffic, noting any limiting factors (i.e., bridge piers, Right of Ways, slopes, etc.)

4) <u>Traffic Volumes</u> – At a minimum, provide the average daily traffic (ADT) for the work zone (including mainline and any ramps). Ideally, provide 24-hour traffic distributions. If traffic information is available for detours or alternate routes, this data should be included. Include Construction Congestion Cost (CO3) runs.

5) <u>Restrictions on Operation</u> – Identify if there will be any restrictions on operating hours. (e.g. night work only, northbound-Friday/southbound-Monday, lane closures, weekday work only, etc.)

6) <u>Posted Speed Limits</u> – Specify both the regular speed limits and any restricted speed limits that will be utilized during construction.

7) <u>Detour Route</u> – Specify whether a detour will be utilized during the project and the preferred route to direct traffic (if applicable), including speed limits along the detour or alternate routes.

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 reusable sand subbase for one or both alternatives, or that only a certain overall percentage of the project length has reusable sand, they are to specify this in their LCCA request. The length of the project that has reusable subbase should be based on a percentage of soil borings meeting existing specifications. To determine if there is sufficient depth to reuse sand in-place, a preliminary pavement design may be necessary.

Utility Relocation
Utility relocation costs can differ between alternates for some projects. For reconstruction projects, utilities sometimes fall within the proposed cross-section. Compaction to obtain density can also be a concern over old utilities due to the possible damage caused by vibrations. 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 construction costs:
    a. Public Utilities: only include relocation costs that will be billed to MDOT.
    b. Private Utilities: no relocation costs will be included in the LCCA.
2) The amount of time and maintenance of traffic plan due to utility relocation for any work prior to construction of the project.
3) Any time that would be added to the project schedule because of utility relocation during project construction.

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 (including crossovers, temporary roadways, or widenings). The Region is to develop cost estimates of each impacted design element for both pavement alternatives 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. Please see the *Michigan DOT User Guide For Mechanistic-Empirical Pavement Design* for further details.

A Region may consider alternate construction practices, specifications, materials, or modifications to the pavement structure. See Appendix D for the pilot process for how project level pavement modifications may or may not be included in the LCCA.

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, 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, Construction Field Services Division 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 EOC for a preliminary review, noting any unique project details (e.g. any known pavement modifications that have been incorporated in accordance with Appendix D, underdrains for one pavement type but not the other, etc.). 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.

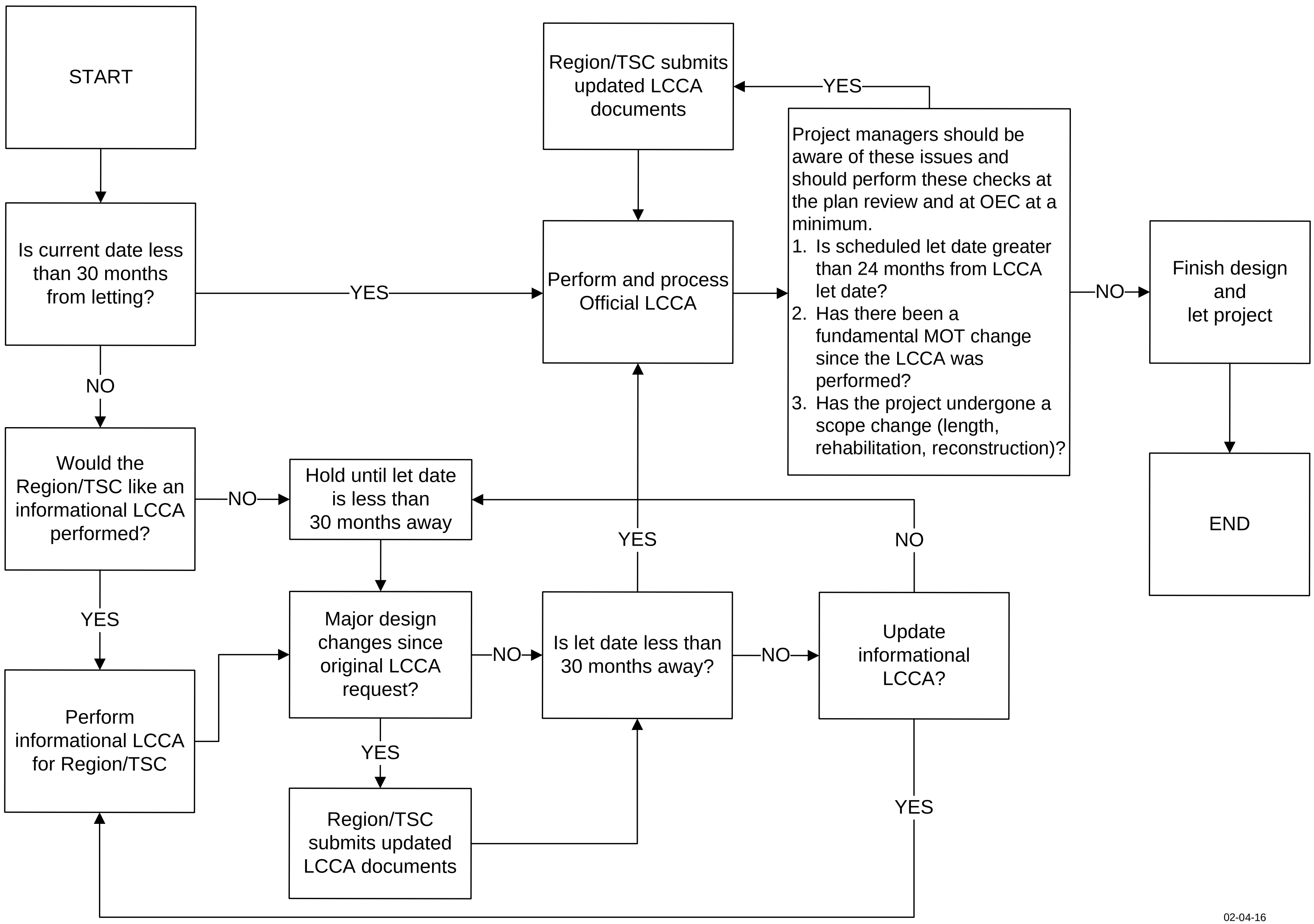
EXHIBIT A

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 30 months before Letting Date	Greater than 30 months before letting	Greater than 30 months before letting
Limitations	LCCA must be redone if: • Letting Date delayed 24 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 3. 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 5) 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 non-inflated 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 undivided roadways (e.g. east & westbound 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, all 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 $1.5 million threshold calculation (See Chapter 2 for calculation of the $1.5 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 6.

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.

Major Rehabilitation with Reconstruction

When at least 25 percent or 4 lane miles, whichever is less of the LCCA includes reconstruction areas within a major rehabilitation project (or vice versa), a combined weighted average EUAC will be calculated and used in determining the low-cost pavement alternative.

1) Calculate the EUACs for the rehabilitation and reconstruction portions of the project separately, using their respective service lives, maintenance schedules and the same units (i.e. per mile, per directional mile or per lane mile).
2) For each pavement type, calculate the combined weighted average EUAC by:
   a. Multiplying the rehabilitation length (using the same units) by the rehabilitation EUAC.
   b. Multiplying the reconstruction length (using the same units) by the reconstruction EUAC.
   c. Adding a and b above together, then dividing by the sum of the rehabilitation and reconstruction length.

Pavement Underdrains

Underdrain use or reuse is generally consistent (using or not using) for both LCCA pavement types. However, when requesting underdrains for one pavement type but not the other, Region staff will need to provide justification. Pavement Management will review the request and may also have another region review the request. Pavement Management will then approve or deny the request. When Pavement Management sends the LCCA to EOC for preliminary approval, there will be a note added describing this unique situation.

Reuse of Sand Subbase

When the LCCA will account for the reuse of existing sand subbase, 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 needed for each design 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 for example, one using new sand and another with reused sand 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 initial construction costs will be assessed for placement & compaction of reusable sand subbase material (assumed to be incidental). The total amount of sand subbase being placed (new and reusable) will be used to calculate the estimated number of construction days to place sand subbase.
   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 prior to the start of the project, 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 public and private 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 for the utility work.
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 Management 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 (production paving and miscellaneous paving areas) 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 end lag time. "Float" may need to 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 specified below.
    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 concrete 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 allow the pavement to reach sufficient strength to be opened to vehicular traffic and support the construction equipment needed to initiate subsequent controlling work items, such as HMA shoulder placement items.

f. For concrete paving on non-freeways constructed part-width, an additional three days of joint sawing/sealing and cure time per applicable stage 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. The first day of work is assumed to be a Monday.

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 5).

Miscellaneous paving areas will follow the maintenance schedules in Chapter 5. 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 for each life-cycled project. 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 MDOT Statewide and Urban Travel Analysis Section, Statewide Model 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 5.

