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Author
Harvey, John T.

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Local and State Government Procurement to Reduce Transportation Infrastructure Environmental Impacts

John T. Harvey, University of California, Davis

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16. Abstract Green Public Procurement is to be understood as a set of policies, actions and practices that leverage acquisitions to address all types of environmental challenges. This white paper lays out the case and a recommended approach for establishing public procurement programs to reduce, as fast as possible, the environmental impacts of keeping and improving transportation infrastructure functionality. The white paper covers various motivations and potential goals, benefits and co-benefits, readiness of industry and state and federal initiatives, identification and addressing of risks and challenges, basic definitions and tools to be used, the overall recommended approach, and a summary of the program elements needed to implement such a program.		

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Disclaimer

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Local and State Government Procurement to Reduce Transportation Infrastructure Environmental Impacts

A National Center for Sustainable Transportation White Paper

John T. Harvey, University of California Pavement Research Center, Department of Civil and Environmental Engineering, University of California, Davis

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EXECUTIVE SUMMARY

Green Public Procurement can be defined as a set of policies, actions and practices that leverage acquisitions to address all types of environmental challenges.

Why would a transportation agency devote the time, effort and resources needed to improve the environmental sustainability of pavement, bridges, drainage, safety features, railways, and other transportation infrastructure? The first, less altruistic reason, is because improving infrastructure sustainability can often, but not always, reduce the life cycle costs of providing high quality infrastructure. The second is the social costs of environmental pollution. The third is the depletion of finite resources. State and local transportation agencies each have their own goals for considering or expanding their use of lower carbon materials (LCM). Some potential co-benefits of implementing low carbon materials and design innovations in public procurement include: cost savings; conservation of finite local resources; creation or expansion of low carbon transportation material industries and workforces; and improvement of performance through material performance testing, benchmarking and specifications. Overall, introduction of low carbon infrastructure, starting with materials, can result in improved cost-effectiveness and reduced environmental impacts, with same or better engineering performance.

Global, national, and California transportation materials and construction industries have made commitments and produced plans and road maps towards meeting climate action goals and are taking actions working with government and other partners. Several states, some local governments, and the federal government have begun “green procurement” or “buy clean” public procurement programs for transportation infrastructure, which are in various stages and address different scopes of materials and practices. These efforts must result in a much faster “pace of change” than is currently occurring to reach carbon reduction and other environmental goals for 2030, 2045 (California), and 2050 (USA).

How to do this? Risks must be identified, addressed, and then managed at a much faster pace through a comprehensive yet cost- and human resource-efficient program. An approach is presented for setting goals, quantifying impacts using verified information, sending market signals for procurement of lower impact materials, creating a pipeline for assessment of the engineering and environmental performance of increasingly lower impact materials, and establishing a program to implement this process.

A faster pace of change is needed to achieve the goals for reducing environmental impacts that our quality of life depends on, including public health, safety, and protection of the investments made by generations. Every sector of the economy will need to make their contributions towards these goals. The goals of procuring agencies can range from initial use of one or several low carbon materials to implementation of a program intended to result in maximum reduction of greenhouse gas emissions and other environmental impact and finite resource use reductions by a target date. They can focus on the environmental impacts but also be highly motivated by the co-benefits identified. The recommended approach can be used to help move California towards meeting 2030 carbon reduction goals and net zero carbon or carbon neutral emissions by 2045, and other agencies towards meeting their own carbon reduction and other environmental goals.

Motivations, Goals, Benefits and Co-Benefits, and Initiatives for Improving the Sustainability of Transportation Infrastructure

Green Public Procurement and Goal of this White Paper

Green Public Procurement can be defined as a set of policies, actions and practices that leverage acquisitions to address all types of environmental challenges[1]. This white paper identifies motivations, benefits and co-benefits, and a recommended approach for implementation by state and local governments of green public procurement programs for transportation infrastructure materials to improve the sustainability of transportation network operation. The intention is to increase the pace of reduction in environmental impacts while also improving transportation infrastructure functionality. The white paper discusses industry readiness, state and federal initiatives, identification and addressing of risks and challenges, basic definitions and tools to be used, an overall recommended approach, and a summary of the program elements needed to implement such a program.

The agency goals covered can range from initial use of one or several low carbon materials (LCM) to implementation of a program intended to result in maximum achievable reductions of greenhouse gas emissions (GHG), other environmental impacts, and finite resource use by a target date. The recommended approach can be used to help move California towards meeting 2030 carbon reduction goals[2] and net zero carbon emissions by 2045[3], and other agencies towards meeting their own carbon reduction and other environmental goals.

One challenge that is outside the scope of this white paper because it is outside the scope of transportation agencies, is the time and effort needed for environmental and other permitting of new or existing lower impact material sources and/or processing production facilities, including retrofits of existing facilities which might trigger new permitting processes. Risk management of environmental and other impacts of any industrial facility is important, however, the typical times currently needed for permitting can be an obstacle for increasing the pace of reduction of environmental impacts from use of current materials. Policies and resources that can assist local permitting agencies to expedite the process for proven lower impact materials can help overcome this challenge. This is typically outside the scope of transportation infrastructure agencies. but it should be

[1] https://ustr.gov/sites/default/files/files/Issue_Areas/GovernmentProcurement/USUETTC6GPPBestPractices.pdf

[2] https://calepa.ca.gov/climate-dashboard/

[3] https://www.gov.ca.gov/2022/11/16/california-releases-worlds-first-plan-to-achieve-net-zero-carbon-pollution/

identified as a potentially serious constraint warranting communication with sister agencies.

Motivations and Setting Program Goals

Why would a transportation agency devote the time, effort and resources needed to improve the environmental sustainability of pavement, bridges, drainage, safety features, railways, and other transportation infrastructure? The first, less altruistic reason, is because improving infrastructure sustainability can often, but not always, reduce the life cycle costs of providing high quality infrastructure. Much of sustainability is tied to using fewer and less impactful resources and getting the maximum life out of the materials and construction, which also improve cost-effectiveness. The second is the social costs of environmental pollution. Social costs include the costs of adverse health outcomes, agricultural production losses, and changes in property values. The third is the depletion of finite resources, which for infrastructure made from concrete and asphalt particularly focuses on depletion of locally available aggregate resources. Hauling of aggregate from more distant locations is also tied to cost and pollution because hauling aggregates from farther away pollutes more and costs more.

Regarding global warming impacts, the social cost of carbon (SCC) is an estimate of the cost, in dollars, of the damage done by each additional metric tonne of greenhouse gas emissions, which is also an estimate of the benefit of any action taken to reduce a tonne of carbon emissions[4]. The official estimate for global SCC from the Biden administration is $51 per metric tonne (MT) of CO_2-e. A recalculation by the US EPA in November 2022 increased the SCC to $190/M [5]. Others have found a mean of $185/MT and a range of $44 to $413[6]. Local and state governments are already paying part of these social costs from climate change when they pay the costs of wildfires, flooding, drought, and sea level rise.

State and local transportation agencies each have their own goals for considering or expanding their use of lower carbon materials. For some transportation agencies, those goals are focused on making their contribution towards reducing global warming impacts. Fourteen states have established net zero greenhouse gas emission (GHG) goals by 2045 (California, three other states[7]) or 2050 (federal government, 10 states) and/or 2030 goals such as reducing GHG emissions by 45% compared to 2005 emissions[8]. More than 50 cities in the US, including at least nine in California, have set GHG emissions goals[9], as

[4] https://www.brookings.edu/articles/what-is-the-social-cost-of-carbon

[5] https://www.epa.gov/system/files/documents/2022-11/epa_scghg_report_draft_0.pdf

[6] Comprehensive evidence implies a higher social cost of CO_2 https://www.nature.com/articles/s41586-022-05224-9

[7] States' Climate Action Map: https://ccci.berkeley.edu/states-climate-action-map

[8] States with Net Zero Carbon Emissions Goals: https://csg-erc.org/states-with-net-zero-carbon-emissions-targets/

[9] Local Government Climate and Energy Goals: https://database.aceee.org/city/local-government-energy-efficiency-goals California cities are Chula Vista, Fresno, Los Angeles, Oakland, Riverside, Sacramento, San Diego, San Francisco, San Jose

have several counties. While each city and state makes a small contribution to mitigating overall global climate change, roadway agencies in the USA can provide models for others to follow, in addition to making their own contribution to improvement.

