**LCCA Webinar – Questions and Answers (6/13/2023)**

1. How are the environmental costs (e.g. CO2 emissions) taken into the analysis? If taken at all? (Poland)

   Currently LCCA is utilized the determine the net present value between competing alternatives. It is based on costs only.

   However, a similar approach is used when evaluating GHG emissions. This is called Life Cycle Assessment (LCA) and just like in a LCCA, one should not just look at the initial (e.g. embodied carbon) of the initial construction, but the entire life cycle carbon including the use phase and end of life. In many ways, LCCA and LCA are done in with the same processes, with the main difference being the units (e.g. LCCA uses dollars and LCA uses Carbon or CO2).

   Note, the current process is to do LCCA and LCA as separate evaluations, each on its own. Some have recommended that the LCA could be combined with the LCCA based on the cost of carbon, but at this point this is not done. Furthermore, even it is done, our recommendation would be that those CO2 costs be kept separate from the Agency costs and the Users costs because they tell a different story.

   For more information on assessing the environmental side of alternatives, please visit:

   - https://www.acpa.org/wp-content/uploads/2019/02/White-Paper-Concrete-Pavement's-Role-in-a-Sustainable-Resilient-Future-Ver.-1.1.pdf
   - https://www.fhwa.dot.gov/pavement/sustainability/environmental/

2. How to choose asphalt pavement maintenance strategies? Are there any standard periods for how long repairs should be made? (Serbia)

   Typically, maintenance for asphalt pavement, such as seal coating, spot repairs and crack sealing, are considered routine events that are programed on a regular interval (e.g, every 3 to 7years). These are usually used to address isolated areas of distress and/or functional issues such as asphalt oxidation. Most often, they don't a large impact on the LCCA results because their costs are small when compared the initial costs and rehabilitation costs. The exception to this is on lower volume applications such as local roads, streets, parking lots and other low-cost applications where the initial costs and rehabilitation costs are much lower vs applications like state highways or interstates.

   For the more extensive preservation treatments and rehabilitation activities, which includes overlays, that target the ride or structural aspect of a pavement and how it serves the driving public; the timing should be based on the predicted deterioration of the pavement and when the pavement meets a pre-determined condition limit for a ride quality, surface condition, or structural issue such as cracking. These predictions can be based on tools like Pavement ME or local performance prediction curves from a pavement management system. If performance curves are not available, timing can be based on past history.

Regarding the longevity of the repair, this can also be determined using performance prediction curves from mechanistic/empirical design procedures and/or from the past performance data of those treatments that are obtained from a pavement management system. However, the existing condition of the pavement needs to be taken into consideration when doing this evaluation. Treating a pavement in poor condition vs. fair condition with a similar treatment will typically result in a less effective treatment over time.

Having said all this, and if one has NO information, one simple method that can be used to determine rehabilitation timing and longevity is to "match traffic levels," This process assumes that the new pavement and each subsequent rehabilitation activity will carry the same amount of traffic. The steps to do this are:

1. Estimate the life of the original pavement (e.g. using Pavement ME, pavement management performance curve predictions, history, engineering experience, etc.).
2. Determine how many vehicles are carried in that time. (e.g. the Pavement last 20 years and carries 50 million vehicles).
3. Assume that each major rehabilitation will carry that same amount of traffic.
4. Using the traffic growth rate (e.g. 3%), estimate the life of each rehabilitation by calculating the time needed to match the original traffic volume (e.g 50 million vehicles).

The advantage of this process is that it takes into account both growing traffic levels and the damage that occurs as the pavement ages.

3. Is it possible that some parameter, such as the depth of the rut, should be a parameter that will be predicted for 50 years? (Serbia)

Yes, it already is, and it should be used. Rutting is a key performance factor when designing a pavement using mechanistic/empirical procedures, such as Pavement ME (others are cracking, and IRI or ride). This is the primary reason we recommend using M/E procedures, or some other predictive performance curve. These M/E procedures give you the predicted performance for the specific pavement being evaluated and one can base the rehabilitation timing on that specific pavement based around specific thickness, traffic, weather, soil, features, materials, etc. of that pavement; rather than past historical pavements that may or may not be representative of the pavement under review.

4. What possible approaches can be adopted when the exact timeline of different maintenance activities is not known? (The Netherlands)

The 2nd presentation by Mr. Mack was specifically set up to try and address this. Because a pavement's performance is a function of specific design features, construction quality, anticipated traffic, weather conditions, etc.; the EXACT timeline for a specific pavement set of activities in the future will never be known at the time the LCCA is done (as Niels Bohr, Nobel Laureate in Physics said *"Prediction is very difficult, especially if it's about the future!"*)

Still, we can use the tools that are available to help guide us. As a starting point, we recommend using the M/E procedures, such as Pavement ME, to give us the predicted performance for the specific pavement (see question 4).

