The City of
OKLAHOMA CITY

Enhanced Pavement Management Program Pilot
Strengthening Mobility and Revolutionizing Transportation (SMART)
DOT-SMART-FY22-01

Overview/Project Description

The City of Oklahoma City proposes an Intelligent, Sensor-Based Infrastructure project via SMART to improve operations and maintenance by using sensors to monitor conditions of pavement quality as part of an Enhanced Pavement Management approach. The American Public Works Association (APWA) defines pavement management as "a systematic method for routinely collecting, storing, and retrieving the kind of decision-making information needed to make maximum use of limited maintenance (and construction) dollars"; while the City of Oklahoma City presently has a pavement management program, SMART is an opportunity to assess, investigate, and potentially enhance our existing program to recognize operational and financial efficiencies that also afford substantive benefits across the transportation network.

Oklahoma City is one of the largest cities by land area in the United States; we are a municipality that crosses into four counties – Oklahoma County, Canadian County, Cleveland County, and Pottawatomie County – and, per Census 2020 data, we are now the 22nd most populous municipality in the country. However, these residents are spread across 621 square miles, an extraordinary size so vast we can fit within our city limits the combined land areas of South Bend, Berkeley, Fort Lauderdale, Miami, Boston, Anaheim, San Francisco, Providence, St. Paul, Minneapolis, Pittsburgh, Tempe, Newark, Buffalo, and Oakland.

Our transportation infrastructure is commensurate: more than 3,592 miles of roadway outfitted with 765 signalized intersections and 51,275 traffic control signs plus a network of interstates (including six interstate interchanges, including the "crossroads of America" at I-35 and I-40); a forthcoming 9.5-mile bus rapid transit route with 32 platform stops; 22 streetcar stops across 4.8-miles of streetcar track; 52 electric-assist bikeshare bicycles; 1,313 fixed-route bus system stops across 21 routes serving 283 square miles with annual ridership greater than two million; and an expanding mileage of bicycle and pedestrian facilities both on- and off-street throughout Oklahoma City. According to FHWA's Highway Statistics 2020, the Oklahoma City urbanized area ranks 44th for total roadway miles among 69 urbanized areas across the United States; however, when ranked per miles of roadway for every 1,000 residents, the Oklahoma City urbanized area jumps to 7th rank.

Technologies have afforded new opportunities for pavement collection data including ground penetrating radar (GPR), traffic speed deflection devices (TSDD), unmanned aircraft systems (UAS), and crowdsourced data. The City's present pavement management program relies on, as it has since 2006, the hiring of private consultants to determine the condition of streets and roads. While this was initially done via observation, Oklahoma City began using an inertial profiler to capture International Roughness Index (IRI) data which is then converted into Pavement Condition Index (PCI). The City utilizes the PCI standards developed by the Army Corps of Engineering "further verified by DOD and APWA" per ASTM D6433-20, "Standard

Practice for Roads and Parking Lots Pavement Condition Index Surveys," and any prospective technology or programmatic change should be in compliance with those standards.

Due to the City's size, half of Oklahoma City's 621 square miles is driven each year and with it updated PCI conditions. However, this method is admittedly costly; because of Oklahoma City's sheer size, collecting IRI/PCI data is structured so one half of the City is driven and new data collected every year, meaning it takes a full two years before an entirely new regime of pavement condition data. This data collection is currently performed as a contractual rate of $500,000 per half of the City. At no point in time is the City operating with up-to-date, much less real-time, pavement condition data for the entire city; the end result has been a prioritization of arterial streets and roads rather than residential or neighborhood resurfacings, which are costly, time-consuming, and generally spread across large areas and thus may not be as robustly evaluated as arterials.

Nonetheless, this IRI/PCI data collected is already made publicly available and updated through the City's open data portal at data.okc.gov on a GIS-based map of Oklahoma City. FHWA's Pavement Management Roadmap recognizes that the "method used to collect pavement condition information has a significant impact on data quality" (page 10); Oklahoma City would benefit from the opportunity to more closely assess automated pavement condition assessment technologies as they have demonstrated improved measurement accuracy, shortened time for data collection, and improved rating crew safety. It is important, however, that irrespective of the data collection method, the data itself must be reliable. Data quality is arguably the single most critical component of a Pavement Management System and thus its prominent role prior to scaling a prospective project across 621 square miles.