The introduction and use of LCM will often also reduce air and water pollution and their associated societal costs. For example, California has heavily populated areas with severe air pollution. A recent UC Merced study estimates that the value to society in the San Joaquin Valley, with approximately 10% of California's population, in healthcare costs, productivity losses, school absences, and opportunity costs from air pollution adverse health outcomes totaled $498 million from emergency room visits and $224 million from hospital admissions in one recent year[10]. The tools used to quantify carbon emissions, life cycle assessment (LCA) and environmental product declarations (EPD), also provide quantification of air and water pollution impacts and reduction of these impacts can be included in the goals of green procurement programs. The use of LCA and EPDs as part of a green procurement program can help identify and quantify emissions causing water pollution from the direct emissions from materials manufacturers (referred to as Scope 1 emissions), indirect emissions from electricity and other energy supplies and use (referred to as Scope 2 emissions), and emissions produced by other manufacturers and suppliers in the supply chain of the final product and from use of the product (referred to as Scope 3 emissions)[11].

Benefits and Co-Benefits

The goals of many agencies may be also focused on co-benefits of using low carbon materials. A co-benefit can be defined as an outcome simultaneously meeting several interests or objectives, such as reducing GHG emissions and achieving other objectives. Some potential co-benefits of implementing low carbon materials and design innovations in public procurement include:

- Achieve Cost Savings: low carbon (alone and as a stand-in for other environmental impacts) infrastructure can at times have initial cost savings compared with conventional materials, and if they exhibit similar or better performance, they can also have life cycle cost savings. In many cases, there may initially be higher costs until the cost benefits of economies of scale can be achieved in the longer term. Federal and other grant programs to state and local agencies can contribute to cost savings in addition to the inherent reduced costs of some LCM.

- Conserve Finite Resources: Many locations in California have finite local aggregate resources available for use in construction materials and/or costly hauling distances, with some regions scheduled to run out in less than 10, 20 or 30 years[12]. Lack of local aggregate results in increased transportation distances and costs,

[10] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC11032670/

[11] https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance

[12] Aggregate Sustainability in California: https://www.conservation.ca.gov/cgs/Documents/Publications/Map-Sheets/MS_052_California_Aggregates_Map_201807.pdf

increased GHG and air pollution emissions, and potentially increased road damage. Some low-carbon transportation material approaches involve reclaiming of aggregates (RAP, RCA[13], or processed building demolition, as examples) which can help reduce the use of finite aggregate resources[14], provided that their use results in the material meeting or exceeding engineering performance requirements.

- Create or Expand Local Low-Carbon Transportation Material Industries and Workforces: Some approaches for creating low-carbon transportation materials will result in the creation or expansion of new local industries and new jobs. The Biden White House has estimated that 170,000 new jobs were created from the clean energy and climate investments of the Inflation Reduction Act (IRA) in its first year[15], and points to a study that estimates that 1.5 million new jobs will be created from these investments over its first 10 years[16]. The Rocky Mountain Institute estimates that 334,000 new jobs have been created from the first two years of the IRA climate and clean energy provisions[17]. The Tax Foundation estimates a net loss of 29,000 from the IRA over its budget window but does not provide breakdowns of how much of the predicted job loss, if any, is from the clean energy and climate parts of the bill, and how much from its other provisions[18]. There are few detailed calculations available regarding how much of the projected job creation comes from development of new LCMs, however, there are many new companies in California and across the country looking at feedstocks such as previously unused minerals, agricultural and forest waste biomass, mining waste products, and new ways of processing recycled materials from other industries to create new LCMs[19]. All new materials need to be evaluated for engineering performance, and analyzed for when, how, and where their use will result in environmental benefits[20].
- Improve Performance Through Material Performance Testing, Benchmarking, and Specifications: Introduction or increased use of low carbon transportation materials will require improved performance related testing and specifications to ensure that they meet the intended performance requirements of currently used materials, which includes benchmarking of performance of those current materials. Introduction of performance related testing and specifications can lead

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[13] RAP is reclaimed asphalt pavement, RCA is recycled concrete aggregate
[14] FHWA Recycling Policy; https://www.fhwa.dot.gov/pavement/recycling/index.cfm
[15] https://www.whitehouse.gov/briefing-room/statements-releases/2023/08/16/fact-sheet-one-year-in-president-bidens-inflation-reduction-act-is-driving-historic-climate-action-and-investing-in-america-to-create-good-paying-jobs-and-reduce-costs/
[16] https://laborenergy.org/fact-sheets/lep-analysis-of-the-inflation-reduction-act-key-findings-on-jobs-inflation-and-gdp/
[17] https://rmi.org/on-the-climate-bills-second-birthday-surging-successes-but-a-split-reality/
[18] https://taxfoundation.org/research/all/federal/inflation-reduction-act/
[19] See for examples: https://www.sciencedirect.com/science/article/abs/pii/S0008884619302327; https://escholarship.org/content/qt14r6b3x8/qt14r6b3x8.pdf; https://doi.org/10.1016/j.wasman.2023.03.035
[20] See for example: https://www.sciencedirect.com/science/article/abs/pii/S0959652618300088

to benchmarking of construction materials currently used by transportation agencies for the first time.

Overall, the use of low carbon infrastructure, starting with materials, can result in improved cost-effectiveness, reduced environmental impacts, with same or better engineering performance. Achieving these co-benefits requires evaluation and analysis of each material and determination of their appropriate use.

Industry, State and Federal Initiatives

Global, national, and California transportation materials and construction industries have made commitments and produced plans and road maps towards meeting net zero or carbon neutral emissions goals. They are taking actions working with government and other partners. Examples for the three most important industries for transportation infrastructure are:

- Concrete:
    - The Global Cement and Concrete Association (GCCA) and the Portland Cement Association (PCA) in the USA have road maps for carbon neutrality by 2050[21],[22]. Cement binder is responsible for approximately 85 to 90% of the carbon intensity of concrete mixes. Cement production is responsible for approximately 7%[23], 0.7%[24] and 2[25]% of global, national and California carbon emissions in recent years, respectively. A difficult to calculate portion of cement is used in transportation infrastructure, in addition to buildings and a host of other applications.
    - The American Concrete Pavement Association and the National Ready Mix Concrete Association are the industries that use cement to mix with aggregate to make concrete to build pavement, bridges, sidewalks, culverts and other transportation infrastructure. They have made commitments, and produced plans and information supporting the GCCA and PCA goals and road maps[26,27].

[21] https://gccassociation.org/concretefuture/wp-content/uploads/2021/10/GCCA-Concrete-Future-Roadmap-Document-AW.pdf
[22] https://www.cement.org/a-sustainable-future/roadmap-to-carbon-neutrality/
[23] https://www.iea.org/reports/technology-roadmap-low-carbon-transition-in-the-cement-industry
[24] Calculated from https://cementproducts.com/2024/04/15/cement-plant-co2-emissions-stay-their-flat-course-in-epa-ghg-inventory/ and https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emission
[25] https://ww2.arb.ca.gov/ghg-inventory-graphs
[26] https://www.acpa.org/wp-content/uploads/2019/02/White-Paper-Concrete-Pavement%E2%80%99s-Role-in-a-Sustainable-Resilient-Future-Ver.-1.1.pdf
[27] https://www.nrmca.org/wp-content/uploads/2022/07/Top10WaysReduceConcreteCarbonFootprint.pdf

    - The California Nevada Cement Association (CNCA) has produced a plan to meet California's goal of net zero carbon emissions by 2045[28].
- Asphalt:
    - The National Asphalt Pavement Association (NAPA) has produced a road forward document towards net zero emissions in the asphalt paving industry by 2050[29]. Asphalt pavement materials production is responsible for approximately 0.02%[30] and 0.4%[31] percent of global and national carbon emissions in recent years.
    - Asphalt binder, which is mixed with aggregate to make asphalt paving materials, is responsible for approximately 40 to 60% of the carbon intensity of asphalt mixes[32], with approximately the same range of carbon emissions coming from the heat used in the mixing process. The Asphalt Institute, representing North American oil refiners producing asphalt binders, has commissioned a study to "comprehend, analyze and project various scenarios for policy, agency adoption and market changes related to external net-zero carbon goals"[33]. They are also preparing a global-first program for issuing environmental product declarations for asphalt binders[34].
- Steel:
    - The US steel industry is represented by organizations focused on different types of steel products. These include the following steel products used extensively in transportation infrastructure: reinforcing bar for concrete used in many types of infrastructure, structural plate steel used in bridges, and a wide range of steel products used in the roadway for bridges, lighting, signage, and safety features. Steel production represents approximately 8% of global carbon emissions[35] with an unknown percentage of products used in transportation infrastructure. There are several initiatives both internationally and in the USA working on finding pathways to reducing

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[28] https://www.calcima.org/files/CNCA_CarbonNeutrality_SecondEdition_VFINAL_(07_19_23).pdf
[29] https://www.asphaltpavement.org/climate/industry-goals
[30] Calculated from https://ourworldindata.org/co2-emissions and estimates in Filani et al. Framework to Quantify Life Cycle Global Warming Impact from the Build-Out and Maintenance of Global Roadway Networks, National Center for Sustainable Transportation (under review).
[31] Calculated from https://ourworldindata.org/co2-emissions and https://www.asphaltpavement.org/uploads/documents/Sustainability/SIP-106_GHG_Emissions_Inventory_for_Asphalt_Mix_Production_in_the_US_%E2%80%93_NAPA_June_2022.pdf
[32] https://www.asphaltpavement.org/uploads/documents/Sustainability/SIP-106_GHG_Emissions_Inventory_for_Asphalt_Mix_Production_in_the_US_%E2%80%93_NAPA_June_2022.pdf
[33] https://www.asphaltfoundation.org/ai-foundation-sustainability-initiative/
[34] https://www.asphaltinstitute.org/sustainability/
[35] https://www.mckinsey.com/industries/metals-and-mining/our-insights/decarbonization-challenge-for-steel

environmental impacts of steel product manufacture and downstream fabrication and net zero carbon emissions[36].