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. More details on these inputs can be found in Chapter 6.

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 4. SOFTWARE

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

Two pavement design methods are used by MDOT. The first is the 1993 version of the AASHTO Guide for Design of Pavement Structures, by way of using the software titled "DARWin Version 3.1." The second (currently in the process of being implemented) is the 2008 AASHTO "Mechanistic-Empirical Pavement Design Guide," using the software "Pavement ME Design." See the manual *Michigan DOT User Guide for Mechanistic-Empirical Pavement Design* for further details.

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 5. 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 incorporates 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

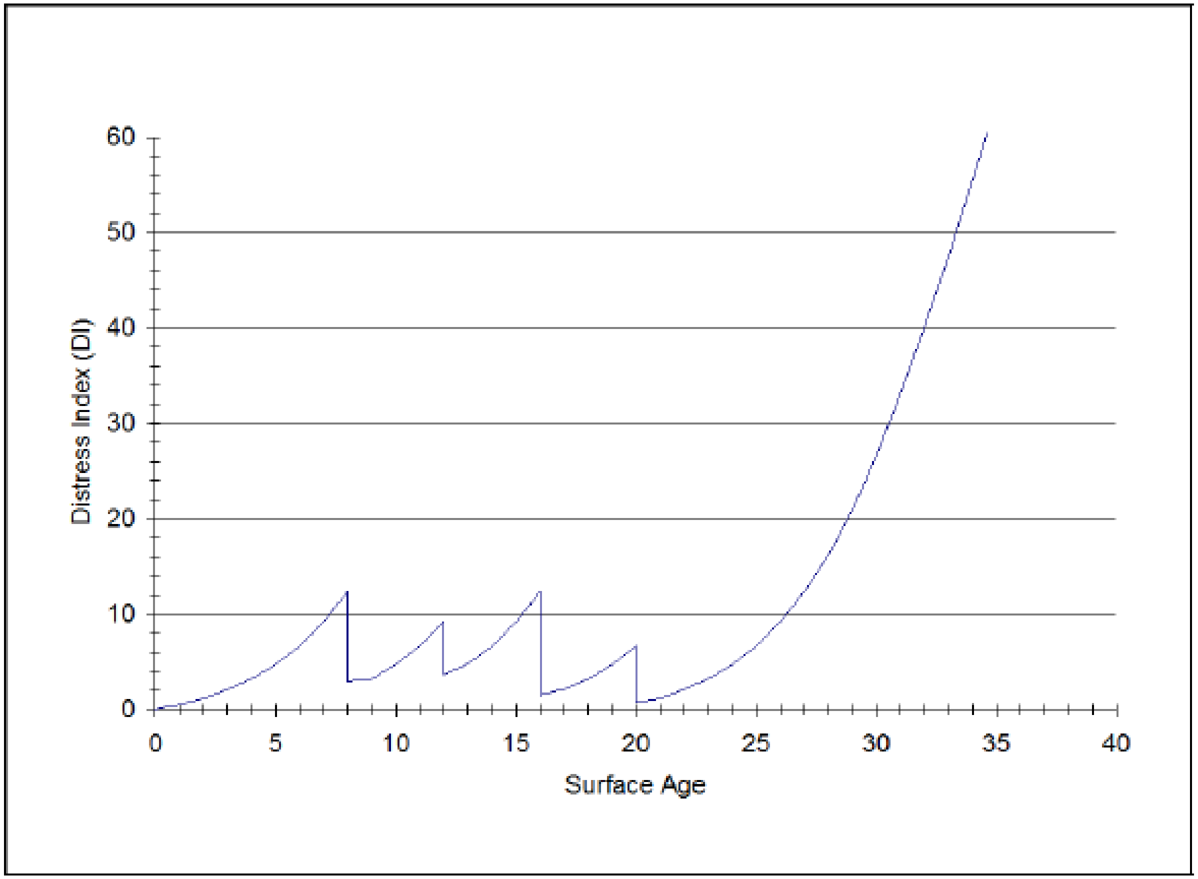
Fix Type: New/Reconstruction HMA Pavement

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	$27,085*	0.48
Prev. Maintenance	12	9	4	7	3	10	$38,975*	0.62
Prev. Maintenance	16	12	1	6	6	12	$49,374*	0.90
Prev. Maintenance	20	7	1	8	5	13	$29,000*	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 (2016: 1.5%)

* based on actual averaged maintenance costs

Fix Type: New/Reconstruction HMA Pavement



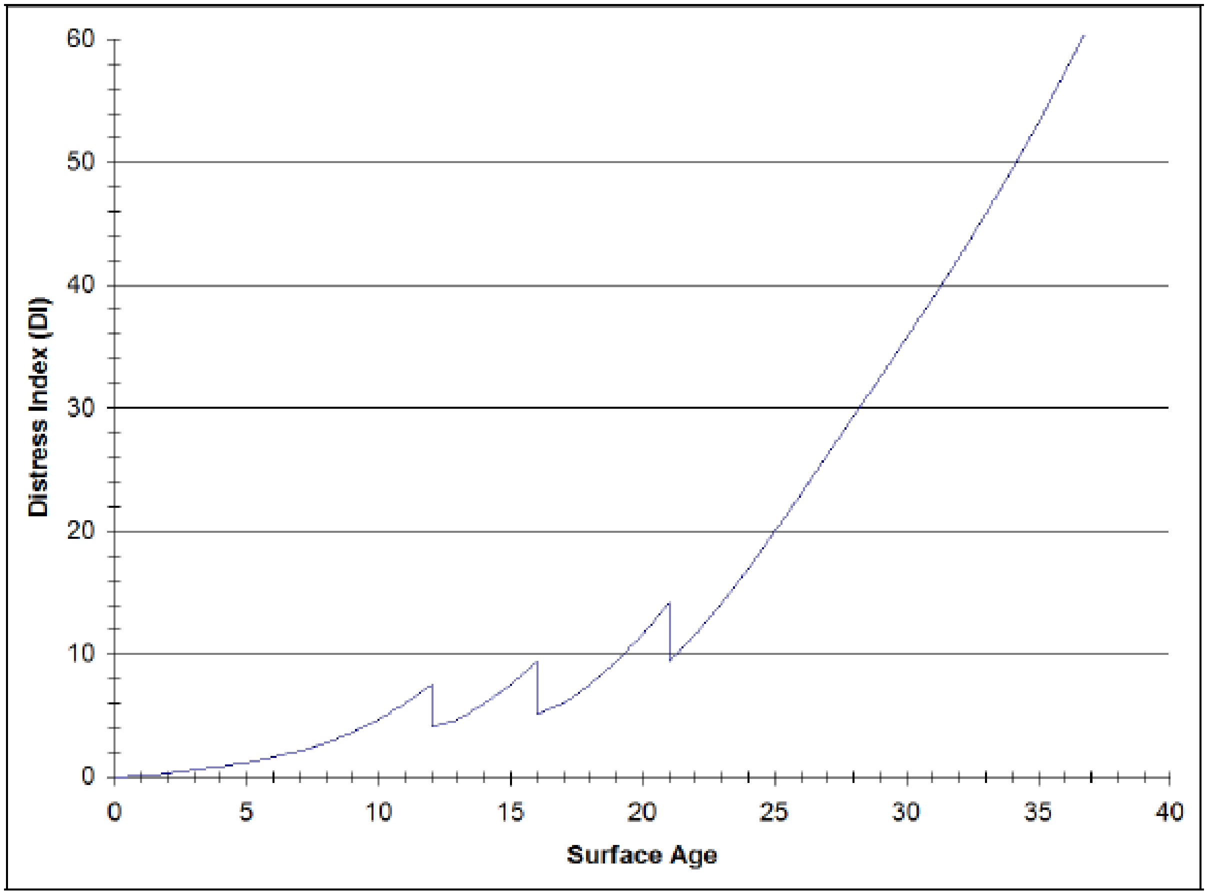
Fix Type: New/Reconstruction Concrete Pavement

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			26	Computed	
Prev. Maintenance	12	8	4	14	3	17	$38,455*	1.34
Prev. Maintenance	16	9	5	13	3	16	$41,056*	1.48
Prev. Maintenance	21	14	9	11	2	13	$66,723*	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 (Maintenance) $/ (1 + i)^n$
i = Real Discount Rate (2016: 1.5%)