Indeed, Oklahoma City has in the past made use of various data collection methods – the aforementioned inertial profiler, mobile LiDAR imagery, and datasets purchased from private entities – our need is to determine how to best structure an Enhanced Pavement Management program at the City; how to reconcile past data and processes with any potential new data or new processes; functional efficiencies, if any, to be gained by differing approach between arterial resurfacing and residential resurfacing; a conceptual map of "when" and "where" to target interventions based on deterioration curves as a preliminary effort to capture real-world conditions; costs associated with program development, program execution, program planning, staffing, equipment, and, eventually, an estimate on needed staff; and recommended amounts of attic stock for equipment with maintenance and long-term costs as a consideration.

Pavement is one of the most ubiquitous features of our built environment and, as such, its maintenance has significant cost impacts. For example: estimates of Oklahoma City surfacing parking lots alone are around 4% of total land area, greater than the portions of Oklahoma City covered by lakes. The utilization of technology to refine and enhance pavement management offers a clear and present opportunity to advance community technologies and systems to improve transportation efficiency and safety.

Project Location

Per the NOFO, a demonstration project location has yet to be determined. While there is no dearth of pavement across Oklahoma City, location criteria will need to be developed in conjunction with the selected platform or technology. Area traffic counts will be integral as will consideration of nearby land uses/activity centers, existing pavement condition, climate/seasonality factors, and the confluence of modes in a given area (e.g. pedestrians, cyclists, and transit).

Community Impact

One of the reasons SMART presents such a significant opportunity for Oklahoma City is precisely because the scale of benefits likely to flow from an Enhanced Pavement Management approach are substantial. Every mode of transportation, whether motorized or unmotorized, would benefit from better managed pavement writ large. Many of the benefits discussed in the section for the third Technical Merit Criterion, "Expected Benefits," address wider community impacts such as the SMART grant program priorities discussed in the NOFO, but serve as examples of community impact, including safety and reliability, reduced emissions, and improved travel time even for residents outside of Oklahoma City.

Oklahoma City residents themselves, however, have identified pavement condition not merely as a major concern, but the number one concern. Since 2005, the City of Oklahoma City has commissioned 16 scientifically significant Citizen Surveys to poll residents on their opinions of, perceptions of, and needs from the City including services and infrastructure. Throughout all 16 surveys, the most recent of which was conducted in 2022, residents have overwhelmingly ranked "condition of City streets" as their single-highest priority and, as such, have expressed dissatisfaction with the condition of City streets.

Improved pavement management could impact the community positively, too, by affecting their transportation costs. In the National Cooperative Highway Research Program's report "Guidebook for Assessing the Social and Economic Effects of Transportation Projects," consideration is given to benefits associated with vehicle operating costs (VOC). VOC savings can be derived from improved roadway conditions which impose less stress on vehicles; the three primary variables are road attributes, such as roughness; vehicle attributes, such as the weight and operating characteristics of the vehicles themselves; and regional factors, which includes considerations such as speed limit, fuel prices, relative prices of new vehicles, parts and labor, stage of technological development, and driver training and driving attitudes. The report states explicit projects "that make improvements to road surfaces, including rehabilitation and resurfacing efforts, reduce VOC due to the smoother road traveling conditions" (page 43).

Technical Merit Criterion #1: Identification and Understanding of the Problem to Be Solved

The objective of the City is to develop a logical, well-planned, and cost-effective pavement maintenance approach to stretch public funding and allow more streets to be repaired. The City and its residents have both identified and understand well this problem. For example, residents can file claims against the City of Oklahoma City to be heard by City Council; many of these claims are, in fact, for vehicle damage sustained from the poor condition of City streets. An ad hoc analysis was conducted for approved claims paid out by the City to Oklahoma City residents as reimbursement for damage to vehicles caused by potholes; the agendas of all Oklahoma City Council meetings held during calendar year 2021 were reviewed and all approved vehicle damage claims logged. In total, across 29 meetings there were 58 claims approved for a total of $21,372.09.

From fiscal year 2018 to 2021, the City of Oklahoma City's Public Works Department reported a cumulative expenditure of approximately $291 million in the combined category of "resurfacing and widening"; during that same four-year period, however, arterial streets and residential streets were measured to determine the percentage of each with a PCI of 70 or greater. Arterial streets of 70 or above increased nine percentage points (32% to 41%) while residential streets 70 or above increased just two percentage points (62% to 64%) in those four years. Many of these projects were funded by the Better Streets, Safer City program, a temporary one-cent

sales tax overwhelmingly approved by Oklahoma City voters in the fall of 2017; other funds for resurfacing and maintenance also originated from two prior general obligation bond election.