While these industries have made plans and commitments, they cannot achieve them alone. They need partnership with government procurers to develop or update specifications, test methods, design methods, and procurement practices that will create markets for infrastructure with lower environmental impact. They also need partnership in changing engineering and decision making culture to implement innovation at a faster pace, with appropriate due diligence for risk and appropriate protection and reward for those who innovate. Transportation infrastructure materials, design, and construction industries also need consideration of the fact that they are typically not high-margin businesses attracting large sums of investment capital to change their practices and products.

Several states have begun "green procurement" or "buy clean" public procurement programs for transportation infrastructure (and buildings), which are in various stages and address different scopes of materials and practices. A federal-state buy clean initiative has also been established[37]. The Federal Highway Administration has recently launched its Low Carbon Transportation Materials program offering grants to states and local governments to implement programs to improve sustainability of transportation infrastructure materials through procurement[38]. The U.S. EPA is developing a label program for low embodied carbon construction materials that aims to simplify the process of specifying and procuring construction products and materials with reduced embodied carbon as compared to similar products[39].

What Needs to be Done

All the initiatives and programs developed by governments and industries will require coordination, identification of and addressing challenges, and changes in practice. These efforts must result in a faster "pace of change" than is currently occurring to reach carbon reduction and other environmental goals for 2030, 2045 (California), and 2050 (USA).

How to do this? Often, the perceived answer is to "get engineers and decision-makers to be less risk averse". However, this answer does not address the fact that decision makers and engineers are hired (and engineers are licensed) to manage and minimize risk.

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[36] As examples: https://3stepsolutions.s3-accelerate.amazonaws.com/assets/custom/010856/downloads/SteelTSExecutiveSummary.pdf; https://steelprinciples.org/

[37] Including California, Colorado, Hawaii, Illinois, Maine, Maryland, Massachusetts, Michigan, New Jersey, New York, Oregon, Washington, and Minnesota. https://www.sustainability.gov/buyclean/

[38] https://www.fhwa.dot.gov/lowcarbon/

[39] https://www.epa.gov/greenerproducts/label-program-low-embodied-carbon-construction-materials

At a high level what needs to be done can be boiled down to the following:

> *Risks must be identified, addressed, and then managed at a faster pace through a comprehensive yet cost- and human resource-efficient program.*

As risks of innovations are evaluated at a faster pace, decisions must be made at a faster pace regarding which innovations to move forward to the next steps, and resources used to move innovations forward need to be applied at a faster pace. The primary changes for faster implementation of transportation infrastructure innovations are[40]:

- **Engineering Performance:** faster risk assessment for engineering performance (determined by materials, design, construction quality) to determine if the innovation provides same or better functionality and life compared with current technologies over their life cycle, for the matrix of different applications where the innovation can be used. This includes:
  - Faster development of specifications, guidance, training for practitioners, and education for future practitioners that allow innovations to become part of standard practice. Use of performance related tests and specifications is a major component of engineering risk assessment and mitigation of risk when implemented.
  - Faster implementation of design methods that use mechanistic calculations in addition to empirical observations of performance. These types of design methods (called mechanistic-empirical or M-E) can be updated much faster to allow designers to consider innovations than can traditional empirical design methods. Performance related testing and specifications provide the data and constraints for inputs to M-E design. This is an issue for pavements primarily, as bridges and other infrastructure more widely use M-E type design methods.
  - Faster, easier to understand, and more widespread communication of engineering risk assessment results.
  - Faster assessment of constructability to determine the challenges in producing transportation infrastructure with the innovation.
- **Environmental Benefits:** faster assessment of environmental claims to determine if claims match reality when subjected to standard life cycle assessment (LCA) review. This includes consideration of the full life cycle for the innovation including the supply chain, use stage, and end of life.
- **Cost-effectiveness:** faster assessment of cost-effectiveness of innovations, with regular updates as scale is increased. Even where costs (initial and/or life cycle) are increased relative to current practices, faster evaluation of cost-effectiveness will

[40] Presented at White House Office of Science and Technology Policy Concrete Innovation Summit, 19 July 2024. https://www.transportation.gov/sites/dot.gov/files/2024-08/OST-R%20Newsletter_August%202024-Final_0.pdf and augmented in panel discussions; applicable to all transportation infrastructure innovations.

allow comparisons between innovations, and analysis of tradeoffs between reducing environmental impacts in the transportation infrastructure sector versus investments in other sectors of the economy to achieve the same goals[41].

- **Scalability:** faster assessment of scalability to determine what portion of the solution the innovation provides for the environmental and resource use problems at the regional, national, or global scales when full market penetration is achieved, and what constrains scaling up. Constraints on scalability can include permitting timelines, raw material resources, land use, toxic waste products, energy resources, capital, and other factors.
- **Market Signals:** development of benchmarks and market signals for reduction of environmental impacts to incentivize use of lower impact materials and disincentivize use of higher impact materials by the constructors.
- **Permitting:** faster risk assessment and permitting for extraction and processing of new innovative materials, and greater use of local materials that require less transportation where that transportation is one of the major impact sources.

Basic Information and Approaches

Full Life Cycle and Complete System, Cost and Environmental Impacts

Full Life Cycle, Complete System

"Full System" and "Complete Life Cycle" based decision making will provide the most comprehensive solutions, leading to significant and lasting improvements in sustainability through procurement.

The complete life cycle for pavement looks at:

- Consequences of current decisions as far into the future as can be calculated with some certainty
- Effects of current decisions on the ability to make future decisions

The full system for pavement considers:

- Resources, processes, context of structure/traffic/climate/soil
- All environmental and resource use impacts of interest
- Interactions and effects on other systems

[41] Using marginal cost of abatement approach, for example: https://escholarship.org/uc/item/7208x78q

The complete life cycle for a pavement is shown in Figure 1, and other transportation infrastructure has similar life cycles. Example full system considerations are shown in Figure 2.

