CHAPTER 2 LCCA APPROACHES

2.1 LCCA Basis

When making decisions about pavement design, LCCA:

- Compares pavement alternatives; and
- Identifies the best strategy based on current information as well as meeting the project performance objectives.

The study of costs, over a long analysis period, gives useful insight into which pavement alternative is the most cost effective. LCCA accounts for relevant costs, which include initial construction, maintenance and rehabilitation, project support, work zone effects, and user costs. The result of LCCA is a comparison of pavement alternatives.

The total life-cycle cost associated with a project is divided into two types of costs:

- *Agency Costs* are costs that Caltrans pays for initial construction and future maintenance and rehabilitation with support cost.
- *User Costs* are the costs associated with the public motorists for the additional travel time and vehicle operation costs caused by construction related traffic delays converted to a dollar amount.

2.2 LCCA Elements

The elements required to perform a LCCA are:

1) Pavement alternatives
2) Analysis period
3) Traffic data
4) Discount rate
5) Future maintenance and rehabilitation sequences
6) Costs (both Agency and User)
7) *RealCost Version 2.5CA* software

2.2.1 Source

The LCCA procedures described herein were derived from the FHWA's *RealCost User Manual* (2004) and *LCCA Technical Bulletin* (1998), "Life-Cycle Cost Analysis in Pavement Design," and the *Life-Cycle Cost Analysis Primer* (2002). The additional tables, figures, and other resources included in this manual are specifically developed for projects in the State Highway System to guide the data inputs needed for running *RealCost Version 2.5CA*.

2.3 Selecting Pavement Alternatives

A LCCA begins with the selection of pavement alternatives that will accomplish the same performance objectives for a project. For example, comparisons can be made between

flexible vs. rigid pavements; rubberized hot mix asphalt (RHMA) vs. conventional hot mix asphalt (HMA) pavements; HMA mill-and-overlay vs. HMA overlay; and 20-year vs. 40-year pavement design lives. Each selected pavement alternative must be a viable pavement structure that is both constructible and cost effective.

This manual includes decision tree flowcharts to guide selection of pavement alternatives based on pavement project type. Pavement project types are divided into the following categories:

- New construction/reconstruction (see Figure 2-1 flowchart)
- Widening (see Figure 2-2 flowchart for Lane Widening, Figure 2-3 flowchart for Shoulder and Intersection Widening, Figure 2-4 flowchart for Ramp Widening)
- CAPM and rehabilitation (see Figure 2-5 flowchart for existing rigid pavement CAPM and rehabilitation projects and Figure 2-6 flowchart for existing flexible pavement CAPM and rehabilitation projects)

The HDM Topic 603 provides definition for each of the project type.

Please note that the flowcharts do not show all possible alternatives, which may be considered for a particular project. Additional pavement alternatives can be analyzed as determined by the project development team. However, the lowest life-cycle pavement design must be identified and where required in HDM Topic 612. For example, if the new construction flowchart indicates that a 40-yr Flexible and 40-yr CRCP (Continuously Reinforced Concrete Pavement) must be analyzed, a 40-yr JPCP (Jointed Plain Concrete Pavement) may also be analyzed. In order for 40-yr JPCP to be selected, it must be the lowest life-cycle cost of the 3 pavement alternatives.

2.3.1 Use of Flowcharts for Selecting Design Alternatives

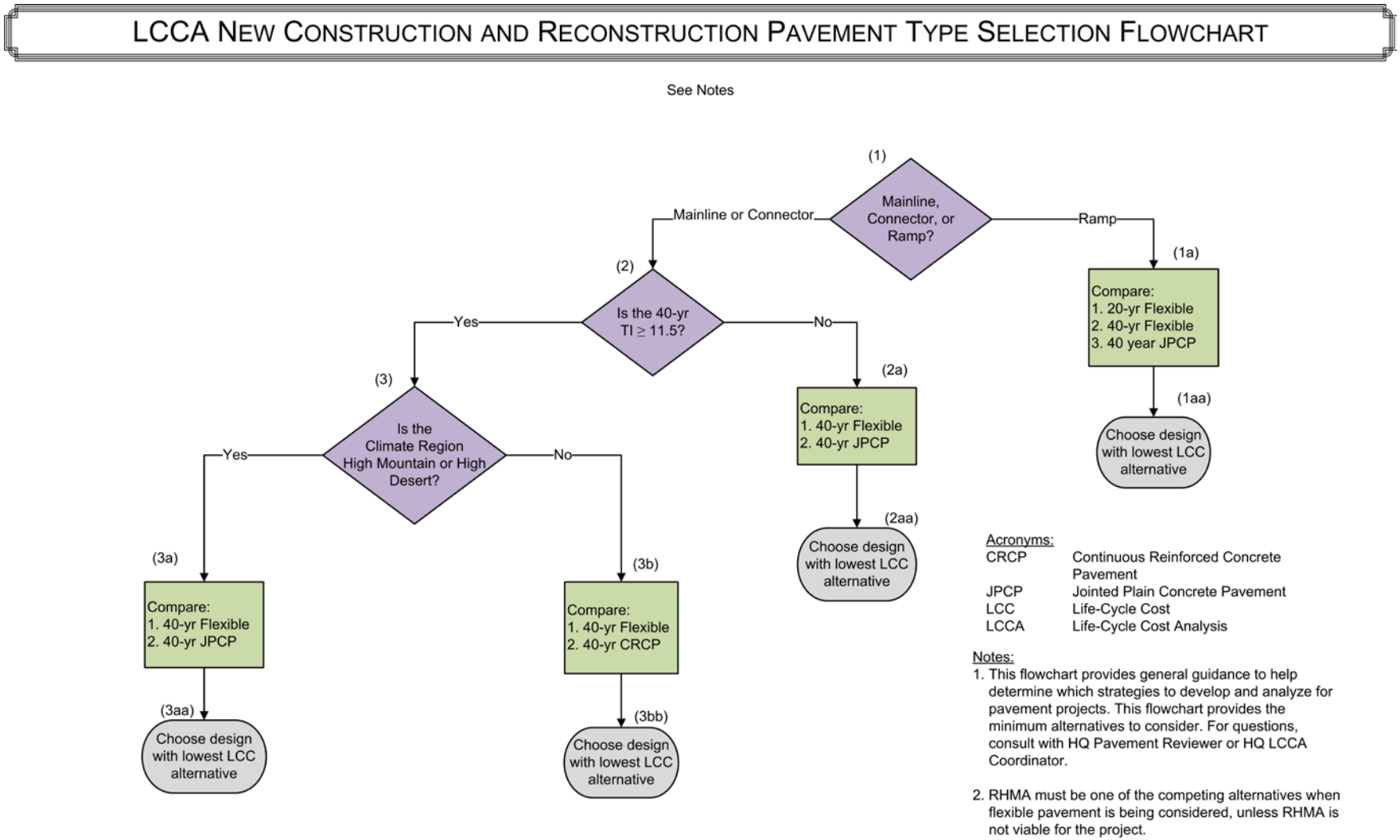


Figure 2-1 New Construction and Reconstruction Pavement Alternatives Selection Flowchart

Instructions for Using New Construction or Reconstruction Flowchart:

(1) Using Figure 2-1, select whether the pavement is for a mainline, connector, or ramp. Go to (1a) or (2).

(2) If the pavement is for a mainline or connector, determine whether the 40-year TI is greater than or less than 11.5. Go to (2a) or (3).

(2a) If the 40-year TI is less than 11.5, compare a 40-year flexible pavement with a 40-year JPCP pavement. Choose the pavement alternative with the lowest life-cycle cost (LCC) (2aa).

(3) If the 40-year TI is greater than or equal to 11.5, determine whether the project is in a high mountain or high desert climate region. Go to (3a) or (3b)

(3a) If the project is in a high mountain or high desert climate region, compare a 40-year flexible pavement with a 40-year JPCP pavement. Choose the alternative with the lowest LCC (3aa).

(3b) If the project is not in a high mountain or high desert region, then compare a 40-year flexible pavement with a 40-year CRCP pavement. Choose the pavement alternative with the lowest LCC (3bb).