First, in 2007, Oklahoma City voters approved an $835.5 million package that included a proposition devoted solely to streets at a total of about $529 million. Of that total, about $350 million went to 75 resurfacing projects at a cumulative cost of $152 million and 75 reconstruction projects at cumulative cost of $196.5 million; these combined 150 projects represent about 66% of $529 million as they exclude about $180.5 million for road widenings.

Oklahoma City voters overwhelmingly approved another general obligation bond in 2017, this time for an overall $967.4 million. Significant public engagement processes were undertaken and, among the findings, the two most important topics for Oklahoma City residents in considering the City's general obligation bond were "sidewalks" and "resurfacing," with the vast majority of respondents identifying "streets, bridges, and traffic control" as their top priority among nine. A single proposition included 179 resurfacing projects – 159 arterial, 23 residential – at a cost of approximately $294 million. Despite the disproportionate number of arterial street projects to residential street projects, the cumulative cost of those 159 arterial projects is about the same as those 23 residential projects; while arterial street project costs averaged about $994,000 the residential street project costs averaged about $6 million, or nearly half the overall $294 million total.

Both the temporary Better Streets, Safer City sales tax extension and the voter-approved propositions from the City's general obligation bonds provided significant funding to pavement management, but the costs of road widening and road resurfacing projects continue to mount so much so that ongoing maintenance, which is predominately funded via the City's General Fund, would require an indeterminate but undoubtedly substantial allocation. If a sustainable method of pavement management can be determined, it can move Oklahoma City closer to a sustainable funding source; this will only become increasing vital as Oklahoma City continues to grow.

With a crude population density of just over 1,000 per square mile; a growing population (between 2010 and 2020, Census data reflects added population of 117,483, a percent increase of about 21%); greenfield development expanding urbanization into Oklahoma City's rural areas, adding substantially higher average annual daily traffic counts causing many rural roads to degrade more quickly and thus require more frequent interventions. Thus, one of our challenges is the sheer size of Oklahoma City and its transportation network. Oklahoma City is expected to grow through 2050 with as many as 300,000 additional residents to the population, and with them, the challenges of added lane miles, greater transit service demand, increased congestion, increased vehicle miles traveled, increased emissions, increased freight traffic, and increased maintenance needs for our roads and streets. Thus, enhancing Oklahoma City's pavement management with technologies that better capture the condition of pavement data combined with a program design that can better enable City workers to connect an intervention with condition to achieve cost savings while prohibiting significantly costlier downstream interventions.

Technical Merit Criterion #2: Appropriateness of Proposed Solution

Sufficient technological development has occurred in the pavement management practice, as evidenced by programs such as those at the City of Lexington, Tennessee, the recent pavement condition RFQ published by the Akron Metropolitan Area Transportation Study MPO, and the North Florida Transportation Planning Organization; the benefits realized by such respective communities indicates good reason to anticipate public benefits from their application in Oklahoma City. Moreover, scale must be a consideration, not just with regard to the applicability of technology but as part of the challenge given Oklahoma City's 621 square miles and low population density.

Pavement management programs generally include the same fundamental six steps: (1) assessment of inventory, where it is determined what and where will be assessed; (2) pavement inspection, or the initial process of collecting raw condition data irrespective of methodology; (3) condition assessment, whereby the raw condition data is quantified via a numerical indicator (i.e. Pavement Condition Index, International Roughness Index, etc.) to establish a unified form of express suited to comparative analysis; (4) condition forecasting, where standard degradation curves are used to anticipate deterioration for the purposes of proactively planning interventions; (5) scenario modeling, and (6) capital improvement planning, with these latter two harnessing data to look ahead and plan operationally and financially for forward-looking interventions and, for Oklahoma City's purposes, would likely be applicable to a ten-year general obligation bond planning process or another similar major capital campaign. While it may not be feasible to reach such an end stage goal through SMART, Enhanced Pavement Management should ultimately inform proactive management insofar as a tool to maintain an overall high citywide PCI rather than a tool that provides an unforeseen PCI benefit outside of a larger strategy or campaign.