* based on actual averaged maintenance costs

Fix Type: New/Reconstruction Concrete Pavement



PAVEMENT PRESERVATION STRATEGY

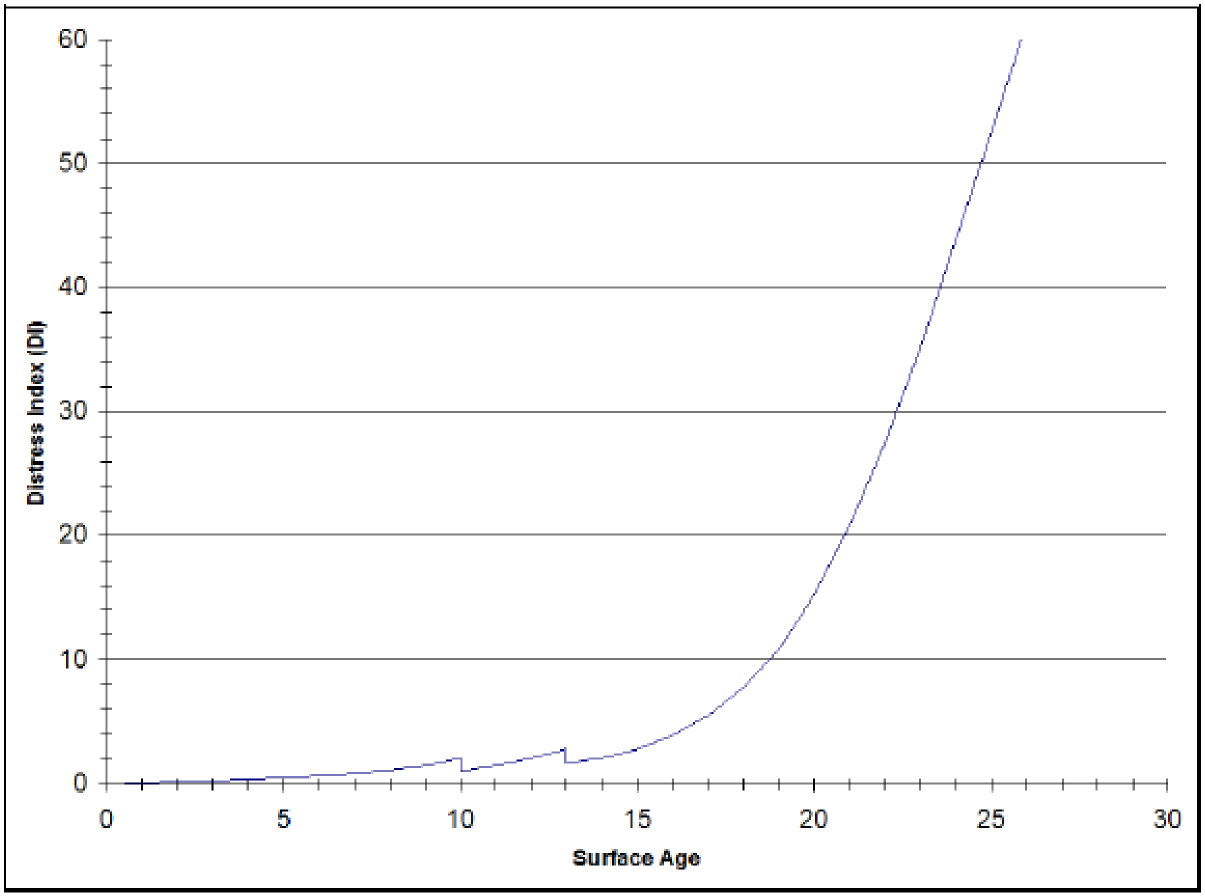
Fix Type: Rehabilitation Unbonded Concrete Overlay on Repaired Concrete

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	$22,789*	1.05
Prev. Maintenance	13	3	2	10	2	12	$37,776*	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 (2016: 1.5%)

* based on actual averaged maintenance costs

Fix Type: Rehabilitation Unbonded Concrete Overlay on Repaired Concrete



PAVEMENT PRESERVATION STRATEGY

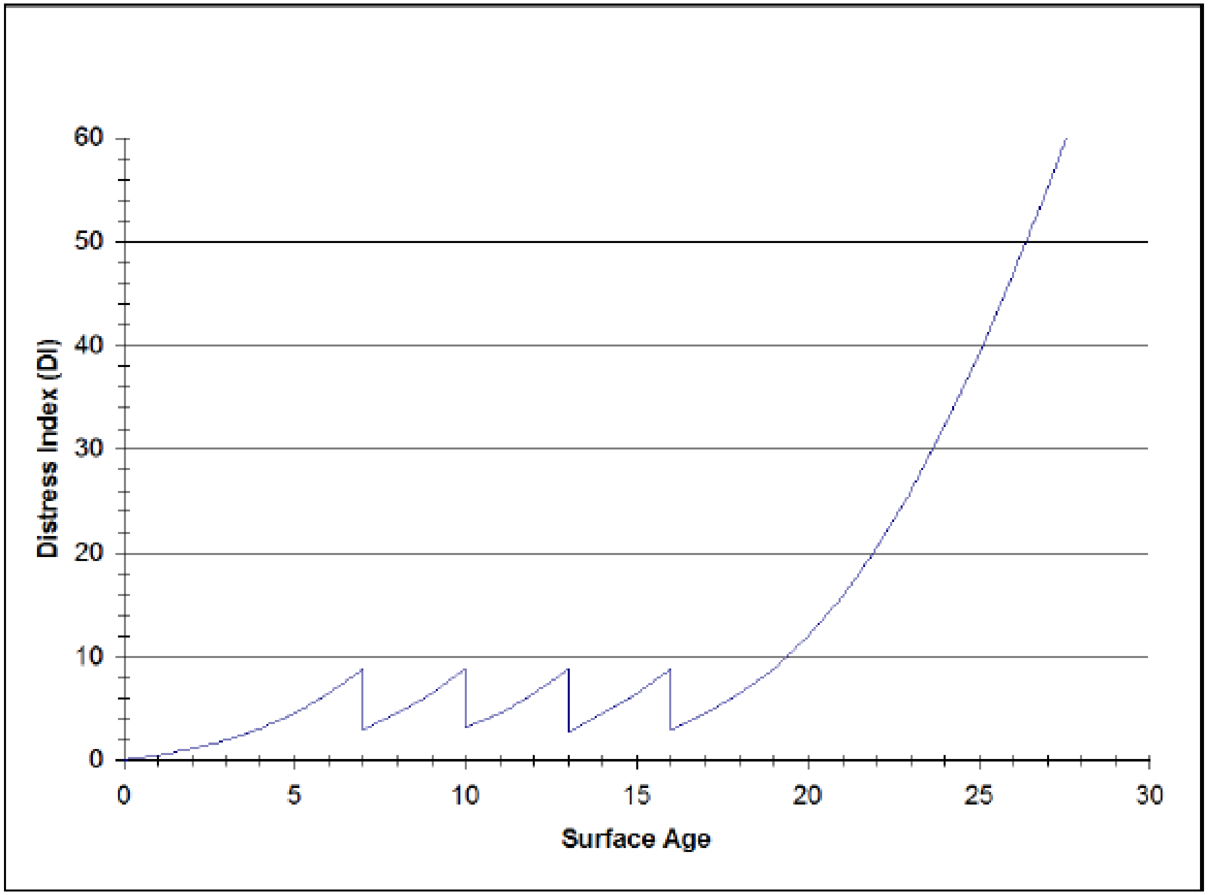
Fix Type: Rehabilitation HMA Overlay on Rubblized Concrete

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	$20,266*	0.38
Prev. Maintenance	10	9	3	7	3	10	$48,354*	0.65
Prev. Maintenance	13	9	3	7	3	10	$29,304*	0.53
Prev. Maintenance	16	9	3	7	3	10	$47,789*	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 (2016: 1.5%)

* based on actual averaged maintenance costs

Fix Type: Rehabilitation HMA Overlay on Rubblized Concrete



CHAPTER 6. LCCA PROCESS, PRESERVATION STRATEGY & DATA UPDATES

A. Input for Future LCCA Process Updates

Identification, discussion, 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.

To start the LCCA process review cycle, input will be solicited from construction industry and MDOT representatives. Each agency will compile a description of the issue, along with their rationale and recommendations, on why a certain component of the life-cycle process should be changed, included, or deleted. This information will be placed on an issue summary form, completing one form for each individual issue. Once the issue summary forms are shared with all parties, joint meetings will occur to discuss the issues, attempting to find resolution. All parties will need to agree on a proposed change, otherwise it becomes a potential impasse issue. After all the issue summaries are discussed, each agency will select up to five potential impasse issues to bring before an Impasse Panel for a discussion and final decision. The Impasse Panel will be comprised of three MDOT members, appointed by the Chief Operations Officer. Each agency will have the opportunity to explain their issues, as well as their position on the other agencies' issues. The decisions of the Impasse Panel are final and will not be reviewed until the next scheduled process review. However, in the event that a process related issue is identified that should not wait until the next regularly scheduled process update for input, the Chief Operations Officer may initiate meetings to address that issue.

Because MDOT is working within certain constraints, there are some items that may be rejected for consideration. Industry may submit issues, even if they may be in one of these areas, and a determination will be made regarding whether each issue will be considered in the process review. The Impasse Panel may be called upon to make this determination.