(1a) If the pavement is for ramps, compare a 20-year flexible, a 40-year flexible, and 40-year JPCP pavement. Choose the pavement alternative with the lowest LCC (1aa).

Widening Flowchart:

The following flowcharts provide instructions on how to choose alternatives for various widening projects, including widening lane, ramp, shoulder, and intersection.

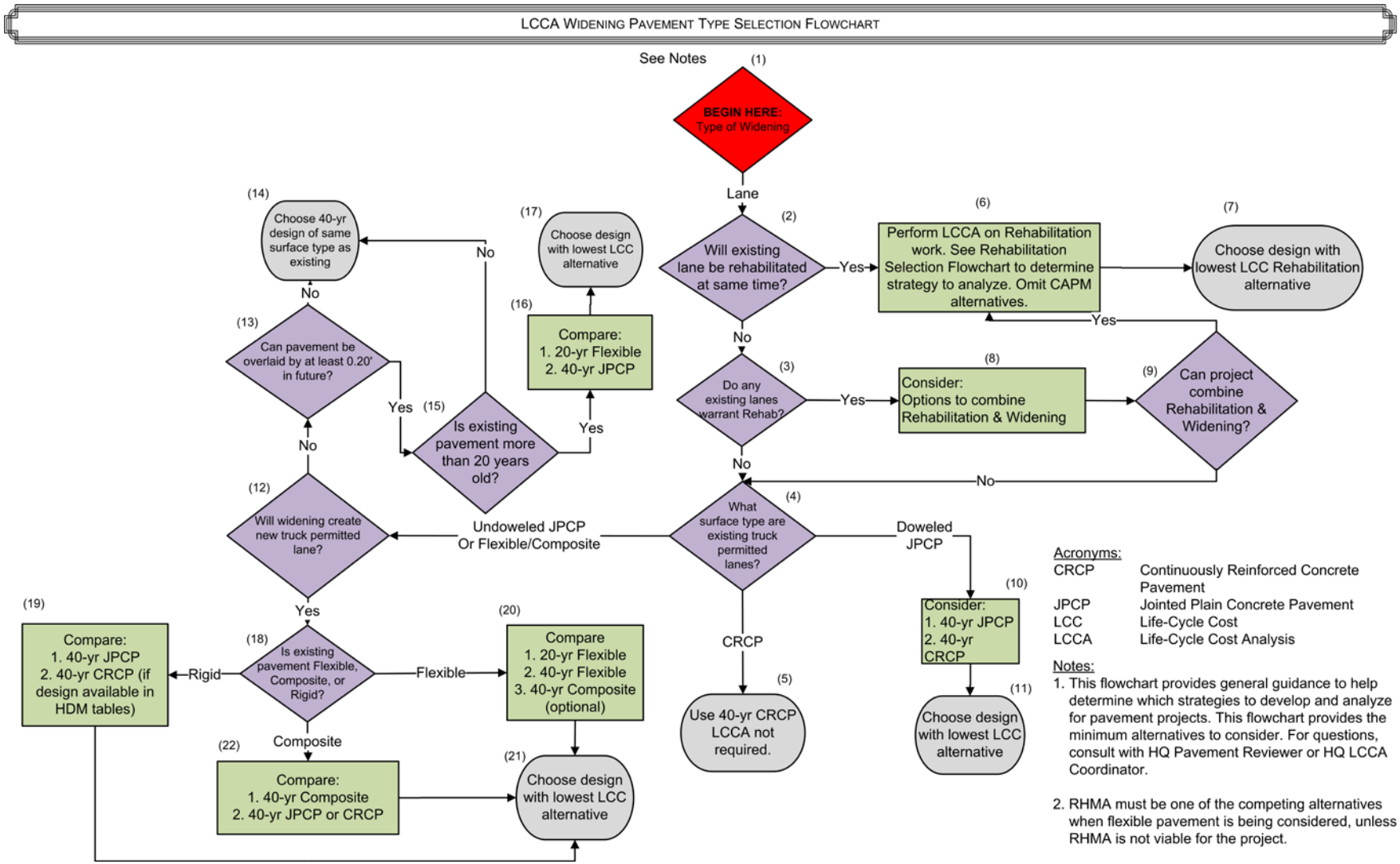


Figure 2-2 LCCA Lane Widening Flowchart

Instructions for Using Lane Widening Flowchart

Using Figure 2-2:

(1) Begin here, and then proceed to step (2).

(2) Decide if existing lane will be rehabilitated at the same time. If yes, proceed to step (6). If no, proceed to step (3).

(6) If existing lane needs rehabilitation, perform LCCA on Rehabilitation work. Determine the strategy to analyze by using the Rehabilitation Selection Flowchart. Proceed to step (7).

(7) Choose the alternative with lowest Rehabilitation cost.

(3) Decide if the existing lanes warrant Rehab. If yes proceed to step (8). If no, proceed to step (4).

(8) If existing lanes warrant rehab, consider between the options to combine Rehabilitation & Widening. Proceed to step (9).

(9) Decide whether the Rehabilitation & Widening can be combined. If yes, proceed to step (6). If no, proceed to step (4).

(6) If existing lane needs rehabilitation, perform LCCA on Rehabilitation work. Determine the strategy to analyze by using the Rehabilitation Selection Flowchart. Proceed to step (7).

(7) Choose the alternative with lowest Rehabilitation cost.

(4) Choose the type of surface for truck permitted lanes. Choose between Doweled JPCP step (10) or CRCP step (5) or (Un-doweled JPCP or Flexible/Composite) step (12).

(5) If the CRCP surface is chosen, use 40-yr CRCP. LCCA is not required.

(10) If the Doweled JPCP is chosen, consider between a 40-yr JPCP and a 40- yr CRCP. Proceed to step (11).

(11) Choose the design with the lowest LCC alternative.

(12) If un-doweled JPCP is chosen, decide if the widening will create a new truck permitted lane. If yes, proceed to step (18). If no, proceed to step (13).

(18) Decide if the existing pavement is Composite, Flexible or Rigid. Proceed to step (22), (20) or (19), respectively.

(22) If the existing pavement is Composite, compare between a 40-yr Composite and a 40-yr JPCP or CRCP. Proceed to step (21).

(20) If the existing pavement is Flexible, compare between a 20-yr Flexible, 40-yr Flexible or 40-yr Composite (optional). Proceed to step (21).

(19) If the existing pavement is concrete, compare between a 40-yr JPCP and a 40-yr CRCP. Proceed to step (21).

(21) Choose design with lowest LCC alternative.

(13) Decide if the pavement can be overlaid by at least 0.20' in the future. If yes, proceed to step (15). If no, proceed to step (14).

(15) Determine if the existing pavement is more than 20-yrs old. If no, proceed to step (14). If yes, proceed to step (16).

(16) If the existing pavement is more than 20 yrs. old, compare the options of a 20-yr Flexible and a 40- yr JPCP. Proceed to step (17).

(17) Choose design with lowest LCC alternative.

(14) Choose 40-yr design of same surface type as the existing surface type.