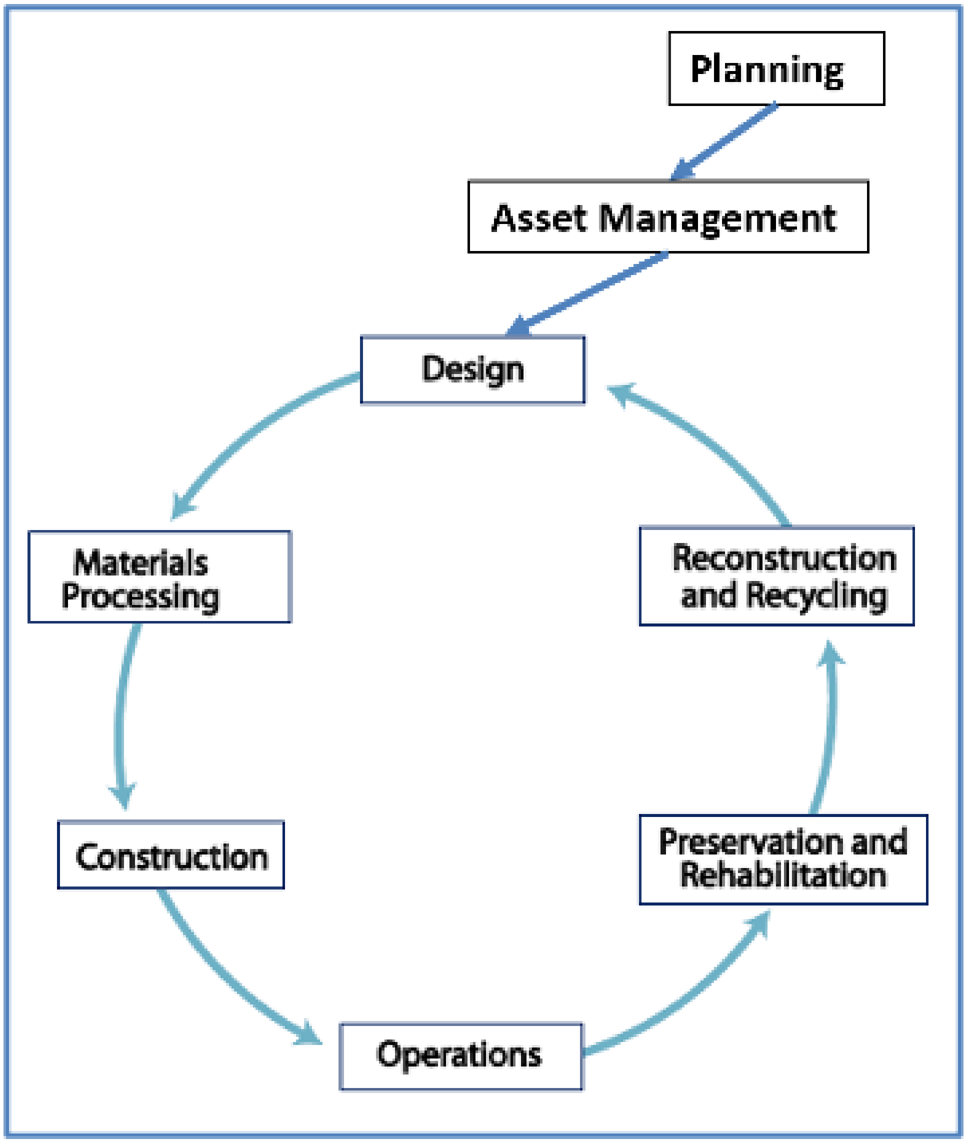

Figure 1. Pavement and other transportation infrastructure life cycle

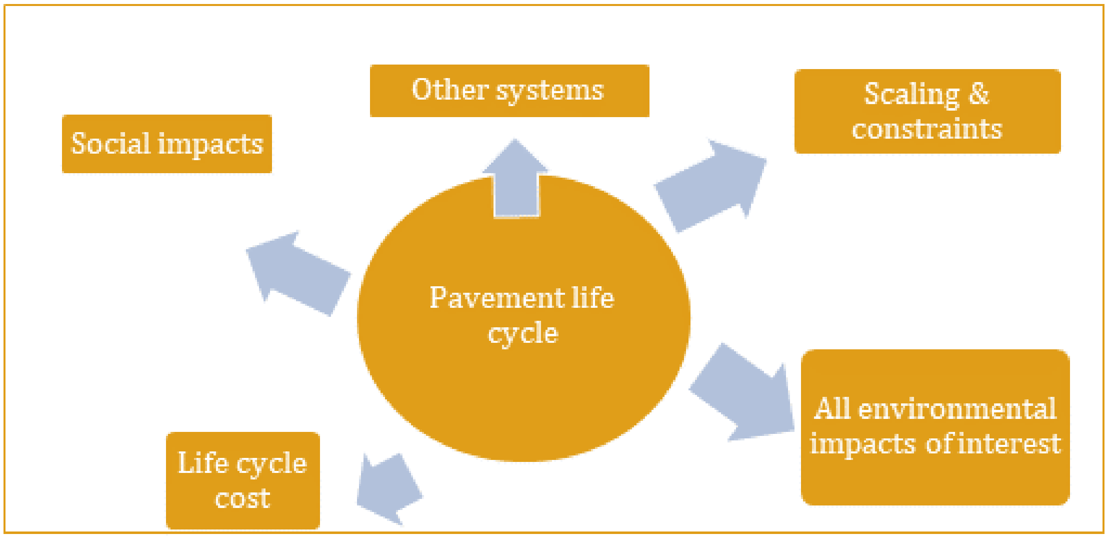

Figure 2. Example full system consideration

Quantification of environmental impacts across the complete life cycle requires identification of the future life cycle for a material as shown in Figure 1. For an infrastructure material, the engineering performance related properties of that material, how the material is used in the pavement design, and the construction quality control when it is built determine how long the infrastructure will last before it needs to be replaced or reconstructed. They also determine how much maintenance and rehabilitation will be needed prior to replacement or reconstruction. A material with lower initial environmental impact but a shorter life, or a material that requires more maintenance and rehabilitation, may have a greater environmental impact over the same amount of time than a material with a higher initial environmental impact.

This is illustrated in the simple example in Table 1, which shows that over a 60-year life, Alternative A has a greater life cycle environmental impact than Alternative B, even though Alternative A has a 15% lower initial environmental impact than Alternative B (it also has 15% less initial cost). The reason is that Alternative A has a 15-year life while Alternative B has a 20-year life. The same principle of needing to consider not only initial impacts but also the complete life cycle to choose the alternative with the lowest life cycle impacts applies to both environmental impacts and cost-effectiveness, as shown in the figure. It should be noted in this example that of the engineering performance of Alternative A while keeping its initial global warming potential or cost advantage could make it the preferred alternative. Also, consideration of a different set of initial impacts other than cost or global warming potential could change the answer to favor A instead of B.

The importance of considering a complete life cycle can be extended to comparisons of pavement rehabilitation alternatives, new or reconstructed pavement types, preservation/maintenance/rehabilitation schedules, pavement design lives, and other decisions.

Table 1. Simple example for the consideration of lower initial impact shorter life and higher initial impact longer life alternatives

Analysis period = 60 yrs	
Alternative A **0.85 GWP or $**	**Alternative B** **1.0 GWP or $**
15 year life to replacement	20 year life to replacement
15	20
30	40
45	
Total GWP or $ 3.4	Total GWP or $ 3.0

Environmental Life Cycle Assessment

Complete life cycle assessment

Environmental life cycle assessment (LCA) is an approach for quantifying environmental impacts over the life cycle of any product[42]. Most LCA follows the 14040 and 14044 standards of the International Standards Organization (ISO), which are relevant to any product. LCA is the primary approach for quantifying environmental impacts over the life cycle of transportation infrastructure which can include an infrastructure material or a complete infrastructure project (roadway, pavement, bridge, etc.)[43]. LCA approaches have also been developed for network level analyses of assets, such as in a pavement management system[44].

ISO standards call for comparison of alternatives using LCA only when considering their complete life cycles. This is often not possible because the future life cycle is unknowable, or is dependent on decisions outside of the organization, such as a material producer or a contractor who is producing a material but who is not responsible for how it will be used in the infrastructure design.

Environmental Declarations and Environmental Product Declarations (EPD)

An environmental declaration is a means for an organization to communicate information about the environmental impact or impacts of a product without sharing proprietary information. Type I environmental declarations produced following ISO 14024 are a type of ecolabel, such as the US EPA's Energy Star label, declaring that the product meets specific environmental criteria and are third-party certified by an organization that verifies the environmental claims. Type II environmental declarations are produced by companies

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42 https://www.iso.org/standard/37456.html; https://www.iso.org/standard/38498.html

43 https://www.fhwa.dot.gov/pavement/sustainability/hif15001.pdf; https://www.fhwa.dot.gov/pavement/sustainability/hif16014.pdf

44 https://doi.org/10.1007/978-3-662-44719-2_2

following ISO 14021 to make an environmental claim or claims, such as recyclability or the amount of recycled content. Type II environmental declarations are not third-party verified or certified[45]. Type III environmental declarations are called environmental product declarations (EPD). EPDs are third-party verified and certified statements based on life cycle assessment of the waste and emissions from the processes used to produce something, and the calculation of the environmental and resource use impacts of the processes, waste, and emissions. The most common impact of interest is global warming potential (GWP), and also typically calculated are impacts to air quality, water quality, and finite resource use (energy from different types of sources, fresh water consumption, as examples). ISO Standard 14025[46] establishes the principles and specifies the procedures for developing EPD programs that publish EPDs and the requirements for Type III EPDs. It specifically establishes the use of the ISO 14040 series of standards in the development of EPD programs and Type III EPDs. Another newer standard, ISO 21930, defines what is needed to produce a Type III EPD[47] for construction materials, providing more details for construction products than are included in the more general ISO 14025, but relying on ISO 14025 for requirements for programs that publish EPDs.

The rules for construction materials EPDs in ISO 21930 are based on previous European Standard EN 15804. ISO Standards 14025 and 21930 require that EPDs be assembled following a relevant product category rule (PCR) for the product type. PCRs are put together by industry organized committees that include stakeholders from outside that industry, including LCA experts, and often material purchasers such as government agencies. PCRs have specific details needed for their product categories in addition to what is in the ISO standards[48]. Competitive industries are invited to comment on PCRs and ISO 14025 has requirements for third-party critical review of PCRS by a committee with expertise about the industry and LCA.

Less than complete life cycle assessment and consideration in EPDs for procurement of materials

When the complete life cycle of a material cannot be known by the material producer, a life cycle assessment can be done that only includes the environmental impacts of the processes that the material producer controls as a means of reporting to customers the impacts in that truncated life cycle. The different scopes for stages in the life cycle that can be considered in an EPD are shown in Figure 3 taken from ISO 21930. Only EPDs published following the same PCR should be compared with one another when less than a complete life cycle is considered in the EPD. This helps to ensure fair comparisons between EPDs.