MDOT will develop the implementation plan to allow proper allocation of limited resources. 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.

The next LCCA Process Review is expected to begin in 2022 and follow the approximate schedule shown below. A finalized schedule will be developed prior to the start of the Process Review. Subsequent cycles will occur every four years.

Step	Activity	Assigned To	Approximate Target Completion Date
1	Develop a list of issues for discussion during the process review. Document each issue in writing, in a pre-determined Issue Summary format.	MDOT technical experts, Paving industry groups	February 2022
2	All documented issues are shared between the parties.	MDOT technical experts	April 2022
3	MDOT conducts meetings with both industries (joint meetings) in an attempt to resolve the issues. MDOT documents each meeting and sends a summary to both industries with decisions for each issue (agreement or potential impasse issue)	MDOT technical experts, Paving industry groups	August 2022
4	Each party identifies the issues that they wish to go before the Impasse Panel. This will be limited to 5 issues from each party.	MDOT technical experts, Paving industry groups	September 2022
5	The MDOT Impasse Panel Coordinator works with MDOT technical experts, APAM, and MCA to develop the Impasse Issue Summary documents in a pre-determined format. Each party will submit their recommendation, response and reasoning on each Impasse Issue.	MDOT Impasse Panel Coordinator	October 2022
6	The completed Impasse Issue Summary documents are given to the Impasse Panel and shared with MDOT technical experts, APAM, and MCA.	MDOT Impasse Panel Coordinator	November 2022
7	The Impasse Panel holds meetings for the identified issues and makes decisions for each. Representatives for MDOT, APAM, and MCA attend the meetings to present their recommendations.	Impasse Panel, MDOT technical experts, Paving industry groups	March 2023
8	The decisions of the Impasse Panel are documented and distributed to all parties.	MDOT Impasse Panel Coordinator	April 2023
9	Set implementation schedule.	MDOT technical experts	May 2023
10	Implement.	MDOT technical experts	Late 2023

Note: The amount of time for individual steps is expected to vary, and deviations from this schedule may be necessary for those and subsequent steps. More specific dates will be developed in early 2022.

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.

Updates will be performed in accordance with the process in place when the updates begin. In addition, data (e.g. Distress Index, IRI, maintenance projects, etc.) 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. However, note that 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 March and September every year. The March publication will be based on price data ending with the prior December letting. The September 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 at the time 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 (by quantity) of low bid data, when possible, following steps 1-4 listed below. Unit prices will be determined for a regional area except when steps 1-4 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.

The steps listed below are the order in which price data will be queried. Steps 1 & 3 are on a regional area basis. Steps 2 & 4 are on a statewide basis. If a given unit price cannot 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 3 & 4.

In rare instances, project unit prices may be encountered that are significantly higher or 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. When an abnormal unit price is identified by MDOT or either paving industry, they will work together to come to consensus on whether it should be included. If they cannot reach consensus on the inclusion or exclusion of specific unit prices, the decision will be made by MDOT's Engineering Operations Committee.

Steps are as follows:

1) 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, within a regional area.
    a. Subsequently, after a project meets the first step criteria, for a given hot mix asphalt mixture (ie.3E3, 3E10, etc.), there must be a minimum of 6000 tons of the mixture on the project in order for it to be included in the data set.
2) Statewide weighted average of projects that meet the individual project thresholds per Step 1.
3) Prorate the unit price for the next closest concrete thickness (using both sides of the thickness when available) within 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.
4) 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 Step 1 above, the query will be for individual mix types (ie. mix traffic level) 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 Step 1 are compiled into a "LCCA 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 "LCCA 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 "LCCA qualified project list."

1) A regional weighted average unit price for projects in the last 24 months is determined first.
2) If a regional price cannot be determined, a weighted statewide average price is calculated.

3) 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 or other information 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 January. For information on the current rate, see http://www.whitehouse.gov/omb/circulars.

F. Maintenance Costs

Published maintenance costs will be inflated using the annual Producer Price Index (PPI), using the procedure explained via the example below:

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

If the index decreased, costs would be deflated accordingly.

The PPI for “material and supply inputs to highway and street construction” (BHWY) was utilized until mid-2010 when it was discontinued. The Bureau of Labor Statistics (BLS) replaced it with the “other nonresidential construction” index (BONS). In late 2014, BLS created a new index: “inputs to highways and streets, excluding capital investment, labor, and imports” (listed at BLS as: WPUIP231231). All three indices must be utilized in combination for future updates. The new index will be correlated with the old indices 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.

The latest cost values, as well as other CO3 information, can be found on MDOT's CO3 webpage:

- http://www.michigan.gov/mdot/0,4616,7-151-9625_54944-227053--,00.html

CHAPTER 7. DEFINITIONS

APAM – Asphalt Pavement Association of Michigan.

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, or a concrete surface placed on an HMA 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.

Equivalent Uniform Annual Cost (EUAC) – a value that represents the sum of all present value costs as if they were to occur uniformly throughout the analysis period.

Fix Life – The anticipated pavement life provided by the fix, <u>excluding</u> 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.

MCA – Michigan Concrete Association.

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 aggregate materials 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 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.

AASHTO Mechanistic-Empirical Pavement Design Guide, American Association of State Highway and Transportation Officials, 2008.

AASHTOWare Pavement ME Design Version 2.2, American Association of State Highway and Transportation Officials, 2015.

Michigan DOT User Guide for Mechanistic-Empirical Pavement Design, Interim Edition, Michigan Department of Transportation, 2015.

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

Title	Phone Number
Pavement Management Engineer	517-636-4928
Lead Pavement Design Engineer	517-636-6006
Pavement Design Engineer	Vacant
Pavement Selection Engineer	517-636-4966
Pavement Analyst	517-636-4952

APPENDIX A: LCCA PRODUCTION RATES

The following rates were reviewed, modified, and published as a result of the 2009/2010 LCCA Technical Agenda.

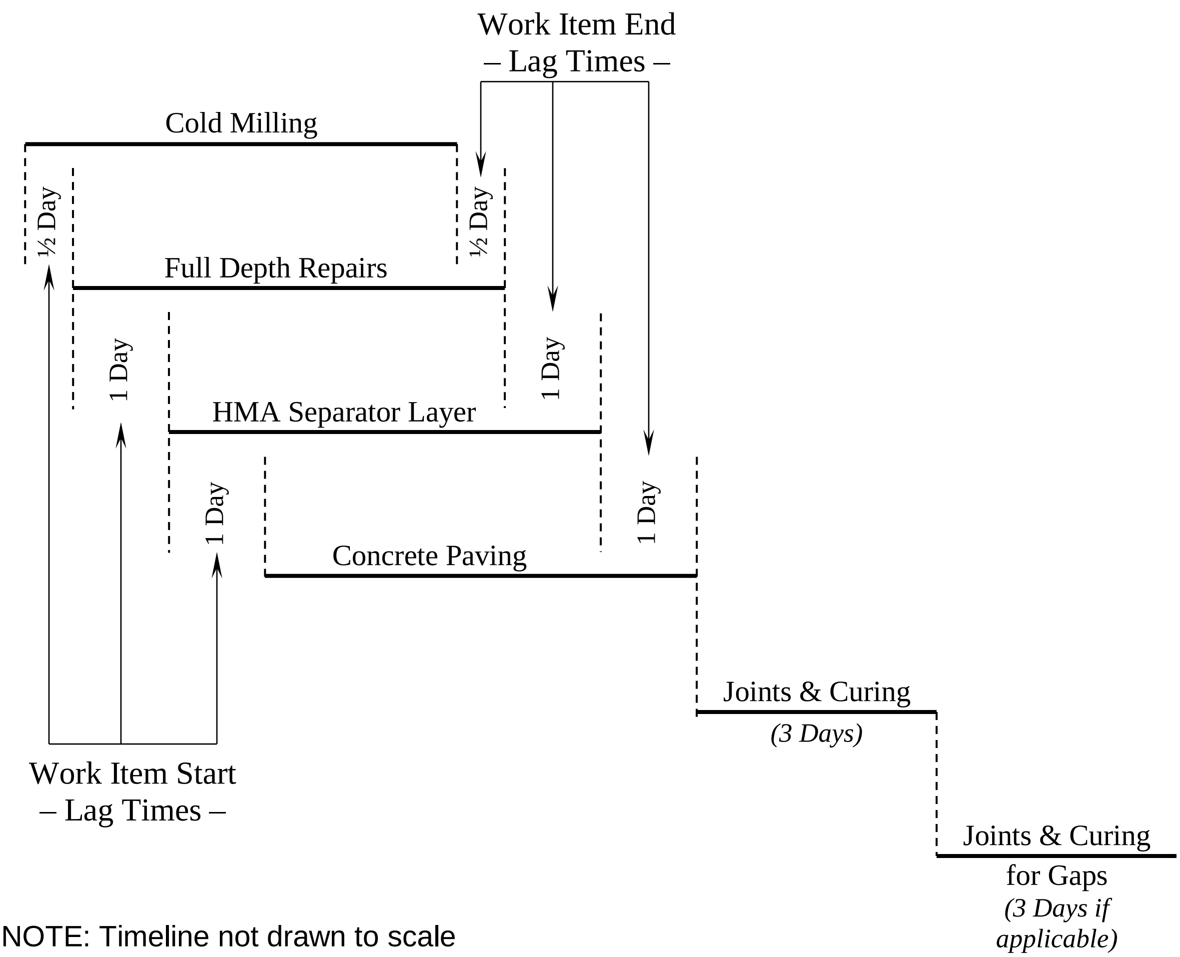
Life Cycle Cost Analysis (LCCA) Production Rates				
Work Items	**Units**	**Freeway LCCA Rates**	**Non-Freeway LCCA Rates with a Detour**	**Non-Freeway LCCA Rates Constructed Part-width**
Embankment, CIP Embankment, LM Excavation, Earth Granular Material, Cl II Granular Material, Cl III Subbase, CIP	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	Syd/day	800 (6′ repair) 500 (4′ repair)	700 (6′ repair) 450 (4′ repair)	600 (6′ repair) 350 (4′ repair)