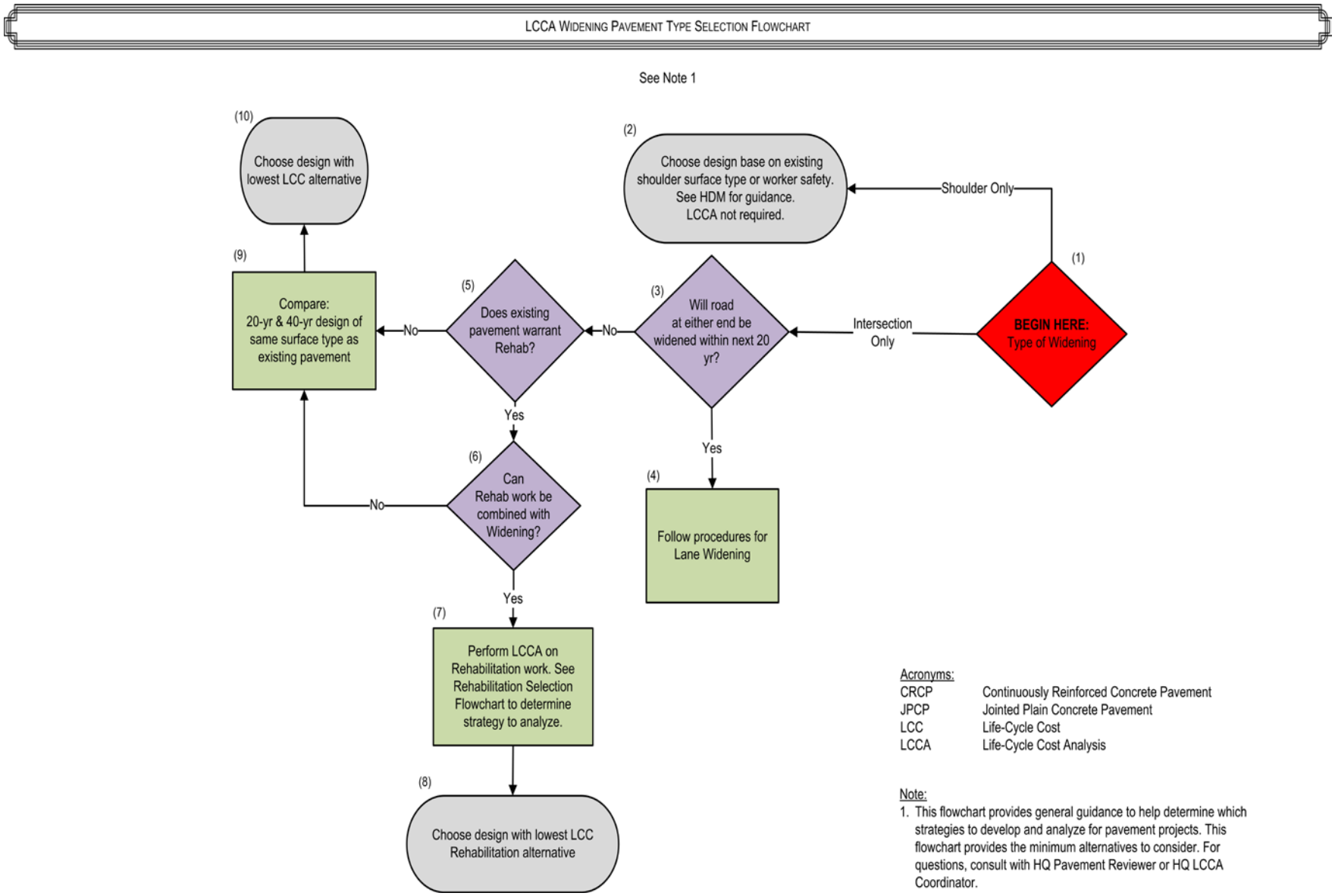


Figure 2-3 Shoulder and Intersection Widening Flowchart

Instructions for Using Shoulder and Intersection Widening Flowchart

Using Figure 2-3:

(1) Begin here, and then proceed to step (2) for Shoulder Widening or proceed to step (3) for Intersection Widening.

(2) Choose design based on existing shoulder surface type or worker safety. See HDM for guidance. LCCA not required.

(3) Decide if the existing road will be widen within the next 20-yrs. If yes proceed to step (4). If no, proceed to step (5).

(4) Follow procedures for Lane Widening.

(5) If the existing road does not need to be widened within the next 20 yrs, decide if the existing pavement warrants Rehab. If yes, proceed to step (6). If no, proceed to step (9).

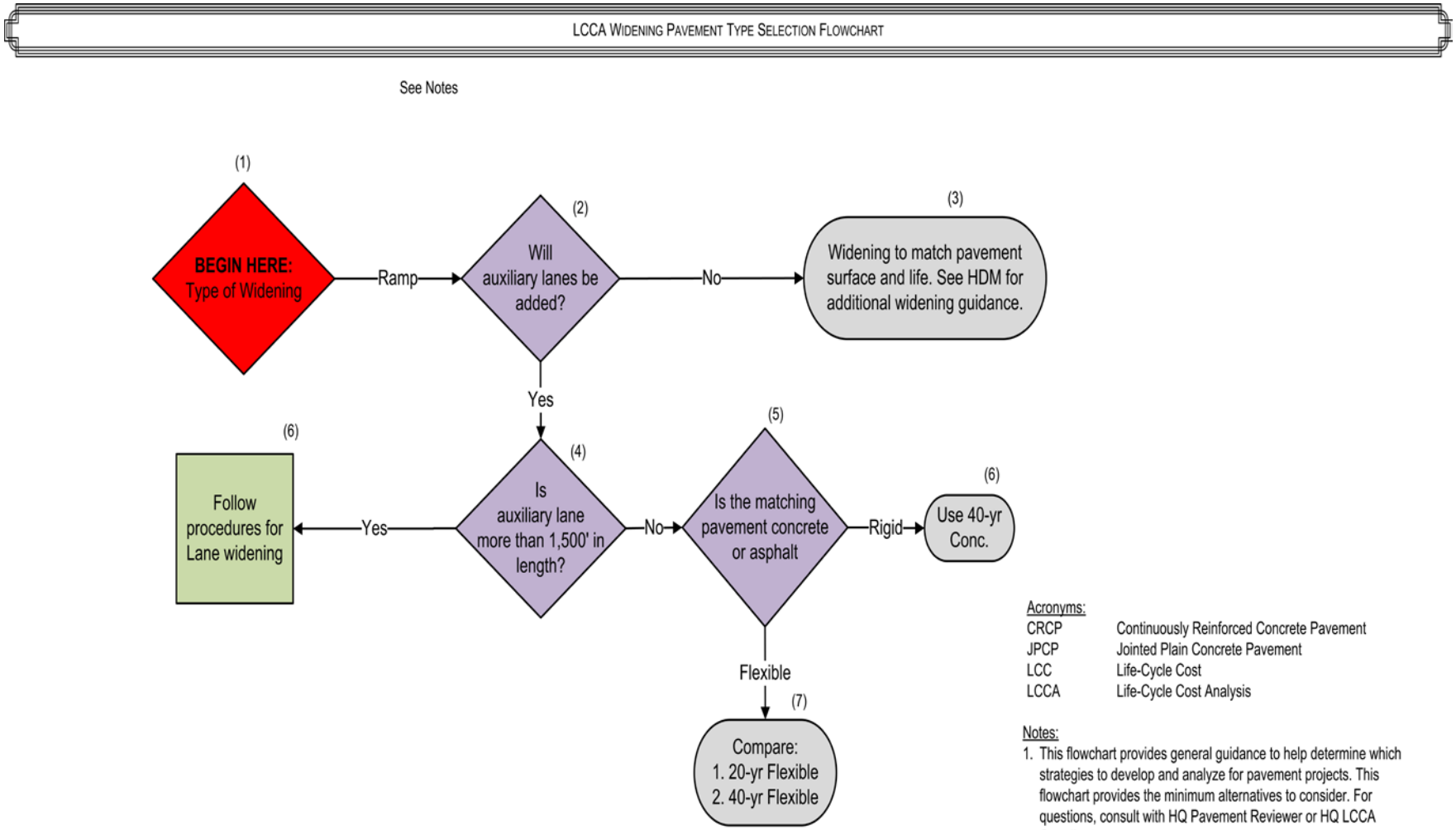
(6) If the existing pavement warrants rehabilitation, decide if rehabilitation can be combined with widening. If yes, proceed to step (7). If no, proceed to (9).

(7) If rehabilitation and widening can be combined, perform LCCA on rehabilitation work. See rehabilitation selection flowchart to determine strategy to analyze. Proceed to step (8).

(8) After LCCA on rehabilitation work, choose design with lowest LCCA rehabilitation alternative.

(9) If the existing pavement does not warrant rehabilitation and cannot be combined with widening, compare 20-yrs & 40-yrs design of same surface type as existing. Proceed to step (10).

(10) After comparing alternatives from step (9), choose design with lowest LCC alternative.