[45] https://www.hhc.earth/knowledge-base/what-are-the-differences-between-types-environmental-declarations
[46] https://www.iso.org/standard/38131.html
[47] https://www.iso.org/standard/61694.html
[48] https://www.fhwa.dot.gov/pavement/sustainability/hif21025.pdf; https://www.fhwa.dot.gov/pavement/sustainability/epds/what/; https://ncst.ucdavis.edu/research-product/recommended-approach-use-cradle-gate-environmental-product-declarations-epds

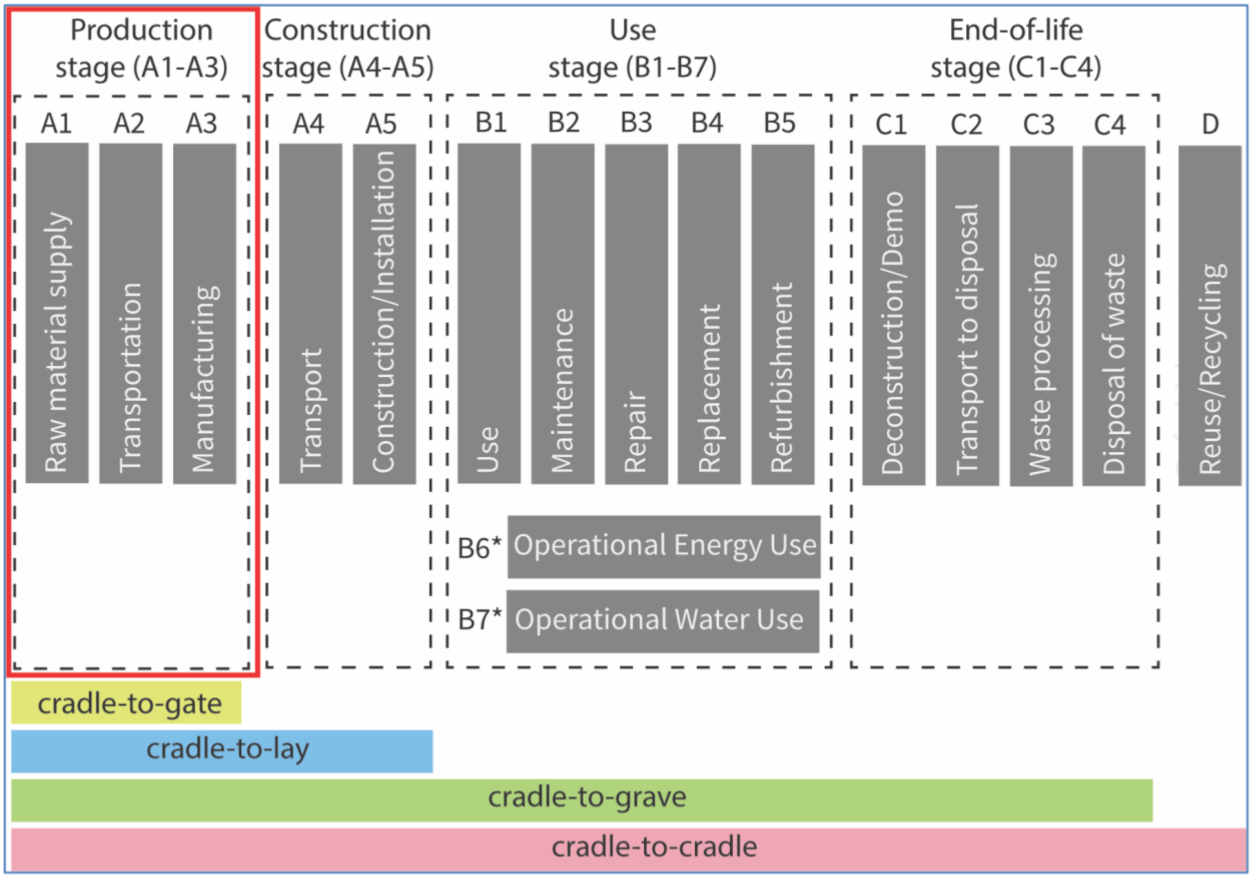

Figure 3. Life cycle stages that can be included in EPDs (from ISO 21930)

At this time, most EPDs for civil infrastructure materials in North America are only for the material production stage of the life cycle of the infrastructure, which includes sub-stages A1 through A3 shown highlighted in Figure 3. These are sometimes referred to as a "cradle-to-gate" EPD. In A1-A3 EPDs, the impacts are calculated starting from the extraction of raw materials from the earth and ending at the point at which the material (product) leaves the gate of the last manufacturing/processing location. Common civil infrastructure materials for which cradle-to-gate EPDs exist are cement, asphalt mixtures, concrete mixtures, steel, lumber, and aggregates.

The concrete, asphalt and steel industries have robust A1-A3 EPD programs that meet ISO standards and are ready to be used in public procurement programs in the USA[49]. Industries in the supply chain of asphalt and concrete mixes (binders, additives, admixtures, aggregate, among others) and steel product (fabricators, coating appliers among others) industries are also developing PCRs and establishing EPD programs to

[49] https://www.nrmca.org/association-resources/sustainability/environmental-product-declarations/; https://www.asphaltpavement.org/programs/napa-programs/emerald-eco-label; https://www.aisc.org/pressreleases/press-releases/epa-grant-supports-further-development-of-steel-industry-epds/ (there are a number of steel product categories and industry associations for them)

support the EPD programs for those which will enhance the comprehensiveness and precision of environmental emissions data available for public procurement.

A1-A3 EPDs are a key tool in the approach for introducing sustainability into a transportation infrastructure materials procurement program. Future steps in the use of EPDs in materials procurement are to expand their scope to additional stages that are within the control of a low-bid contractor (also called design-bid-build, the predominant form of contract for infrastructure work in the USA). The additional stages that the contractor directly controls are the transport of the material from the production site to the construction site (A4), the impacts from the construction (A5), primarily related to construction equipment use. The performance related properties of the materials and the construction quality (how the materials are placed during construction) influence the durability of the infrastructure which controls the timing and intensity of future maintenance and repair (B2 and B3) and the time to rehabilitation (B5, called refurbishment) and eventual replacement (B4). If the contractor produces or purchases materials that cannot be recycled in the future because something has been included in them or done to them that results in poor durability if reused in new materials, or makes it so they cannot be processed economically, or which produces worker, public, or equipment safety problems, it can be considered in stage D. For pavements, the constructed smoothness that is a result of the contractor's construction quality controls part of the pavement vehicle interaction, with rougher pavements causing additional fuel use and resultant emissions (B6 operational energy use). The contractor is also often responsible for demolishing and removing parts of existing infrastructure (C1 through C4).

Industry product category rules are being updated to consider A4 and A5, and the ideas for considering the other stages outlined above are being discussed. Inclusion of A4 and A5 also allows consideration of pavement maintenance, rehabilitation and reconstruction strategies that primarily involve recycling of materials in the existing infrastructure either in-place or using mobile equipment within or very near the construction site, which together are called "cold recycling"[50]. Public procurement to improve the sustainability of transportation infrastructure should be prepared to consider these expanded scopes as they develop, as future steps after following the approach based on A1-A3 EPDs discussed later in this white paper.

Life Cycle Cost Analysis

The same life cycle information used for environmental life cycle assessment (LCA) can also be used for life cycle cost analysis (LCCA). Life cycle cost analysis is typically done as part of comparing conceptual design alternatives, or in later phases of design to compare alternative design details. LCCA and project-level LCA in conceptual design are powerful tools supporting the selection of transportation infrastructure design alternatives that have both lower environmental impacts and better cost-effectiveness. Where lower

[50] https://dot.ca.gov/programs/maintenance/pavement/cold-recycling-main; https://dot.ca.gov/-/media/dot-media/programs/maintenance/documents/office-of-asphalt-pavements/469fdrpdr-guidestg6ada.pdf

environmental impact decisions will cost more rather than save money over the life cycle, the cost-effectiveness of different alternatives can be compared by using LCA and LCCA to calculate the life cycle cost per unit reduction in life cycle environmental impact. This is called comparison of "marginal cost of abatement", or in simpler terms comparison of "bang for the buck", and the life cycle cost and life cycle impacts are compared on what is called a "supply curve"[51]. This kind of comparison identifies the lowest cost alternative to achieve a desired environmental impact reduction, or it identifies the alternative that produces the maximum environmental impact reduction for a fixed amount of funding available.

Engineering Performance

It is essential that materials or infrastructure designs being compared for environmental impacts in procurement or project development have the same functional performance. Materials and designs that have lower initial environmental impacts but that do not meet engineering performance requirements put public safety at risk and require more frequent maintenance, rehabilitation, and replacement, which will likely cause increased GHG emissions over the complete life cycle.