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 three days of joint sawing/sealing and cure time per applicable stage to address paving gaps and repaving for access management will be included in the simplified linear schedule.

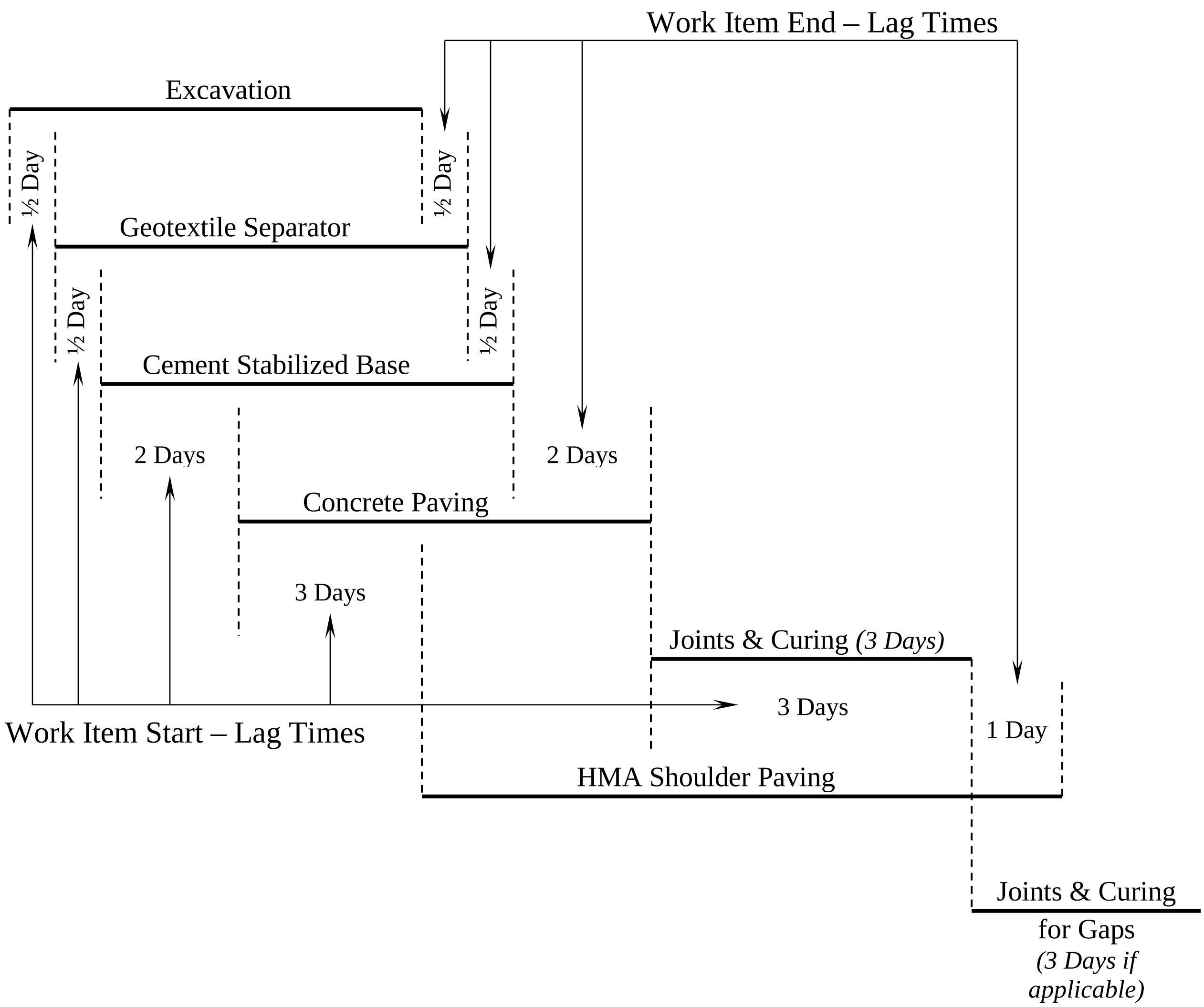
<u>Example 1: Unbonded concrete overlay example</u>: starting with cold-milling of the existing composite pavement, followed by full depth repairs, etc.



NOTE: Timeline not drawn to scale

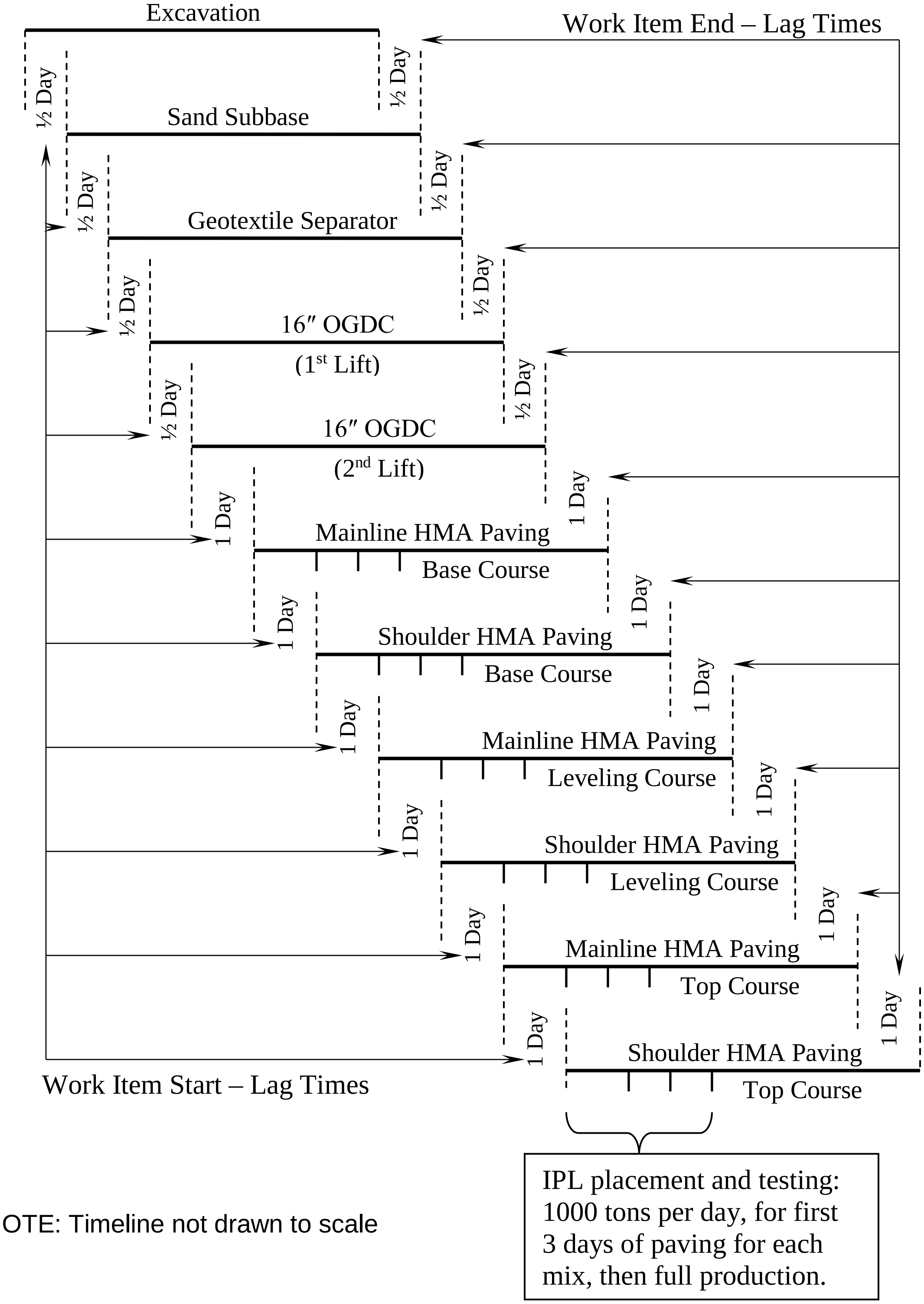
<u>Float Example</u>: if Full Depth Repairs take 3 days, but Cold Milling takes 5 days, then there are 2 days of "float" for Full Depth Repairs so that it can meet minimum work item start and end times. So the Work Item Start Lag Time for Full Depth Repairs could be up to 2 ½ days instead of ½ day.