If that is not available, the FHWA requires performance information of the national highway system and all State DOT's have a pavement management system of some type that shows the performance information of current treatments. However, not all DOTs have the same selection of maintenance and rehabilitation treatments. Likewise, there are different materials and products that are constantly evolving that do not have performance information.

As such, we recommend that agencies and LCCA practitioners look beyond their borders and jurisdictions to other agencies with similar climates and materials for their experience with the performance of those treatments. Furthermore, there are research test sections that can provide performance information at different facilities, such as MnROAD, LTPP sections, WesTrack and others that can provide performance results.

Next, we recommend to never one just one single LCCA. Rather, look at multiple LCCA's that look at multiple scenarios for each alternative, with multiple activities with range of costs (e.g. use the Decision Tree Analysis process and account for real price changes).

As a minimum, I (J. Mack) typically start with 3 LCCA scenarios – one showing good performance with light rehabilitation activities, a 2nd with expected performance and expected activities (often based on the state LCCA guidelines or historical data), and a 3rd with poor performance with heavy rehabilitation activities. I then run these 3 scenarios two additional times where I start each set of activities 5 years early (e.g. if the 1st rehab in my first runs started in year 20, I drop it back and start the sequence at year 15) and then run another set where I start the activities 5 years later (e.g. Year 25). These set of LCCA runs bracket the LCCA results over a number of different possible outcomes and often shows one alternative is clearly better than the other. When there is no clear difference, I typically run the analysis with different cost estimates accounting for real price changes. I know this sounds like a lot, but once it is in a spreadsheet, it consists of just changing a few parameters and recording the results

Note, the decision tree analysis and Probabilistic analysis shown in the attached slide deck are simply doing this same thing; but with 1000 of LCC runs instead of just 9.

5. Could you suggest some possible ways to accurately predict the salvage value in case a pavement undergoes recycling at its end-of-life? (The Netherlands)

Salvage value (SV) can be determined in two different ways. The most common process is "Remaining Service Life" (RSL) where the analysis period ends, and the pavement is functionally and structurally still performing. The RSL of the pavement has value and is calculated using the following formula:

$$RSL = \frac{Remaining\ Life\ of\ last\ rehabilitation}{\text{expected life of the Last Rehabilitation}}\ x\ \text{Last Rehabilitation Cost}$$

For example, assume a 10-year rehab applied in year 46 of a 50-year LCCA analysis period (4 years used – 6 years remaining) and its costs is $10,000,000. The RSL-SV = (10-4)/10 x $10M = 6/10 x $10M = $6 M.

The second way to calculate the net value from sale or re-use of removed / recycled pavement materials (e.g. as RAP or millings for asphalt pavements or recycled concrete for rigid pavements). In this case, the materials are assumed to be removed and the SV is the cost that those material could be sold for at today's prices (remember LCCA uses a real DR which assume a $1000 expense is the same $1000 expense at any future time). Typically, the SV calculated this way is not very large because it is discounted over 35 + years or longer period.

6. Can you also recommend software packages other than RealCost that can be used to conduct stochastic LCCA analysis or a risk-based analysis? (The Netherlands)

   Slide 44 of Tim Martin's presentation has a list. You can also develop your own spreadsheet as Jim Mack has done and presented. In addition, many states that do LCCA have developed their own spreadsheets and tools. I typically find them by googling something like "MN DOT LCCA"

7. Thanks Tim and Jim! Great webinar. Not a question, but just an FYI that you may already be aware - OMB has "Revisions to OMB Circular No. A-94" (https://www.regulations.gov/document/OMB-2023-0011-0001) for public comments that closed on June 6th. (Virginia)

   Thank you for letting us know. Unfortunately, we were not aware of this revision. We were aware of the revisions to Circular A–4, which covers benefit-cost analysis of regulations, but not this one.

8. Do you think, the using cumulative distribution of "difference in LCC" between competing alternatives might be bit easier to interpret? It collapses two curves in to one? (Virginia)

   Yes, I do. There are many different ways to show the results from a probabilistic LCCA and I believe that this is a good way to do it. The only reason I did not show it was because I was concerned about not having enough time.

   Just as a matter of explanation, what person asking the question is recommending is that in the Monte Carlo simulation for a probabilistic LCCA, one additional calculation be made which is ***Pavement A LCCA – Pavement B LCCA***. When the results are positive, Pavement A is better and when the results are negative, pavement B is better. Then by plotting either the Probability Density Function or the Cumulative Probability functions around zero, one can easily see if Pavement A or Pavement B is better (if most results re Positive, Pavement A is better and if most results are negative, Pavement B is better)