Technical Merit Criterion #3: Expected Benefits

Oklahoma City's proposed Enhanced Pavement Management is likely to generate a wide range of expected benefits and, based on those identified in the NOFO and BIL, are likely to deliver benefits in the following ways. Enhanced pavement management would yield **safety and reliability** benefits; for example, 2015 research published from the *Journal of Transportation Engineering* titled "Effects of Pavement Surface Conditions on Traffic Crash Severity," found "poor pavement condition increases the severity of multiple-vehicle crashes on all roads," and research published in a 2013 edition of *Accident Analysis & Prevention* titled "Impact of Pavement Conditions on Crash Severity" found "poor pavement condition scores and ratings were associated with proportionally more severe crashes."

Pavement management can contribute significantly to **resiliency**. In October 2020, the South Central Climate Adaptation Science Center conducted downscaled climate projections specifically for the City of Oklahoma City using NOAA's Geophysical Fluid Dynamics Laboratory; findings included that the "average annual high temperatures for the period from 2036-2065 are projected to increase by about 2° F … to about 5° F for the high-end scenario above the historical annual average high temperatures from 1981–2005 … [b]y mid-century, projections indicate there will be about 13 to 28 more very hot days on average per year for Oklahoma City … [o]n average, OKC currently experiences ~9 very hot days on an annual basis. More very hot days will significantly impact human health and comfort, as well as put strain on city infrastructure such as cooling systems, road surfaces, and water resources (NCA 2014)." Oklahoma has experienced 98 weather and climate disasters between 1980 and October 2022 that each did an adjusted-for-inflation damage total of at least $1 billion. Overwhelmingly, these billion-dollar disasters are categorized as "severe storm" to NOAA given they produced wind gusts of at least 58 miles per hour and/or hail of one inch in diameter or large and/or a tornado. The four counties Oklahoma City stretches into have all experienced their own disaster declarations too since 1953: Oklahoma County (47), Canadian County (39), Cleveland County (40), and Pottawatomie County (40). With expectations of more intense heat, the increased possibility of inundating rainfall events, and the region's frequency of severe storms, the need for enhanced pavement management additionally affords more active response to impacts from natural hazards and harsh conditions, providing an additional dimension of safety and reliability benefit, too.

As far as **equity and access** benefits, research published by the national transportation research nonprofit TRIP in 2017 found "79 percent of major locally and state-maintained roads

in the Oklahoma City urban area are in poor or mediocre condition, costing the average motorist an additional $832 each year in extra vehicle operating costs, including accelerated vehicle depreciation, additional repair costs, and increased fuel consumption and tire wear. Statewide, 45 percent of Oklahoma's major locally and state-maintained urban roads and highways have pavements in poor condition and 29 percent are rated in mediocre condition. Twelve percent of major urban roads are in fair condition and the remaining 14 percent are rated in good condition." Additionally, the National Cooperative Highway Research Program (NCHRP) assessed models estimating the effects of pavement conditions on vehicle operating costs; NCHRP determined any increase in pavement roughness, irrespective of vehicle type or pavement type, is associated with operating costs in two ways: (1) fuel consumption and (2) vehicle repair and maintenance. Any 1-point change in the IRI scale affects fuel consumption by approximately 2% for passenger/light duty vehicles and 1-2% for heavy trucks; for vehicle repair and maintenance, any 5 IRI point change affects costs by 40% for passenger cars and 50% for heavy trucks. Thus, enhanced pavement management could offer benefits by reducing the cost of motorized travel through targeted, proactive pavement condition interventions.

This relates to **climate** benefits, too, as another study, "Pavement Roughness and Fuel Consumption," was published by the Concrete Sustainability Hub at MIT in 2013, sponsored by both the Portland Cement Association and the Ready Mixed Concrete Research & Education Foundation. This research made use of the Federal Highway Administration's own Long Term Pavement Performance (LTPP) data, and similarly found "roughness alone contributed to the consumption of an additional 30,000 gallons per mile for the representative road section over the study period … [t]his equates to the cumulative release of 300 tons of CO_2 per mile of pavement." Per the U.S. EPA's National Emissions Inventory data, CO_2 emissions in Oklahoma County, where the majority of Oklahoma City resides, are the highest in the state for mobile, on-road, non-diesel light duty vehicles. Additionally, there could be opportunity to overlap with the research award from FHWA as part of the Climate Challenge Initiative, which awarded a $283,448 grant to the Oklahoma Department of Transportation for a pavement project titled "Evaluating the Broader Impacts of Balanced Mix Design (BMD) and Warm Mix Asphalt (WMA) Specifications and Incentives in Oklahoma through a LCA Framework."