Acronyms:

CRCP	Continuously Reinforced Concrete Pavement
JPCP	Jointed Plain Concrete Pavement
LCC	Life-Cycle Cost
LCCA	Life-Cycle Cost Analysis

Notes:

1. This flowchart provides general guidance to help determine which strategies to develop and analyze for pavement projects. This flowchart provides the minimum alternatives to consider. For questions, consult with HQ Pavement Reviewer or HQ LCCA Coordinator.

2. RHMA must be one of the competing alternatives when flexible pavement is being considered, unless RHMA is not viable for the project.

Figure 2-4 Ramp Widening Flowchart

Instructions for Using Ramp Widening Flowchart

Using Figure 2-4:

(1) Begin here, and then proceed to step (2).

(2) Decide if auxiliary lanes will be added. If yes, proceed to step (4). If no, proceed to step (3).

(4) If auxiliary lanes are to be added, decide if lanes will have more than 1,500 feet in length. If yes, proceed to step (8). If no, proceed to step (5).

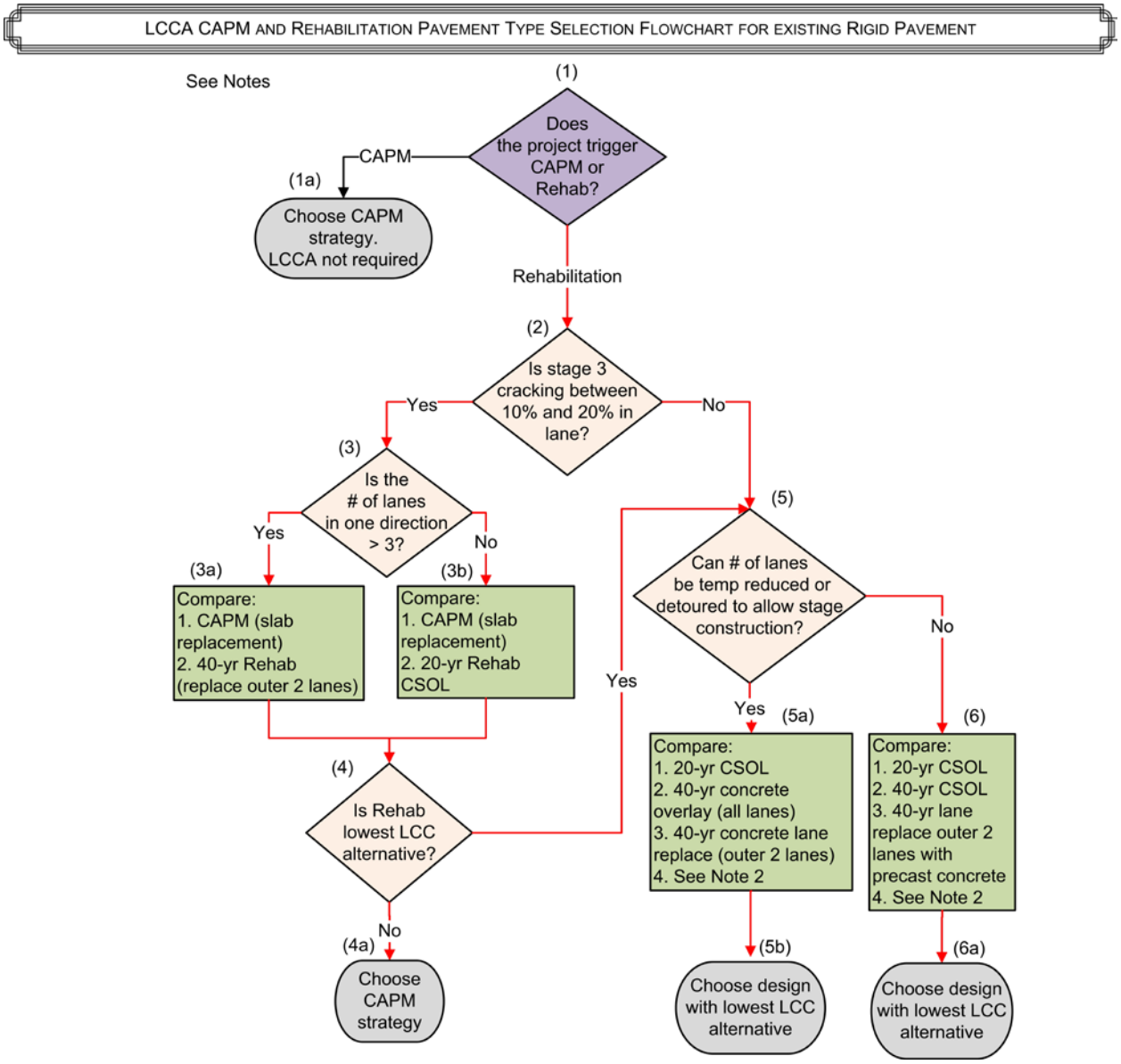
(8) If auxiliary lane is more than 1,500 feet, follow procedures for lane widening.

(5) If auxiliary lane is less than 1,500 feet, decide if the matching pavement is concrete or asphalt. If concrete proceed to step (6). If asphalt proceed to step (7).

(6) If matching pavement is concrete, use 40 yr.

(7) If matching pavement is asphalt, compare between 20-yr vs. 40 yr.

(3) If no auxiliary lanes are to be added, widen ramp to match pavement surface and life. See HDM for additional widening guidance.



Acronyms:	**Notes:**
CAPM Capital Preventive Maintenance **CSOL** Crack, Seat, and Overlay **FDR** Full Depth Reclamation **LCC** Life-Cycle Cost **LCCA** Life-Cycle Cost Analysis	**1. This flowchart provides general guidance to help determine which strategies to develop and analyze for pavement projects. This flowchart provides the minimum alternatives to consider. For questions, consult with HQ Pavement Reviewer or HQ LCCA Coordinator.** **2. Where constraints exist, such as sound walls or floodplains, consult with HQ Pavement Reviewer or HQ LCCA Coordinator.** **3. RHMA must be one of the competing alternatives when flexible pavement is being considered, unless RHMA is not viable for the project.**

Figure 2-5 CAPM and Rehabilitation Pavement Alternatives Selection for Existing Rigid Pavement Flowchart

Instructions for Using CAPM and Rehabilitation Flowchart for Existing Rigid Pavement:

Using Figure 2-5:

(1) Begin here and determine if the project is a CAPM or rehabilitation. Go to (1a) or (2).

(1a) If it is a CAPM, LCCA is not required.

(2) If the project qualifies for rehabilitation determine if there is 10% to 20% stage 3 cracking. Refer to the Pavement Condition Report. Go to (3) or (5). Note: if the project has less than 10% stage 3 cracking, it is considered a CAPM project (refer to Design Information Bulletin 81).

(3) If the pavement condition falls between 10% to 20% stage 3 cracking, determine if the number of lanes in one direction is greater than 3. Go to (3a) or (3b).

(3a) If the number of lanes in one direction is greater than 3, compare a CAPM slab replacement and a 40-year rehabilitation in which the outer two lanes being replaced with concrete. Go to (4).

(3b) If the number of lanes in one direction is 3 or less, compare a CAPM slab replacement with a 20-year crack, seat, and overlay (CSOL) rehabilitation. Go to (4).

(4) If the CAPM strategy prevails as the lowest LCC, choose a CAPM strategy for your project (4a). If the CAPM does not give the lowest LCC, and the rehabilitation strategy is lower, go to (5) and run additional LCCA for further analysis.

(4a) Choose CAPM strategy.