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.

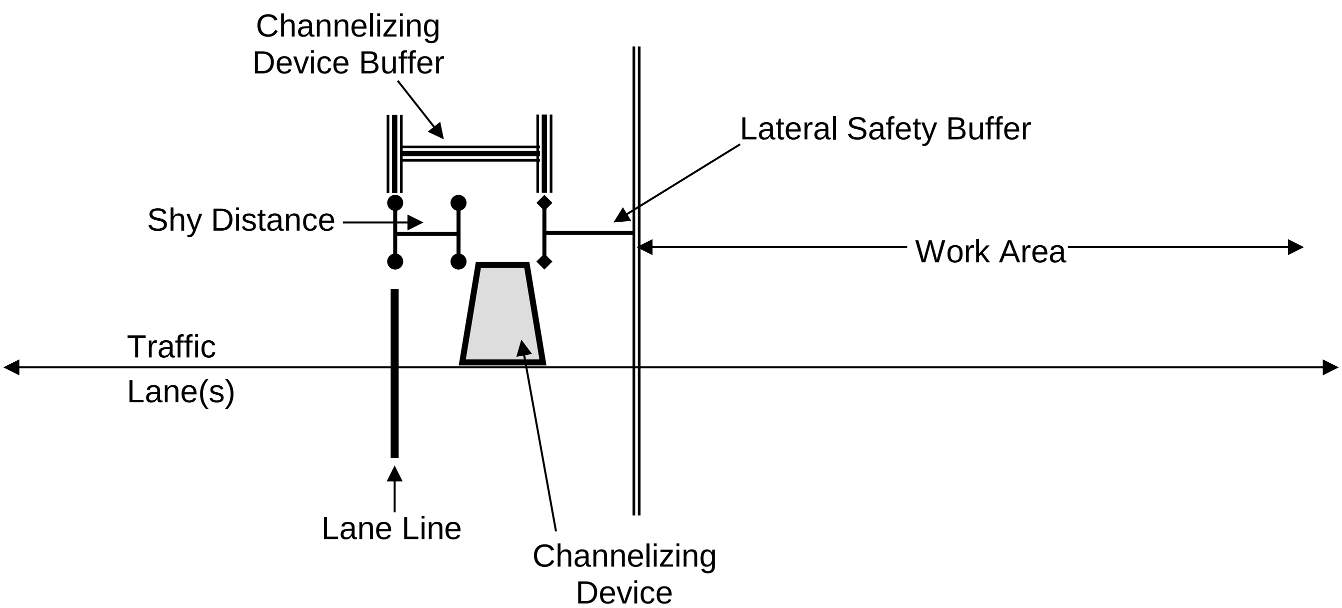


NOTE: Timeline not drawn to scale

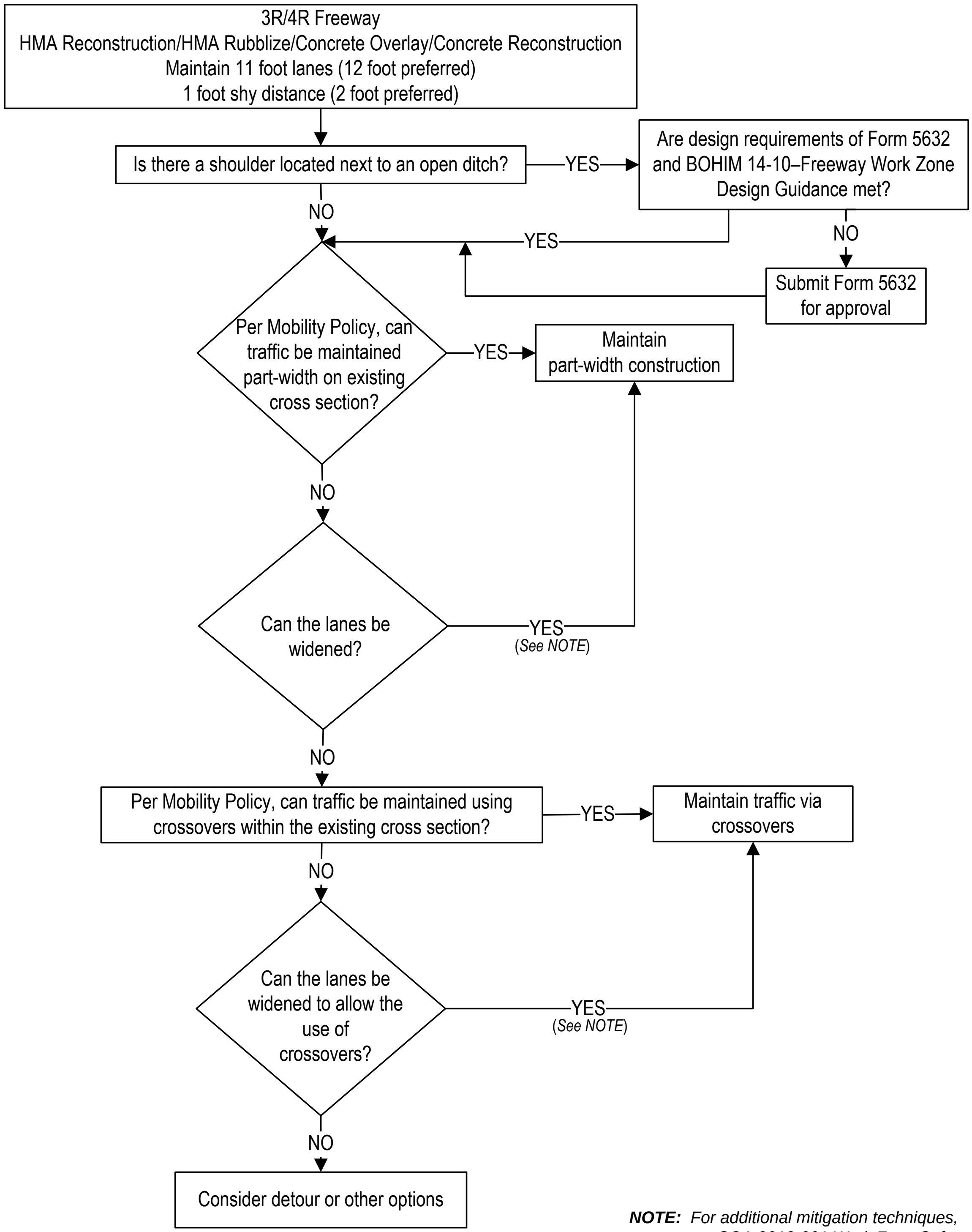
APPENDIX C: LCCA MAINTENANCE OF TRAFFIC FLOWCHARTS