Partnership benefits can be achieved because the City of Oklahoma City enters into specific project-based agreements as well as general mutual cooperation agreements with County Commissioners from the counties that make up Oklahoma City's 621 square miles. These formal agreements, approved by City Council, permit collaboration on street improvements "to streets common" to both the respective County and Oklahoma City, including "grading, drainage and hard surfacing for the safety and benefit of the citizens of Oklahoma City and" the respective County.

Lastly, pavement management affords **integration** benefits as it is the very physical and geographical site of mode integration; be it vehicles, pedestrians, bicyclists, or the broader traveling public, the pavement is the stage upon which all users are set and is thus uniquely vital to the safety, reliability, resiliency, equity, access, and climate. However, important to the continued development of an Enhanced Pavement Management program is the consideration of integration with other City uses and projects.

Project Readiness Criterion #1: Feasibility of Workplan

First, identify sample communities based on pavement management programs, land area, population, VMT, other criteria; document, explore their program design, efficacy, and cost. In doing so, establish a method of logging, storing project work for accessible workflow tracking and longitudinal program resources. Next, review peer-reviewed research, literature on pavement

management technologies, programs, methods of measurement and quantification and conduct a current program assessment: budget, operational planning, method(s) of evaluation, roles and functions, equipment, etc., with a specific focus on data collection, management, and use. Develop estimated project backlog and preliminary "repair categories" towards definitions of efficacy, costs of intervention along PCI range, and definitions of efficacy and cost when converting a road, e.g. gravel to hard, chip seal to asphalt. This analysis should include the funding streams and milestones: general obligation bond program and projects; sales tax program and projects; and planning horizons. Develop a "short list" of pavement management technologies, platforms, devices, equipment, etc. based on criteria informed by Planning activity findings and Oklahoma City context, e.g. population density, to then ultimately determine a demonstration technology; document, deploy, and monitor.

Project Readiness Criterion #2: Community Engagement and Partnerships

Partner organizations include the Oklahoma Municipal Contractors Association (OMCA), the Association of Oklahoma General Contractors (AOGC), the Oklahoma Asphalt Pavers Association (OAPA), and the Oklahoma Ready Mixed Concrete Association (ORMCA); all offer private sector stakeholders and technical experts knowledgeable about pavement management, related technologies, and important perspectives as organizations whose leaders and membership are regularly involved in or doing business with the City. Additionally, the Oklahoma City MSA's metropolitan planning organization is housed in the Association of Central Oklahoma Governments (ACOG); advancements in pavement management can be shared across regional jurisdictions and benefit commuters, travelers, and tourists outside of even just Oklahoma City's municipal boundaries, especially with shared borders and infrastructure with other cities, towns, and counties.

Project Readiness Criterion #3: Leadership and Qualifications

Debbie Miller, P.E., holds a bachelor's degree in civil engineering from the University of Oklahoma and has served as Assistant Director of the City of Oklahoma City's Public Works Department, oversee more than 400 employees across disciplines including engineering, traffic management, stormwater quality, and drainage.

Leigh Demers, GISP, serves as a Business Intelligence Specialist in the City's Public Works Department where she guides the selection and implementation of technologies, data collection, processing, and analysis, GIS, and the management of the wide and deep variety of infrastructure-related data across the Public Works Department as well as the Department's intranet data and resources for engineers, project managers, financial managers, and many others who rely on data for decision-making. Demers holds a bachelor's degree in geography as well as a master's degree in spatial statistics with specialization in remote sensing in addition to a GIS certification all from Oklahoma State University.

Finally, Smith Roberts Baldischwiler, LLC (SRB), is a privately-owned civil engineer and land surveying consulting firm founded in 1981; since then, SRB has grown significantly and now conducts right-of-way services, stormwater management, hydrological and hydraulic analysis and design, highway, roadway, and bridge design, traffic signalization, water distribution, and sanitary sewer improvements for clients across Oklahoma. SRB has worked closely with the City's Public Works Department including the oversight of many City resurfacing projects, frequently providing services including construction administration, inspection, conflict resolution, and putting public safety, work zone safety, and accessibility a primary component of each and every project.