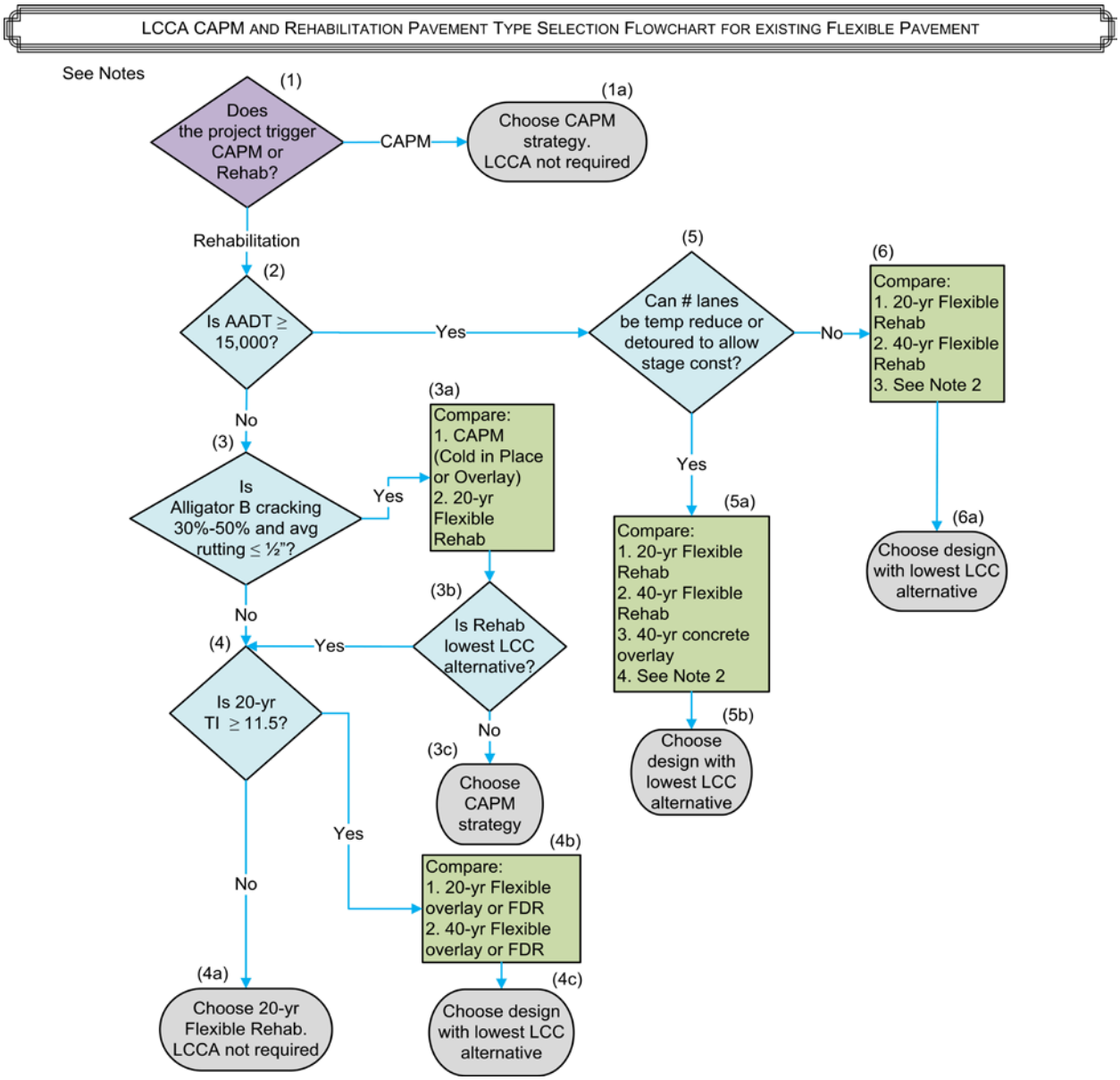
(5) Determine if stage construction can allow for lane reduction or detouring traffic. Go to (5a) or (6).

(5a) If the decision is “yes”, compare 20-year crack, seat, and overlay (CSOL), 40-year concrete overlay (white topping), and 40-year concrete lane replacement of the outer 2-lanes. Go to (5b).

(5b) If there constrains such as sound walls or floodplains which make these alternatives unviable, contact the HQ LCCA Coordinator, otherwise choose the rehabilitation strategy with the lowest LCC.

(6) If you are unable to temporarily reduce the number of traffic lanes or detour the traffic, then compare 20-year CSOL, 40-year CSOL, and 40-year precast concrete lane replacement of the outer two lanes. Go to (6a).

(6a) If there constrains such as sound walls or floodplains which make these alternatives unviable, contact the HQ LCCA Coordinator, otherwise choose the rehabilitation strategy with the lowest LCC.



Acronyms:	**Notes:**
CAPM Capital Preventive Maintenance **CSOL** Crack, Seat, and Overlay **FDR** Full Depth Reclamation **LCC** Life-Cycle Cost **LCCA** Life-Cycle Cost Analysis	**1. This flowchart provides general guidance to help determine which strategies to develop and analyze for pavement projects. This flowchart provides the minimum alternatives to consider. For questions, consult with HQ Pavement Reviewer or HQ LCCA Coordinator.** **2. Where constraints exist, such as sound walls or floodplains, consult with HQ Pavement Reviewer or HQ LCCA Coordinator.** **3. RHMA must be one of the competing alternatives when flexible pavement is being considered, unless RHMA is not viable for the project.**

Figure 2-6 CAPM and Rehabilitation Pavement Alternatives Selection for Existing Flexible Pavement Flowchart

Instructions for CAPM and Rehabilitation Flowchart for Existing Flexible Pavement:

Using Figure 2-6:

(1) Begin here and determine if the project is a CAPM or rehabilitation. Go to (1a) or (2).

(1a) If it is a CAPM, LCCA is not required.

(2) If the existing pavement is qualifies for rehabilitation, determine if the current year AADT is greater than or equal to 15,000. Go to (3) or (5).

(3) If the AADT is less than 15,000, determine if alligator B cracking is between 30% to 50% and average rutting is less than or equal to ½". Go to (3a) or (4).

(3a) If the alligator B cracking is between 30% and 50% and average rutting is less than or equal to ½", compare CAPM (cold in place) or overlay strategy and a 20-year flexible rehabilitation strategy. Go to (3b). (Note: if the project has less than 30% alligator B cracking, it is considered a CAPM project (refer to Design Information Bulletin 81).

(3b) Decide if the rehabilitation is the lowest LCC. If no, go to (3c). If yes, go to (4).

(3c) If the rehabilitation is not the lowest LCC, then choose the CAPM strategy.

(4) If alligator B cracking is greater than 50% or average rutting is greater than ½" check to see if the 20-year TI is greater than or equal to 11.5. Go to (4a) or (4b).

(4a) If the TI is less than 11.5, then choose a 20-year flexible rehabilitation. LCCA is not required.

(4b) If the TI is greater than or equal to 11.5, compare 20-year flexible overlay or full depth reclamation (FDR) with 40-year flexible overlay or FDR. Go to step (4c).

(4c) Choose the alternative with the lowest LCC alternative.

(5) If the AADT is greater than 15,000, determine if the number of lanes can be temporarily reduced or if there is a viable detour to allow construction staging. If yes, go to step (5a). If no, go to step (6).

(5a) If stage construction allows for lane reduction or detour, compare 20-year flexible rehabilitation, 40-year flexible rehabilitation, and 40-year concrete overlay (white topping). Go to step (5b).

(5b) If there constrains such as sound walls or floodplains which make these alternatives unviable, contact the LCCA coordinator, otherwise choose the rehabilitation strategy with the lowest LCC.

(6) If lanes cannot be reduced or detoured, compare 20-year flexible rehabilitation with a 40-year rehabilitation. If these pavement alternatives are not feasible, refer the issues to the Pavement Reviewer or the LCCA Coordinator. Go to step (6a)

(6a) Choose the alternative with the lowest LLC.

Additional Provisions for Selecting Alternatives

The pavement selection flowcharts provide guidance on what pavement alternatives to compare. As a reminder, the following provisions were incorporated into the flow charts development:

1. Rubberized Hot Mix Asphalt (RHMA) must be one of the competing alternatives when flexible pavement is being considered unless RHMA is not viable for the project. If RHMA is not a viable alternative, justification must be included in the Project Initiation Document (PID) or the Project Report (PR). For further information on when and how to use RHMA, see HDM Index 631.3 and the Asphalt Rubber Usage Guide.