Performance related tests and specifications

Engineering performance is assessed using performance related tests (PRT) and performance related specifications (PRS) set limits based on those tests. Use of performance related tests and specifications must be balanced with increased costs, time, and human and equipment capacity to do the testing. Testing and specifications need to focus on the properties of the material that have the most control of performance, i.e., how long the material maintains its functionality in each application. Examples are shown here for asphalt and concrete mixes for paving, concrete mixes for bridges and minor concrete, and steel.

The ways that asphalt mixes fail, and the typical performance related tests are listed here, along with a note regarding whether testing and specifications are included in Caltrans 2023 specifications:

- Rutting resistance, in 2023 standard specifications.
- Stiffness, not in 2023 standard specifications
    - For surface mixes, increases in stiffness with aging causing transverse, longitudinal and then block cracking, not directly addressed in the 2023 standard specifications, but considered in the PG asphalt binder specification. An update to the PG binder specification will also help address this question.

[51] https://www.mdpi.com/2071-1050/11/22/6377

    - For mixes used below the surface layer, increased stiffness improves wheelpath cracking (also called alligator cracking or fatigue cracking) which occurs only under heavy trucks and buses, not in the 2023 standard specifications.
- Wheelpath fatigue cracking is only important where there are heavy trucks and/or buses, and is not considered in the 2023 standard specifications.
- Moisture sensitivity is considered in the 2023 standard specifications.

Caltrans and industry with support from the UCPRC are evaluating adding performance related tests and specifications. Testing for asphalt mix properties related to the distresses identified above as not currently considered in the 2023 Caltrans standard specifications are being evaluated for potential inclusion or update in an updated asphalt mix specification, and are currently included in a non-standard special provision (except for fatigue, for which a fast and practical test is being developed).

The ways that concrete mixes fail, and typical performance related tests are shown here, along with a note regarding whether testing and specifications are included in Caltrans 2023 standard specifications:

- Concrete pavement mixes
    - Drying shrinkage causing cracking is considered in the 2023 standard specifications.
    - Flexural strength or compressive strength needed to resist cracking is included in the 2023 specification, with the type of strength specified depending on the type of infrastructure the concrete is being used for.
    - Coefficient of thermal expansion (CTE), which is important because high thermal expansion can cause cracking in pavement, must be measured in the 2023 standard specifications, and there is a limit for CTE for continuously reinforced concrete.
    - Alkali-aggregate reaction can cause extensive internal cracking, is included in the 2023 standard specifications.
    - Sulfate resistance, which is a reaction to soils leading to disintegration of concrete, is included in the 2023 standard specifications.
    - Reactivity of supplementary cementitious materials (SCM), which is used to check the ability of an SCM to replace cement to improve durability and to reduce environmental impacts, is included in the 2023 standard specifications.
    - Freeze thaw and salt scaling which damage the surface of concrete can be considered in cold regions.

- Concrete mixes for bridges use the same tests shown above with different values for the acceptable test results depending on the application, and also use the following tests:
    - Workability/finishability
    - Chloride permeability where deicing salts are used
- Concrete mixes for culverts, sidewalks and curb and gutter (minor concrete), typically rely on compressive strength, alkali aggregate cracking and sulfate resistance, and SCM reactivity, with different values for the acceptable test results depending on the application.

In addition, new performance related tests for concrete are being investigated and developed by Caltrans e.g., resistivity, resonance, and pozzolanic reactivity. The tests listed above and the new tests will be important for evaluating new concrete materials with lower environmental impacts. Caltrans has developed a concrete sustainability and performance roadmap that will help the Department move in this direction with some overarching guiding principles.

- Steel
    - Performance related tests and specifications are closely prescribed in the specifications and methods of testing associated with each type of steel product, such as reinforcing bar, steel plate, and others.

Cold recycling materials are used for full or partial depth in place or mobile plant recycling (called cold central plant recycling) of existing cracked asphalt, cracked cement stabilized bases, and underlying soil layers to create new base layers on which a thin layer of asphalt can be placed[52].

- Full depth recycling in place (FDR), performance related tests are included in the Caltrans 2023 standard specifications for the different types of stabilizer (the guidance document provides information on choosing the appropriate stabilizer).
- Partial depth recycling (PDR) in place, performance related tests are included in Caltrans non-standard special provisions.
- Cold central plant recycling (CCPR for full or partial depth), performance related tests are included in Caltrans non-standard special provisions.

The lists of example performance related specifications shown above show that there are systems for addressing engineering performance that are at least partially included in current Caltrans standard specifications or specifications that are under development through Caltrans non-standard special provisions. As procurement of new materials with

[52] Partial depth in place recycling was previously called cold in-place recycling (CIR), which one type of cold recycling. Guidance on cold recycling at Caltrans website https://dot.ca.gov/programs/maintenance/pavement/cold-recycling-main and in Caltrans guidance document https://dot.ca.gov/-/media/dot-media/programs/maintenance/documents/office-of-asphalt-pavements/469fdrpdr-guidestg6ada.pdf

lower environmental impacts moves forward, sufficiently comprehensive but simple and practical PRS will need to be incorporated into every day practice. Their use will need to be included in standard specifications, and their use will need to be resourced for both training of people who use and the equipment they will need. The investment is expected to produce a strong benefit to cost ratio.

Updated Design Methods

Pavement, bridge, and other transportation infrastructure will not include new materials with lower environmental impact until and unless the design methods for that infrastructure consider them in such a manner that designers do not have to treat them as "special".

For pavement, this primarily means use of mechanistic-empirical (M-E) design methods or simple to use tools developed from M-E such as catalogs. M-E design methods allow the relatively rapid (<2 to 5 years) inclusion of new materials, as well as changes in truck traffic, changes in climate, and new types of pavement structure. Changes can be made rapidly in M-E design methods based on laboratory testing, modeling, and targeted empirical validation using accelerated pavement testing, test tracks, and pilot projects. The initial implementation of a new material or pavement structure in an M-E design method is then adjusted as longer-term performance data become available, typically from pavement management systems. This is compared with the 10 to more than 20 years needed to update purely empirical design methods because they rely only on observed longer-term performance.

The need for M-E or M-E based pavement design methods that can consider new lower impact materials in routine use has been met for Caltrans and is being put into place for California local governments. For asphalt surfaced pavement, including cold recycling, in California this means use of Caltrans' CalME[53] or the newly developed catalog of CalME designs nearing completion for routine use by local governments. For concrete pavement, this means the use of AASHTO Pavement ME, or Caltrans' simplified catalogs[54] based on Pavement ME and calibration, or the use of the ACPA's PavementDesigner for local government design of lower traffic volume streets and roads[55].

For bridges, which are primarily designed using reinforced concrete and/or steel materials, Caltrans design methods are periodically updated to consider new lower environmental impact materials. Caltrans has considered use of SCMs in concrete for more than 20 years, originally because of their greater durability, and now considering environmental

[53] https://www.ucprc.ucdavis.edu/calme/. Caltrans users contact the Caltrans Office of Asphalt Pavement at Raghubar.Shrestha@dot.ca.gov; other users contact the UCPRC at rzwu@ucdavis.edu
[54] https://escholarship.org/uc/item/54w74550
[55] https://www.acpa.org/expert-help/pavementdesigner-org/

impacts as well. Continued updating as a faster pace of change occurs within concrete materials will be needed in the future.

Design methods for Caltrans and local government "minor concrete" features such as sidewalks, curb and gutter, culverts, and other roadway features typically require a small set of concrete properties as input. Caltrans minor concrete material specifications allow use of lower impact materials. However, very few California local governments have adopted Caltrans materials specifications, or simplified specifications developed for local government that achieve the same goal[56]. In fact, the minor concrete materials specifications of many local governments actually result in shorter lives and higher initial costs than Caltrans specifications because they have not been updated with new information in decades and contain provisions such as minimum cement contents[57].

Scalability

It is important that attention in public procurement primarily be placed on materials and designs that have sufficiently widespread availability to be able to scale to meet an agency's infrastructure needs or major portions of them. For example, attention should be placed on materials that have or can be scaled up to have sufficient raw materials (feedstock materials) to supply a significant percentage of the procurement needs of the agency. Other constraints on scalability are transportation of materials (locally sourced to minimize A2 and A5 transportation impacts), energy sources that might be needed, and complexity of required construction practices. Construction requirements that are too complex or which required too much expensive equipment may be difficult to scale within the agency's pool of contractors or which might be barriers to entry to the agency's procurement pool by new contractors or contractors from outside the region. The ability to scale is more important to consider when evaluating new materials than is current availability. Industry will scale up production if a sufficient market signal is given by the agency and there are no constraints in their supply chain.