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



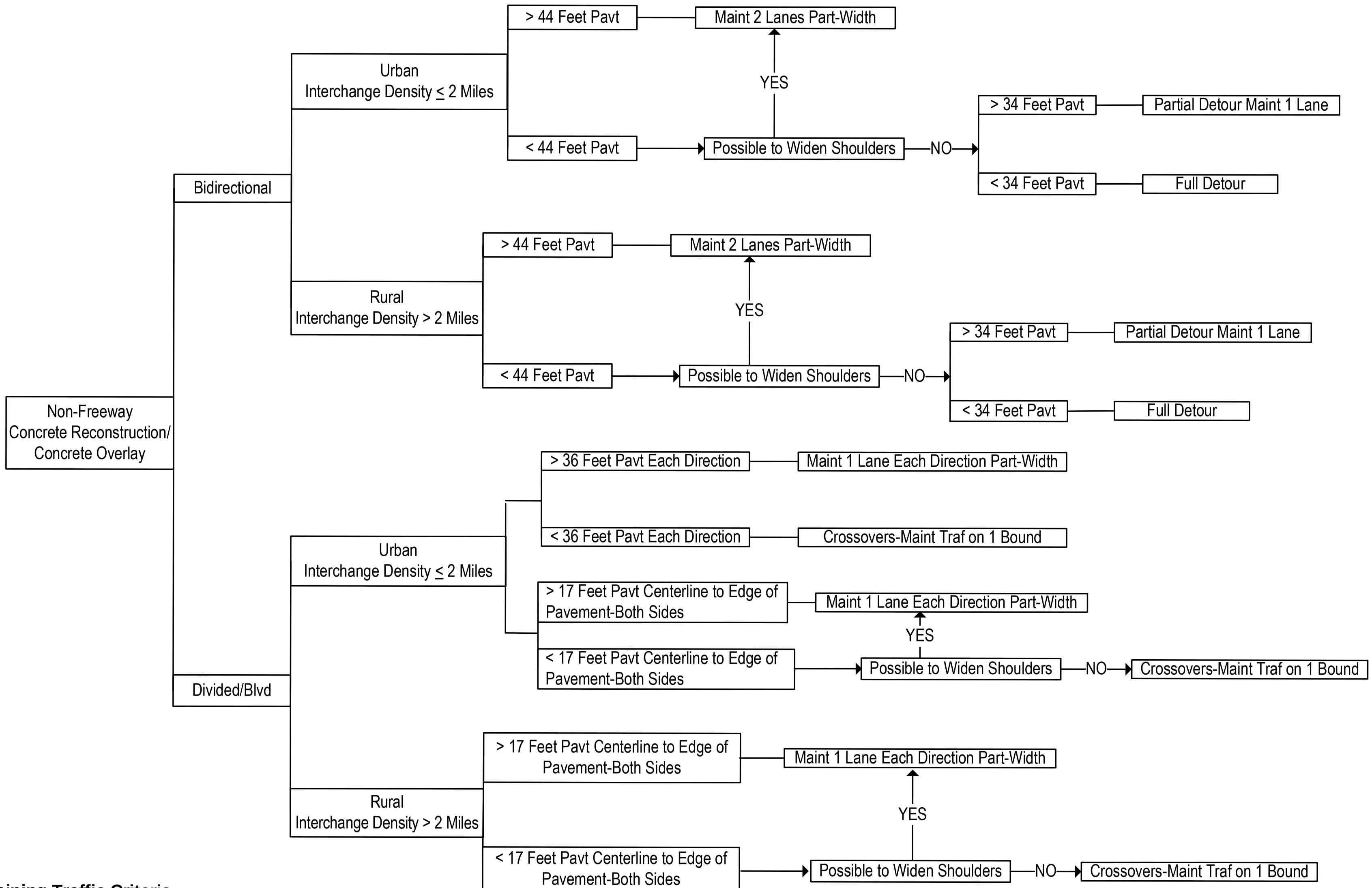
NOTE: *For additional mitigation techniques, see SOA 2013-001 Work Zone Safety Tools for Narrow Shoulders*

Maintaining Traffic Criteria:

1) Traffic will be maintained on a minimum of 11 foot wide lanes.
2) Maintain four-foot wide channelizing device buffer, which includes a minimum of 1 foot of shy distance from the edge of the travel lanes to channelizing devices plus the width of the channelizing devices.
3) Refer to the Work Zone Safety and Mobility Manual for guidance on edge drop protection requirements based on drop off.
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.

05-09-16

Maintaining Traffic for Non-Freeway Concrete Reconstruction/Concrete Overlay

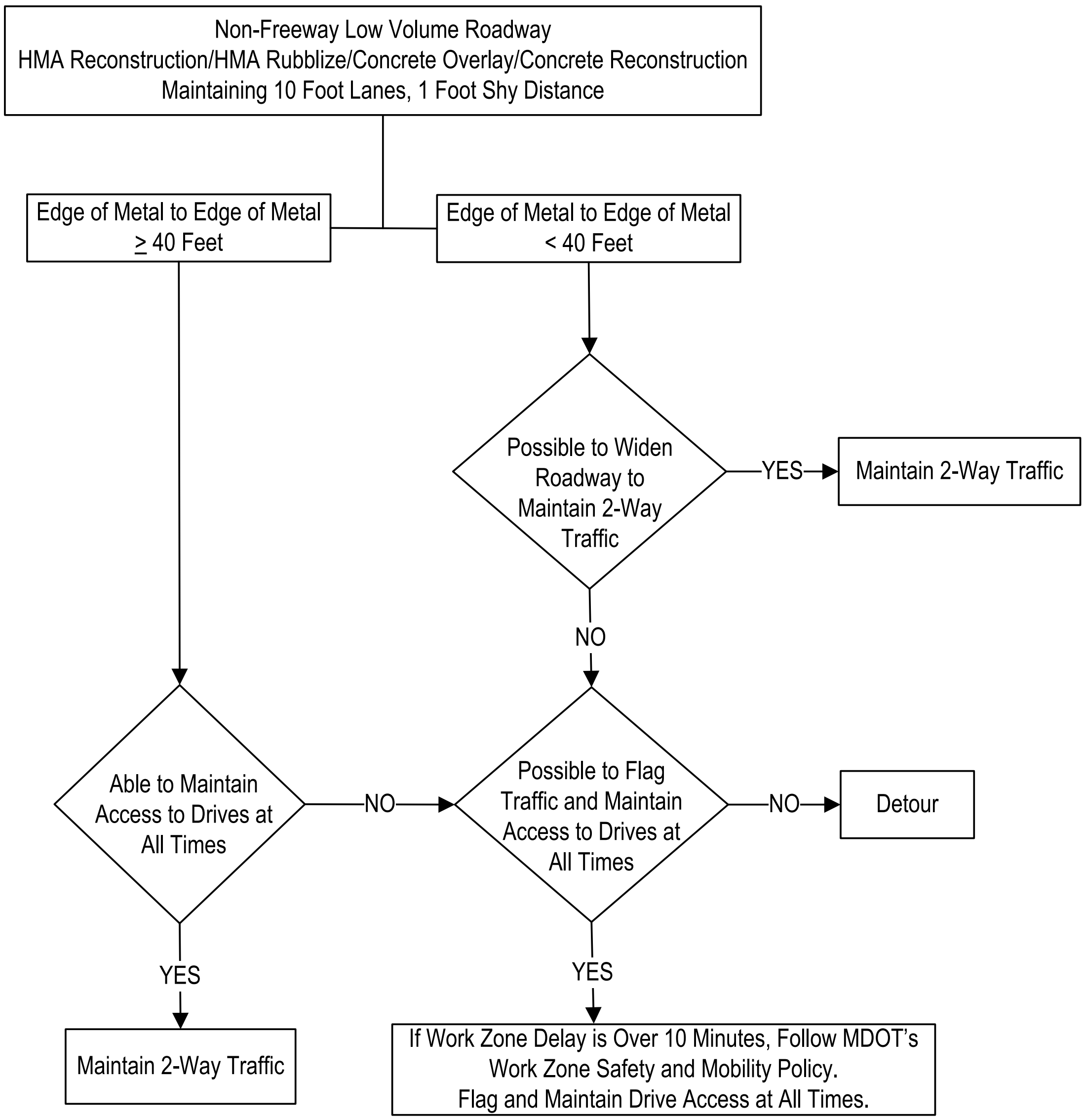


Maintaining Traffic Criteria:

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 a minimum of 1 foot of shy distance from the edge of the travel lanes to channelizing devices plus the width of the channelizing devices.
3) Refer to the Work Zone Safety and Mobility Manual for guidance on edge drop protection requirements based on drop off.
4) Construction joints will match lane lines.
5) Maintain lateral safety buffer of 4 feet minimum.