2. The alternatives being evaluated should provide equivalent improvements or benefits. For example, comparison of 20-year and 40-year rehabilitation alternatives or comparison of new construction of flexible or rigid pavement alternatives is valid because the alternatives offer equivalent improvements. Conversely, comparing alternatives such as pavement rehabilitation to adding lanes, or overlay to drainage repair, do not result in equivalent benefits. Projects that provide different benefits should be analyzed using a Benefit-Cost Analysis (BCA), which considers the overall benefits (safety, environmental, social, etc.) of an alternative as well as the costs. For further information on BCA, refer to the Life-Cycle/Benefit-Cost Model (Cal-B/C) user manuals and technical supplements, which are available from the Division of Transportation Planning website at http://www.dot.ca.gov/hq/tpp/tools.html.

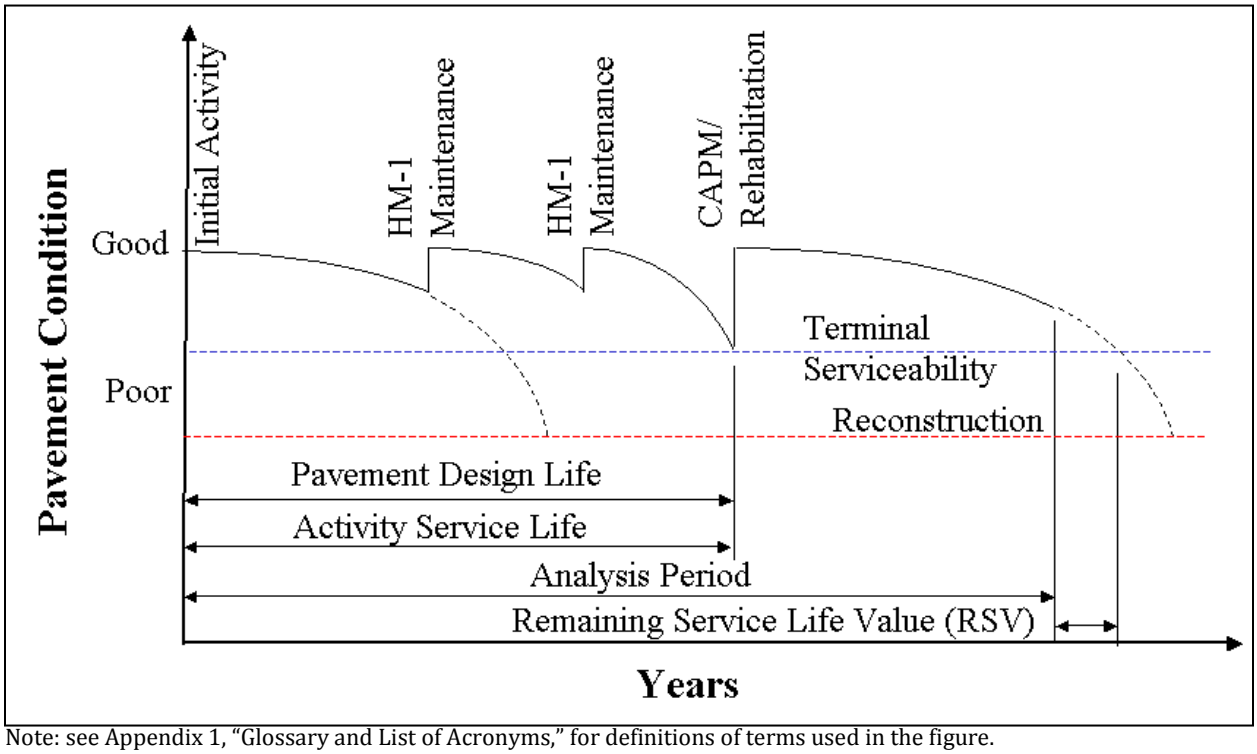
2.4 Analysis Period

The *analysis period* is the period of time during which the initial and any future costs for the project pavement alternatives will be evaluated. Table 2-1 provides the common analysis periods to be used when comparing alternatives of a given design life or lives. When comparing two or more alternatives, determine the analysis period based on the longest design life. For example, an analysis period of 35 years should be used if CAPM and 20-year design life alternatives are compared; and an analysis period of 55 years if 20-year and 40-year design lives are compared.

Table 2-1 LCCA Anaysis Periods

Alternative Life	CAPM	20-Yr	More than 20 years
CAPM	20 years	35 years	55 years
20-Yr	35 years	35 years	55 years
More than 20 years	55 years	55 years	55 years

LCCA assumes that the pavement will be properly maintained and rehabilitated to carry the projected traffic over the specified analysis period. As the pavement ages, its condition will gradually deteriorate to a point where some type of maintenance or rehabilitation treatment is warranted. Thus, after the initial construction, reasonable maintenance and rehabilitation (M&R) strategies must be established for the analysis period. Figure 2-7 shows the typical relationship between pavement condition and pavement life when appropriate maintenance and rehabilitation strategies are applied in a timely manner.



Note: see Appendix 1, "Glossary and List of Acronyms," for definitions of terms used in the figure.

Figure 2-7 Pavement Condition vs. Years

Additional information about M&R strategies for various types of pavements can be found in Section 2.7, "Maintenance and Rehabilitation Sequences."

2.5 Traffic Data

The Traffic data needed to conduct LCCA are:

1. Construction year AADT (both directions)
2. Total truck percentage
3. 2-axle percentage truck AADT
4. Annual growth rate of traffic percentage
5. Traffic index
6. Lane closure chart

2.6 Discount Rate

Discount rate is the interest rate by which future costs (in dollars) will be converted to present value. In other words, it is the percentage by which the cost of future benefits will be reduced to present value (as if the future benefit takes place in the present day). Real discount rates (as opposed to nominal discount rates) reflect only the true time value of money without including the general rate of inflation. Real discount rates typically range from 3% to 5% and represent the prevailing interest of U.S. Government 10-year Treasury Notes. **Caltrans currently uses a discount rate of 4% in the LCCA of pavement structures.**

2.7 Maintenance and Rehabilitation Sequences

After viable alternatives are identified and the information is gathered, determine the pavement M&R schedule for each pavement alternative. Pavement M&R schedules identifies the sequence and timing of future activities that are required to maintain and rehabilitate the pavement over the analysis period.

Pavement M&R schedules found in Appendix 4 of this manual must be used in the LCCA for pavement projects on the State Highway System. To determine the applicable pavement M&R schedule for a pavement alternative in Appendix 4, the following information is needed:

1) *Existing/New Pavement Type.* The types are: flexible, rigid, and composite.

2) *Pavement Climate Region.* There are five groups of climate regions; see map in Figure A4-1, Appendix 4, which is also available on the Pavement Engineering website. Table 2-2 shows the difference between the "Caltrans Climate Regions" and the "Climate Regions for Pavement M&R Schedules".

Table 2-2 Caltrans Climate Region Classification

Caltrans Climate Regions	Climate Regions for Pavement M&R Schedules
North Coast	All Coastal
Central Coast	
South Coast	
Inland Valley	Inland Valley
High Mountain	High Mountain and High Desert
High Desert	
Desert	Desert
Low Mountain	Low Mountain and South Mountain
South Mountain	

3) *Project Type.* The types are: New Construction/Reconstruction, CAPM, and Rehabilitation.

4) *Final Pavement Surface Type.* The final pavement surface type is the pavement alternative being investigated for LCCA. Options include:

   - Hot Mix Asphalt (HMA)
   - Hot Mix Asphalt with Open Graded Friction Course (HMA w/ OGFC)
   - Hot Mix Asphalt with Rubberized Hot Mix Asphalt (HMA w/ RHMA)
   - Rubberized Hot Mix Asphalt-Gap Graded (RHMA-G)
   - Rubberized Hot Mix Asphalt-Gap Graded with Rubberized Hot Mix Asphalt-Open Graded (RHMA-G w/ RHMA-O)
   - Jointed Plain Concrete Pavement (JPCP)
   - Continuously Reinforced Concrete Pavement (CRCP)

5) *Pavement Design Life.* See the HDM Topic 612 for guidance.