Market Signals

The market signals that need to be provided by the procuring agency to drive a more sustainable public procurement program are:

- A sufficient incentive rewarding contractors who use lower environmental impact materials that meet engineering performance requirements for a specific application and functionality, or in the future that meet the requirements of expanded scope EPDs (as discussed previously). Disincentives can be used

[56] https://www.ucprc.ucdavis.edu/ccpic/PDF/CCPIC_4-pgr_conc%20mix%20specs_final_21Jun2019.pdf and https://www.ucprc.ucdavis.edu/ccpic/pdf/CCPIC%20Model%20Concrete%20Paving%20Spec%20v5.1%20(11-02-20)%20for%20posting.docx
[57] https://www.ucprc.ucdavis.edu/ccpic/PDF/CCPIC_4-pgr_conc%20mix%20specs_final_21Jun2019.pdf

alternatively or with incentives, with the ultimate disincentive being denial of ability of a contractor to use a high impact material.

- A sufficiently large percentage of the projects that include the specifications for lower environmental impact materials and require EPDs to quantify those impacts put out to bid by the agency (and other agencies competing for the attention of the same contractors in the region).
- A level playing field and flexibility for contractors and material suppliers to innovate and demonstrate both reduced environmental impacts and meeting or exceeding engineering performance requirements. This is facilitated by using performance related specifications supported by performance related tests, in contrast to prescriptive specifications that prescribe specific materials or how materials are to be designed and produced.
- Transparency and simplicity in how EPDs and engineering requirements are implemented and used. Feedback from stakeholders, communication, and timely improvements in the procurement process as lessons are learned is a part of this.

The development by transportation infrastructure industry associations of programs to publish EPDs for use in procurement and their efforts to reduce the costs and difficulty of producing EPDs will help industry move forward. The EPA's low embodied carbon label program that is under development is another potential opportunity to simplify procurement decisions[58].

This basic approach is conceptually summarized in Figure 4[59]. In the figure, a goal is shown for achieving near to zero CO_2-e emissions soon after 2050. To meet that goal, an initial benchmark value (solid line) is set based on the average emissions from current practice and thresholds are set for increasing incentives for materials with EPDs showing decreasing emissions below the average, and for increasing disincentives for materials with EPDs showing increasing emissions above the average. Alternatively, the system may be set up with only disincentives or only incentives. As materials technologies are improved and implemented for reducing emissions while maintaining same or better engineering performance, the average and thresholds for incentives and/or disincentives are periodically updated (the figure shows updating every five years).

[58] https://www.epa.gov/greenerproducts/label-program-low-embodied-carbon-construction-materials
[59] Adapted from discussion of results of FHWA Global Benchmarking Study on Green Public Procurement, presented at FHWA Sustainable Pavement Technical Working Group, Baton Rouge, LA, 25 April 2024.

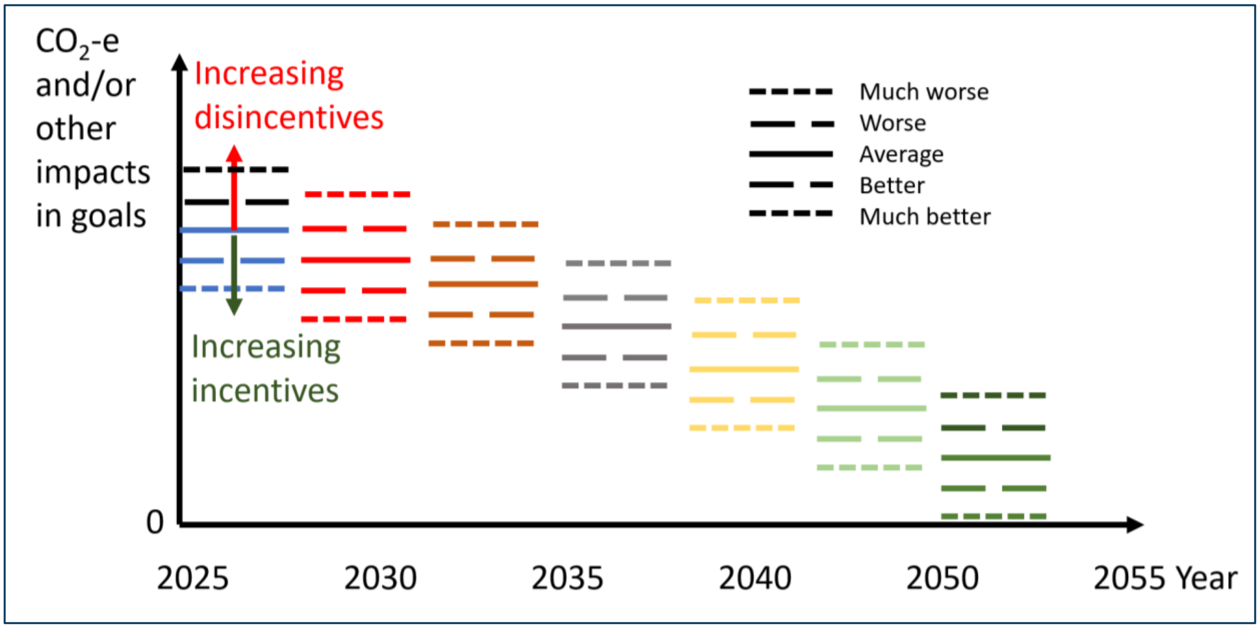

Figure 4. Illustration of approach for systematic reduction of environmental impacts through the use of EPDs, benchmark averages and thresholds

Note: all procurement must meet engineering performance requirements for the functional group

Recommended Approach

Based on the discussion presented up to this point in the white paper, the recommended approach to improve sustainability in transportation infrastructure through public procurement consists of the following:

- Set goals for reducing environmental impacts and finite resource use need to be to set.
    - Goals will come from legislation, regulation and agency policies.
- Quantitative approaches for assessing products used for infrastructure need to be used in routine practice, with practices summarized from a previous white paper[60]:
    - Use A1-A3 EPDs as the quantification tool for materials; consider use of project carbon (and other impacts depending on goals) budgets giving contractors flexibility to meet the overall budget with different combinations of materials.
    - Move to expanded scope EPDs as PCRs with expanded scopes are developed by industry.

[60] https://ncst.ucdavis.edu/research-product/recommended-approach-use-cradle-gate-environmental-product-declarations-epds

- Identify functional groupings within each material type and later the type of pavement infrastructure work based on agency specifications for different applications.
    - Update specifications to include sufficient performance related specifications based on sufficient performance related testing to produce a low risk of accepting materials and later expanded scope infrastructure work that will require more frequent future work.
    - Quickly identify and move to implementation new lower impact materials using a stepwise engineering performance review process, beginning with laboratory performance related testing, followed by small scale construction, then pilots, and finally implementation in standard practice. Evaluate environmental claims for new materials starting with LCA when at laboratory scale testing, and requiring an EPD at the pilot scale evaluation. Develop provisional information needed for standard practice, including specifications, inclusion in structural design methods, testing capacity, and guidance, when moving from small scale construction to pilot scales, and finalize information when moving from pilot scale to standard practice[61].
- Calculate incentive and/or disincentive thresholds for each functional group of materials for the environmental impacts of interest (typically greenhouse gas emissions), and periodically update them with new information.
    - Set benchmarks based on agency or other local data based on averages of current practice and additional thresholds for better than average impacts.
    - Benchmarks can be calculated using EPDs if a sufficiently large set of locally applicable EPDs have been collected to provide a representative set for statistical calculations. Until a sufficiently representative set of EPDs can be collected, benchmarks can be calculated using other data the agency has, such as job mix formulas for A1 and materials sourcing distances to calculate A2 transportation distances. National data are from industry associations are available regarding A3 manufacturing impacts. Different industries (concrete, asphalt, steel) have published data or emissions factors that can be used with the agency's job mix formulas and other data for different stages.
    - Benchmarks should be adjusted at least every two years. They may show a lack of improvement (get worse) at the beginning if the initial data set used to calculate them was not sufficiently representative and primarily included the cleanest producers.
- Market signals
    - Require submittal of plant and material specific EPDs, preferably referencing the engineering performance specifications that they meet. EPD

[61] This approach has been called "Lab2Slab2StandardPractice" and is documented in a soon to be published Caltrans research report.

    - specifications should require production information for the product so that the agency can use production weighting to calculate benchmarks and thresholds.
    - Put a price on the value of impacts for which the agency has goals, and use the price and the benchmark average and better than average threshold values to apply a disincentive and/or incentive price to the materials and later expanded scope of work provided by the contractor and their suppliers.
- Communication and feedback loop
    - Communicate early with stakeholders regarding the goals and approach to be used, particularly contractors and their suppliers, so they can understand the rules and how the approach will operate. Consider feedback from stakeholders regarding details to make the program more fair and transparent.
    - Review progress, problems to solve, and feedback from within the agency and from stakeholders outside the agency to adjust the program as needed to solve problems.
    - Communicate the benefits of improvements in environmental impacts and co-benefits identified in this white paper as the arise. Be honest when there is less than complete success including identification of the reasons why. Transparency builds trust.