05-09-16

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

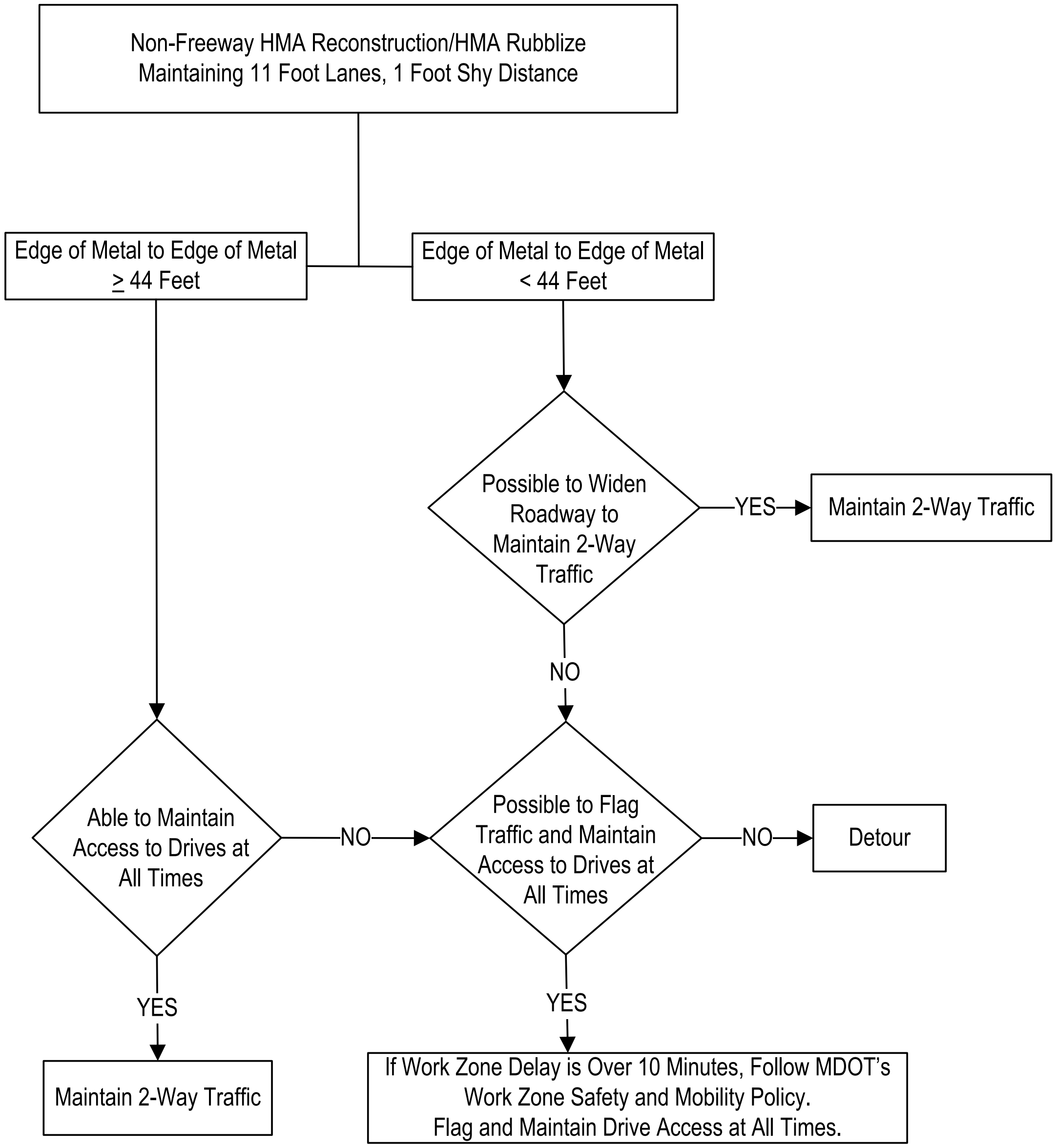


Maintaining Traffic Criteria:

1) Traffic will be maintained on a minimum of 10 foot wide lanes.
2) Maintain a 4-foot wide channelizing device buffer, which includes a minimum of 1 foot of shy distance from the edge of the travel lanes to channelizing devices plus the width of the channelizing devices.
3) Refer to the Work Zone Safety and Mobility Manual for guidance on edge drop protection requirements based on drop off.
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.

05-09-16

Maintaining Traffic for Non-Freeway HMA Reconstruction/HMA Rubblize



Maintaining Traffic Criteria:

1) Traffic will be maintained on 11 foot wide lanes.
2) Maintain four-foot wide channelizing device buffer, which includes a minimum of 1 foot of shy distance from the edge of the travel lanes to channelizing devices plus the width of the channelizing devices.
3) Refer to the Work Zone Safety and Mobility Manual for guidance on edge drop protection requirements based on drop off.
4) Construction joints will match lane lines (longitudinal paint lines).
5) Maintain a 4-foot wide lateral safety buffer.

05-09-16

APPENDIX D: PAVEMENT MODIFICATIONS IN LCCA VERSUS DEMONSTRATION PROJECTS

To further clarify and define how project level enhancements are incorporated into a Life Cycle Cost Analysis (LCCA) (Public Act 79 of 1997) or the Pavement Demonstration Program (Public Act 259 of 2001), the Michigan Department of Transportation (MDOT), in partnership with the paving industry groups of Michigan, have developed this summary. When project level pavement related modifications that differ from a typical MDOT design are considered, they may or may not be accounted for in LCCA, or the project may be added to the Demonstration Program. To determine this distinction, recommended definitions and divisions are further outlined as follows:

A. Pavement Modifications: These projects incorporate a different construction practice, changes in specifications, or unique modifications to the pavement structure, with the aim of improved cost-effectiveness and/or performance of the pavement, and which may eventually be rolled into standard practice.
   1. Examples:
      i. Current pavement & construction examples include those projects using:
         a. Stabilized Base Course
         b. Gap-Graded SuperPave (GGSP)
         c. Alternate Dowel Bar Materials
         d. Alternate Cements
         e. PCC Joints: Seal or No Seal
         f. Drainage Changes
         g. Alternate Aggregate Specifications
         h. Fiber Addition to the Paving Mix
         i. Transverse Joint Spacing Changes
         j. Surface Texture Specifications
         k. Alternate spacing/location of dowel bars
         l. Two-Lift Concrete Pavement Construction
      ii. The following examples of past modifications are now part of standard practice or are permissive use items and will not be considered as a modification or Demonstration Project.
         a. Regression of Air Voids
         b. Material Transfer Device (MTD)
         c. Warm-mix Asphalt
         d. Rubber Modified Asphalt
         e. Recycled Shingles
         f. Echelon Paving
         g. Modified PG Binders
         h. Widened outside lane (i.e. 14′ lane)

2. Modifications that increase the Initial Construction Cost of the standard LCCA greater than 15% will be included in the LCCA. A completed LCCA would be reevaluated if a modification of this type were added later in the project. Prices not yet available from previous projects will be estimated by MDOT pavement specialists and industry groups.
3. For modifications that increase the Initial Construction Cost of the standard LCCA less than or equal to 15%, separate/additional costs would not be included in the LCCA, but the standard LCCA unit prices would be used.
4. The eligibility of these as Alternate Pavement Bidding (APB) projects would need to be evaluated by CFS and Region staff, depending on the nature and/or extent of the modification, on a project-by-project basis. The Engineering Operations Committee (EOC) will need to decide and approve which is more important: a project level modification or APB.
5. MDOT pavement specialists and managers will continuously evaluate pavement modifications for their inclusion into standard practice and reevaluate all modifications at least every 4 years during the LCCA process review. This group will make recommendations to move a pavement modification into standard practice. Approval may or may not be required by the EOC. After approval, costs for pay items involving the modification will be added to the standard LCCA unit prices to be included in future LCCAs.
6. Before a design modification is rolled into standard practice, or allowed permissively, the cost of these modifications will be evaluated on a project-by-project basis to determine whether or not to include them in the standard LCCA unit prices. All standard, (non-modified) pay items will be evaluated for inclusion in the standard LCCA unit prices. Any performance benefits will be rolled into the regular performance curves over time.

B. <u>Demonstration Projects</u>: These projects are those with larger modifications that are made to a pavement and/or its structure with the aim of improved cost-effectiveness, performance of the pavement and/or new construction methods. Additionally, these projects may come with a greater potential risk. These may eventually be rolled into standard practice, with the goal of producing a unique LCCA performance curve based on the actual performance of the demonstrated aspect. However, a population for each demonstrated aspect needs to first be built and then its performance evaluated.

1. Current and past examples include those projects using:
   i. Perpetual Pavement
   ii. Hot In Place Recycling
   iii. Thin Concrete Reconstruct or Overlay
   iv. White Topping
   v. Pre-cast Concrete Pavement (not pre-cast patches)
   vi. Cold In Place Recycling
   vii. Continuously Reinforced Concrete Pavement (CRCP)
2. As long as the project has over $1.5M in paving costs, per PA 79 of 1997 (as amended), these types of projects would not require an LCCA, but would fall under the Demonstration Program legislation, and all its requirements.
3. Unit prices for demo projects will be evaluated on a project-by-project basis to determine their inclusion in the standard LCCA unit prices.

4. As long as these projects are under the Demonstration Program umbrella, they would not be eligible as APB projects unless approved by EOC or the COO.

C. Both: Some projects may fall into either category. These projects would require further evaluation and determination by the Department, early in the design process.
   1. Current examples include those projects using:
      i. Asphalt Stabilized Crack Relief Layer (ASCRL)
      ii. Thickness Changes (pavement and/or base/subbase)
      iii. Fabrics / Geotextiles
      iv. Subgrade stabilization
   2. These types of modifications may or may not be included in the LCCA, depending on the scope of the modification, and will be evaluated on a project-by-project basis.
      i. If a modification is proposed to solve a unique, project specific need, then it would be accounted for in the LCCA, and in the pavement design methodology, if possible. These unique, project-level modifications will be evaluated on a project-by-project basis to determine whether or not to include them in the standard LCCA unit prices. (E.g. a project location has poor subgrade soils, so the Region proposes subgrade stabilization or some form of geo-grid geotextile, in lieu of subgrade undercutting. The pavement design method would take this into account and additional costs would be included in the LCCA.)
      ii. Other non-project specific scenarios would need to be evaluated to determine if the modification would cause the project to fall under the Demonstration Program legislation, and all its requirements.