6) *Maintenance Service Level (MSL).* MSL is the state highway classification used by the Division of Maintenance for maintenance program purposes. From the Pavement Condition Survey, a 'Priority Number' for the project can be found. Then using Table 2-3, MSL can be found. Refer to Appendix 1, "Glossary and List of Acronyms," for further definition of MSL.

Table 2-3 Priority Matrix

Ride Quality	Structural Distress	MSL 1	MSL 2	MSL 3
		Priority Number	Priority Number	Priority Number
Poor Ride	Major	1	2	11
	Minor	3	4	12
	None	5	6	12
Acceptable Ride	Major	7	8	13
	Minor	9	10	14
	None	31, 32, 33	31, 32, 33	31, 32, 33
	No Distress	98, 99	98, 99	98, 99

These M&R schedule tables are integrated into the *RealCost Version 2.5CA* program. The program automatically selects the appropriate M&R schedule, based on the input of the project type, pavement design life, pavement climate region, and MSL. Select the schedule that closely matches the project scope and follow the rehabilitation sequence.

The use of precast panel concrete pavement is currently under development by Caltrans. It offers the potential of rapid construction using materials that are cast and cured away from the construction site which and produce a more durable longer lasting pavement than other options. Please contact the HQ LCCA Coordinator for current information on precast concrete panel concrete pavement M&R schedule, production rate, and cost.

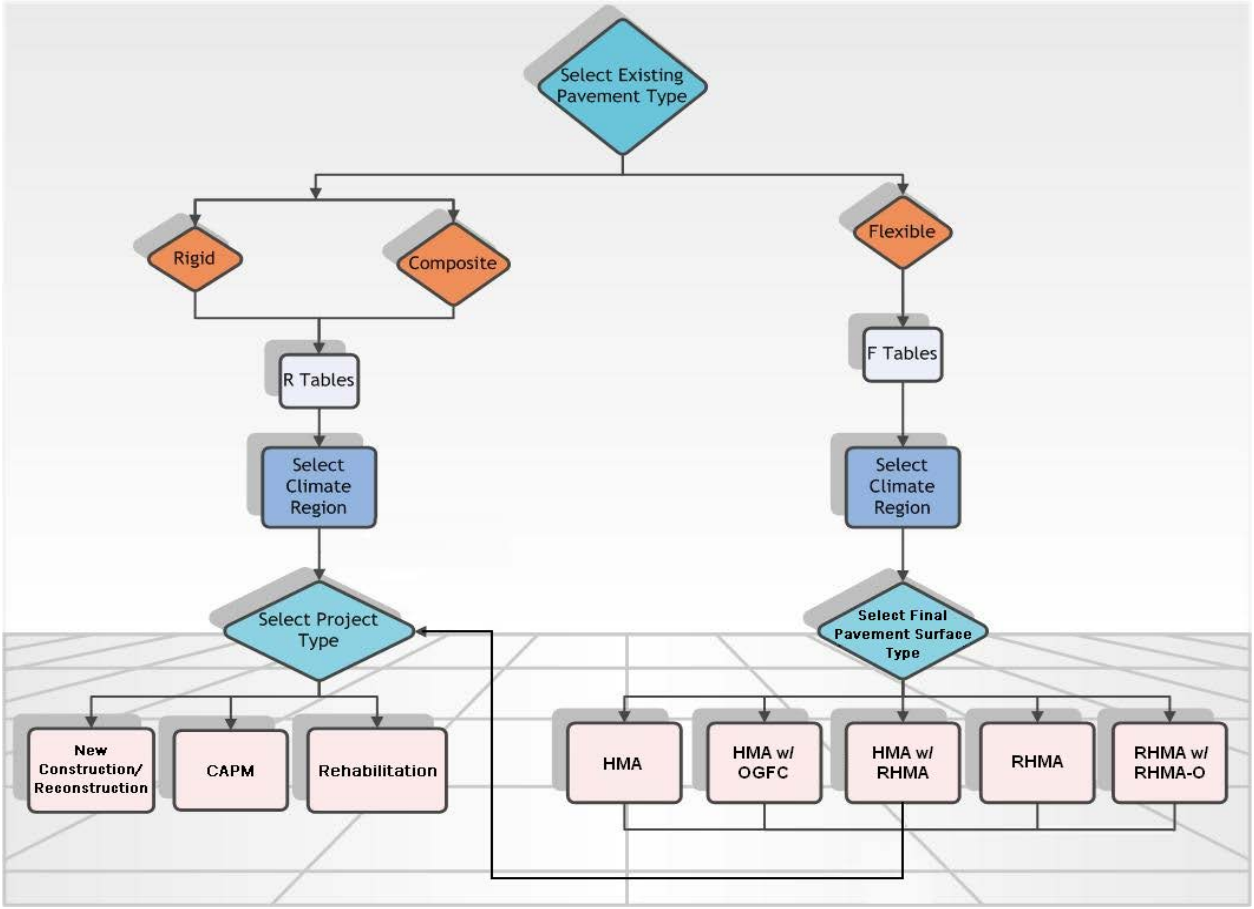


Figure 2-8 Pavement M&R Schedule Determination Flow Chart

Figure 2-9 shows an example of the Pavement M&R Schedules found in Appendix 4 for pavements with RHMA surface type in the State's "coastal" climate region. The M&R schedule tables have been derived from the "Pavement M&R Decision Trees" prepared by each Caltrans district and experience with pavement performance in California (*Note*: these schedules assume there will be no early failures). As shown in Figure 2-9, the M&R schedules include the initial alternative as well as the future CAPM, rehabilitation, or reconstruction activities and their estimated service lives (see "Activity Service Life (years)" box in Figure 2-9. Interim maintenance treatments such as Major Maintenance (HM-1) projects and work by maintenance field crews performed between each scheduled activity have been converted into an annualized maintenance cost in dollars per lane mile ($/lane-mile).

TABLE F-1 (d)
All Coastal Climate Regions
RUBBERIZED HOT MIX ASPHALT PAVEMENT MAINTENANCE AND REHABILITATION SCHEDULE

Final Surface Type	Pvmt Design Life	Maint. Service Level	Year		Begin Alternative Construction		5	10	15	20	25	30	35	40	45	50	55
New Construction/Reconstruction																	
RHMA	20	1,2	Year of Action		0						22	28				50	
			Activity Description		**New / Reconstruct**						CAPM RHMA	Rehab RHMA (20 yr)				CAPM RHMA	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,200					6 900	22 2,500				6 900	
		3	Year of Action		0						22		32		42		51
			Activity Description		**New / Reconstruct**						CAPM RHMA		CAPM RHMA		CAPM RHMA		Rehab RHMA (20 yr)
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,200					10 4,100		10 4,000		9 4,400		22 2,500
CAPM																	
RHMA	5+	1,2	Year of Action		0			6		28		34					
			Activity Description		**CAPM RHMA**			Rehab RHMA (20 yr)		CAPM RHMA		Rehab RHMA (20 yr)					
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	6	900		22 2,500		6 900		22 2,500					
		3	Year of Action		0			10		20		29				51	
			Activity Description		**CAPM RHMA**			CAPM RHMA		CAPM RHMA		Rehab RHMA (20 yr)				CAPM RHMA	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	10	4,000		10 4,100		9 4,400		22 2,500				10 4,000	
Rehabilitation																	
RHMA	20	1,2,3	Year of Action		0					22		28				50	
			Activity Description		**Rehab RHMA (20 yr)**					CAPM RHMA		Rehab RHMA (20 yr)				CAPM RHMA	
			Activity Service Life (years)	Annual Maint. Cost ($/lane-mile) over Activity Service Life	22	2,500				6 900		22 2,900				6 900	

Note: These tables are now an integrated part of *RealCost Version 2.5CA* and are automatically entered with the alternative selections.

Figure 2-9 Example of Pavement M&R Schedule

EXAMPLE 2.1

Using: RealCost Version 2.5CA

Suppose that one of the alternatives being considered for flexible pavement is a "Rehabilitation HMA w/ RHMA" located in the north coast climate region with a maintenance service level of 2. Since the project is Rehabilitation, the design year is 20 years. To determine the appropriate pavement M&R schedule, select these options in the M&R panel section of RealCost Version 2.5CA, and the maintenance schedules for the alternative will be automatically entered into the program.