Recommended Public Procurement Program Elements

The recommended elements of a public procurement program to use the approach described above and to meet the goals of continually decreasing environmental impacts, keeping or improving infrastructure safety and functionality, and achieving these goals cost-efficiently are briefly summarized in the following[62]:

Goal and Scope Setting. The agency's goals should be identified and the scale of effort for the activities needed for the selected scope, including how many materials, how many projects, what quantities of materials, and how much effort is needed for education and outreach and to develop new specifications, testing capabilities, and quality assurance processes.

Upper Management Buy in. Goals, benefits, and co-benefits, scope, schedule, cost and funding, risks and risk management, and internal and external resources need to be identified and communicated with relevant management sponsors and stakeholders, and questions need to be answered to obtain a "charter" to move ahead.

Cross-Division Team and Program Manager. A headquarters (HQ) program manager who manages a cross-division team can facilitate coordination and communication within HQ

[62] Adapted from: https://ucprc-public.s3.us-west-1.amazonaws.com/sppcc/LCTM_Pathways_FHWA.pdf

programs and offices and through the line functions to their counterparts in the district(s) involved. This team should also handle communication with upper management sponsors and coordinate communication with industry.

Dedicated Staffing and Support Resources. Identify staffing and support resources implement the activities in the approach on an ongoing continuous improvement basis. Identify agency staff, and consultants and academic institutions to support agency staff to establish and then which of those resources will be needed to maintain the public procurement operations. Programs will not be as successful if the additional green procurement work is just added to existing workloads.

Materials and Later Infrastructure Work to be Included. Identify materials and material types for inclusion in the public procurement program. This identification process will involve reviewing current high-volume materials used, identifying currently used but underutilized potential low carbon materials (LCM), and identifying new materials that are potential LCMs. All materials should be covered by a product category rule (PCR) that governs the production of the material type, under environmental product declarations (EPD) can be produced. PCRs for asphalt and concrete can handle new configurations of materials and materials with new types of constituents. Information is available from the FHWA asphalt[63] and concrete[64] cooperative centers for LCTM material types and from the national concrete[65] and asphalt[66] industry PCR organizations for each material regarding the range of materials covered under their PCRs. Similarly, information is available from the steel[67] industry PCR organizations. Later this can be expanded to different types of infrastructure work that have expanded scope EPDs.

Outreach and Education for Industry and Within the Agency. An outreach and education program is needed for an agency to reinforce crucial topics including: the agency goals, benefits and co-benefits, establishment of processes, materials considered, updated or new specifications implementation, risk management, EPDs and the role of using EPDs, benchmarking processes, and the role of threshold values in specifications, among others. Similarly, outreach and education are needed for industry regarding goals, opportunities for industry, benefits and co-benefits for both the agency and industry, how the agency will be implementing the program, material types, performance evaluation, quality assurance requirements, program implementation schedule, and risk management. These types of outreach are opportunities to receive feedback from within the agency and from industry.

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[63] Contact Elie Hajj, University of Nevada, Reno elieh@unr.edu; https://www.fhwa.dot.gov/pavement/asphalt/coopmaterials/

[64] Contact Peter Taylor, Iowa State University ptaylor@iastate.edu; https://cptechcenter.org/research/in-progress/advancing-concrete-pavement-technology-solutions/

[65] National Ready Mix Concrete Association, Matthew LeMay, mlemay@nrmca.org, 847-323-0413.

[66] National Asphalt Pavement Association, epd@asphaltpavement.org, 888-468-6499.

[67] American Institute of Steel Construction - Max Puchtel, puchtel@aisc.org

EPD Collection. Some examples are available regarding EPD collection from state and local agencies already collecting them and current practice for specification, and recommendations for the future are in the NCST EPD white paper previously cited[68] and from the FHWA[69]. The minimum material type quantities or costs per project should be identified below which EPDs are not collected because the benefits are not sufficient compared with the cost of applying the public procurement approach. A few State DOTs[70] have experience setting these cutoff limits. Develop the system to receive and review the EPDs for acceptance. Some DOTs have been able to adapt their existing material testing data submission systems to collect EPDs.

Benchmark Average and Better Than Average or Worse Than Average Threshold Values. Threshold values are set to implement the disincentive (for worse than average values) and/or incentive (for better than average values) program. Agencies can as a minimum use national benchmarks being prepared by each industry (i.e., asphalt, concrete, steel), but are highly encouraged to set benchmarks based on state-wide or regional collection of EPDs because of inherent differences in embodied carbon in different parts of the country caused by factors such as electrical grid supply sources, climate, availability of materials, and local specifications. The national industry organizations are producing benchmark averages and threshold values on climate region or state levels, and with some minimum considerations of functional groupings based on engineering performance requirements. These can be greatly improved on in terms of the information used to calculate the impacts, the engineering requirement functional groupings, and the use of agency purchasing data to mass or volume weight the benchmark average and threshold values. Industry organizations have collected EPDs for many states. It should be noted that the sample of EPDs that have voluntarily been published by national organizations will likely tend to have better values ("lower embodied carbon emissions") than EPDs collected under a requirement that all producers must report values, not only those who voluntarily have decided to publish their values.

Materials Specifications Development or Updates. Updating specifications to include performance related testing will facilitate benchmarking of the engineering performance of current materials and produce data for comparison of current materials with new LCM materials. This will provide confidence regarding the expected performance of LCMs. This is also an opportunity to update specifications for current materials to ensure implementation of best practices, including performance related testing[71] and metrics.

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[68] https://www.fhwa.dot.gov/pavement/sustainability/epds/; https://ncst.ucdavis.edu/research-product/recommended-approach-use-cradle-gate-environmental-product-declarations-epds; see Colorado and California EPD specifications as example.
[69] https://www.fhwa.dot.gov/pavement/sustainability/epds/
[70] CDOT and Caltrans examples: https://www.codot.gov/business/designsupport/materials-and-geotechnical/epd; https://dot.ca.gov/programs/engineering-services/environmental-product-declarations;
[71] For acquiring testing equipment, please see response to FAQ EM-Q3; Can an applicant request funding under this Program to acquire materials testing equipment? here: https://www.fhwa.dot.gov/lowcarbon/faq.cfm

Any performance related testing equipment, training, and test strips necessary for evaluation of LCMs should be identified in initial scoping of implementation of the public procurement program.

Projects for Implementation. As implementation is begun, early identification of projects will facilitate communication with district project managers and materials and construction staff, finding champions/leads in the DOT and industry, and identifying and mitigating risks. Identifying projects that have not been let yet can also facilitate inclusion in a project, through the PS&E (plans, specification and estimates) package or bid package. Identification and communication about how any additional agency, state or federal funding available to support implementation will be used to compensate project budgets, and district and HQ costs should be done as soon as possible.

Performance Monitoring. Performance monitoring for evaluation of infrastructure built using the materials and later expanded scopes of infrastructure work will help ensure correspondence of materials constructed in the field with initial testing and assumptions of performance, and along with construction documentation provide lessons learned for the future.

Implementation Strategies from Getting Started to Complete Build-Out

Agencies can consider different strategies for beginning of a public procurement program to reduce environmental impacts, from beginning on a few projects for one or more materials, to planning and implementing a complete program from the start. The appropriate strategy depends on the goals and the strength of the mandate and support from upper management, the resources that the agency can realistically bring to bear, and the risk tolerance. Risk tolerance should consider the risk of business as usual, including not achieving the potential co-benefits, as well as the risk of moving ahead.

Final Thoughts

A faster pace of change is needed to achieve the goals for reducing environmental impacts that the pillars of our quality of life depend on, including health, safety, and protection of the investments made by generations. Every sector of the economy will need to make their contributions towards their goals. This white paper lays out a recommended program developed over the last several decades for the transportation infrastructure sector to increase its pace of change in making those contributions through the use of low carbon materials and materials intended to additionally meet other environmental and finite resource goals.

Data Summary

Products of Research

This white paper presents motivations, useful information, and a recommended approach for implementing a public procurement program for transportation infrastructure, beginning with materials and late expanding to other stages of the infrastructure life cycle. The white paper presents analysis based on information from the author's experience and information from published sources available through the internet, a few of which are journal articles.

Data Format and Content

Data for this study is bibliographic in nature and can be found in the footnotes.

All URLs were accessed between June 1 and August 28, 2024.

Data Access and Sharing

The information collected is completely based on publicly available information cited in the footnotes, and one small example that is demonstrated in the body of the text.

Reuse and Redistribution

The information used in the white paper is available to all readers, as they are available on publicly available internet sources.