Using: Appendix 4 Table Lookup (1)

The M&R schedule can be chosen from Appendix 4. Since the project is in the north coast region, select the M&R schedules with the heading "All Coastal Regions". Next, find among the selected schedules the one that addresses the final pavement surface type for the alternative being considered, for this example "Hot Mix Asphalt w/ RHMA". Thus, the appropriate schedule will have the heading "Table F-1 (c), All Coastal Climate Regions, Hot Mix Asphalt w/ RHMA Pavement Maintenance and Rehabilitation Schedule". Finally, knowing that the project type is Rehabilitation and the MSL is 2, we can find the appropriate row and sequence. In this example, the sequence is the seventh row from the top. From this schedule, it can be determined that the Rehab HMA w/ RHMA alternative is expected to last 23 years and the annualized cost for maintenance (HM-1) is estimated at $3,500 per lane-mile over the activity service life. The M&R schedule also calls for a "CAPM HMA W/ RHMA" at year 23 after the implementation of the Rehab HMA w/ RHMA alternative. This rehab has an annualized maintenance cost of $3,500 per lane-mile over a 10 year activity service life.

Note (1): Tables in Appendix 4 included in RealCost Version 2.5CA Program.

2.8 Estimating Costs

Life-cycle costs include two types of cost: agency costs and user costs.

2.8.1 Agency Costs

Agency costs are direct costs. These costs are an estimate of what it would cost Caltrans to build, maintain, and extend the life of the pavement. Agency costs include initial, maintenance, rehabilitation (including CAPM), support, and remaining service life value costs.

2.8.2 User Costs

User costs are indirect costs (not directly borne by Caltrans). These costs are measured in dollars, which are associated with the additional travel time and related vehicle operating

costs incurred by the traveling public due to construction traffic delays from initial construction and future rehabilitation activities.

Best-practice LCCA calls for consideration of not only agency costs, but also costs to roadway users. *User costs* include travel time costs and vehicle operating costs (excluding routine maintenance) incurred by the traveling public. User costs arise when work zones restrict the normal flow of the facility and increase the travel time of the user by generating queues or speed change through the work zones. Although user costs are also incurred during normal operations, they are not considered in LCCA because normal travel costs are not dependent on individual project alternatives. User costs are given serious consideration and can become a significant factor when a large queue occurs for a given alternative, since Caltrans' duty is to serve the public. These user costs are computed within *RealCost Version 2.5CA*.

2.8.3 Initial Costs

Initial costs must include estimated construction costs to be borne by an agency for implementing a project alternative. The initial construction costs (first activity in the M&R sequence) are determined from the engineer's estimate. Costs for mainline and shoulder pavement, base, subbase, pavement drainage, joint seals, earthwork, traffic control, and time-related overhead should be included. The following items should not be included:

- Add-on costs such as minor items, supplemental work, mobilization, and contingencies.
- Right of way costs.
- Project support costs for design, environmental, project management, construction administration and inspection, etc.

These above items are not included because their actual costs (at PS&E) between alternatives are typically and should be assumed to be equivalent.

Construction costs that will not change between alternatives — such as bridges, traffic signage, and striping — may be excluded if those costs can be separated from the rest of the estimate. In other words, if there are common pay items that are the same between alternatives, they do not need to be included in the initial construction cost estimate.

The initial costs for each alternative must be estimated to the same level of detail and accuracy for all alternatives. This includes needed items of work which may differ with each alternative. Examples of items that are often overlooked in estimating alternatives include:

- Costs to replace pavement at transition tapers and to maintain bridge clearance.
- Costs of pre-overlay repairs for overlay strategies such as digouts and slab replacements.
- Cost to shoulder pavement placement/replacement (including shoulder backing costs).

See the PDPM for information and work sheets for estimating costs in the PID and the PR. A sample initial construction cost estimate spreadsheet can be found on the LCCA website.

2.8.4 Maintenance Costs

Maintenance costs include costs for routine, preventive, and corrective maintenance, such as joint and crack sealing, void undersealing, chip seal, patching, spall repair, individual slab replacements, thin HMA overlay, etc., whose purpose is to preserve the service life of a pavement. Caltrans uses the annualized maintenance costs included in the pavement M&R schedules in Appendix 4. These annualized costs are based on the "Pavement M&R Decision Trees" prepared by each Caltrans district and historical cost data collected by the Division of Maintenance.

2.8.5 Rehabilitation Costs

Rehabilitation (including CAPM) costs for a particular activity should include costs for project support and costs for all the necessary appurtenance work for drainage, safety, and other features.

After an applicable pavement M&R sequence for the pavement alternatives is selected within the *RealCost Version 2.5CA* program (as discussed in Section 2.6, "Maintenance and Rehabilitation Sequences"), use the program to estimate the cost of future rehabilitation activities to be performed after initial construction. For those future rehabilitation activities whose project type is the same as the proposed project alternative, the engineer can assume its rehabilitation costs to be the same as the initial costs estimated for the project alternative.

2.8.6 Future Project Support Costs

Costs for future project support should be estimated based on the costs identified in the proposed future activity for a project alternative, such as for design, environmental, project management, construction administration and inspection, etc. *RealCost Version 2.5CA* has default values built into the program which includes the Agency Support Cost Multiplier. The Agency Support Costs are added to the Agency Construction Costs to determine the total Agency Costs.

For future rehabilitation projects, the *RealCost Version 2.5* uses the following assumptions to estimate total Agency Costs:

- Miscellaneous cost is 10% of the calculated pavement costs. These are miscellaneous items such as joint seal, tack coat, drainage, etc.
- Traffic handling is assumed to be $2,000 per day.
- COZEEP is assumed to be $2,000 per day. This assumes work zone closures requiring CHP enforcement. This option can be omitted if COZEEP is not anticipated.
- Other traffic costs are assumed to be $2,000 per day. This includes additional traffic handling cost such as k-rail.

- Indirect costs, or contingency costs, are computed at 20% of the project construction costs.
- Support costs are computed at 25% of the project construction costs.

For future CAPM projects, the *RealCost Version 2.5* uses the following assumptions to estimate total Agency Costs:

- Traffic handling is assumed to be $2,000 per day.
- COZEEP is assumed to be $2,000 per day. This option can be omitted if COZEEP is not anticipated.
- Indirect costs are computed at 20% of the project construction costs.
- Support costs are computed at 20% of the project construction costs.

The indirect and support cost percentages come from the SHOPP programming estimation.

2.8.7 Remaining Service Life Value

If an activity, typically the last rehabilitation activity, has a service life that exceeds the end of the Analysis Period (AP), the difference is known as the *Remaining Service Life Value* (RSV). Any rehabilitation activities (including the initial construction), except for the last rehabilitation activity within the AP, will not have a RSV. The RSV of a project alternative at the end of the analysis period is calculated by prorating the total construction cost (agency and user costs) of the last scheduled rehabilitation activity.

2.8.8 Calculating Life-Cycle Costs

Calculating life-cycle costs involves direct comparison of the total life-cycle costs of each pavement alternative. However, dollars spent at different times have different present values, the anticipated costs of future rehabilitation activities for each alternative need to be converted to their value at a common point in time. This is an economic concept known as "discounting."

A number of techniques based upon the concept of discounting are available. FHWA recommends the present value (PV) approach, which brings initial and future costs to a single point in time, usually the present or the time of the first cost outlay. The equation to discount future costs to PV is:

$$PV = F\frac{1}{(1+i)^n} \qquad \text{(Equation 2-1)}$$

Where:

F = future cost at the end of nth years

i = discount rate

n = number of years

The equivalent uniform annual cost (EUAC) approach is also used nationally. It produces the yearly costs of an alternative as if they occurred uniformly throughout the analysis period. The PV of this stream of EUAC is the same as the PV of the actual cost stream. Whether PV or EUAC is used, the decision supported by the analysis will be same. **Caltrans requires the LCCA results to be documented using the present value approach.**