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A Target Product Profile for an Innovative Road Construction Technology Solution

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Target Product Profiles (TPPs) are a staple of the health sector. They are used to communicate client needs and requirements for products not currently available on the market, with information on how the new product will be used, by and for whom, and the minimum and ideal performance criteria. TPPs guide the industry to develop products that meet current needs. They are not intended to act as final procurement specifications, but rather as a list of desired requirements, which combined, describes the ideal product considering the context. Clients recognize that innovation is an iterative process and suppliers must balance sometimes competing requirements against product development progress.

Target product profiles have not been widely used outside the health sector, but we think they can serve a useful purpose in cases where there is a clear unmet need for a product, in this case for more climate resilient, cost-effective, and low-emissions roadbuilding materials suited to African contexts.

Problem statement/need for the product

Weak infrastructure is a drain on the productivity of African economies and on the quality of life of its citizens. Poor infrastructure imposes costs of up to 75 percent on the price of goods. This gap is most prevalent in transport and electricity, directly contributing to the continent's persistent poverty and suboptimal economic outcomes.

The effect of weak transport networks is more pronounced in Africa, where over 90 percent of passenger and freight movement occurs on roads, yet this region is the only one where road density has declined over the last two decades. Solving this problem by building a functional, all-weather road network is indispensable to increasing and maintaining high economic and social outcomes. The World Bank and other multilateral development banks' studies have demonstrated the positive economic and social benefits of good road infrastructure (African Development Bank, OECD, World Bank). Roads provide access to domestic and global markets, grant consumers access to a diversity of goods and services, provide lifesaving access to hospitals, increase safe and reliable access to schools, and facilitate migration in the wake of environmental and humanitarian crises. Beyond the high cost of building and maintaining roads and the accumulation of debt that would be needed to meet those costs, low-income countries also face the risk of existing infrastructure being destroyed by extreme weather events associated with a changing climate. How do these economies build road networks that are cheaper and more resilient to climate change?

The World Bank reports “one billion people still live more than 2km away from an all-weather road, where lack of access is inextricably linked to poverty.” This problem is especially pronounced in Africa, where, as noted above, road density has declined over the last two decades. Limited fiscal resources constrain regular and predictable maintenance of existing roads, resulting in ruts, potholes, and uneven surfaces. These conditions add to travel time, raise vehicle maintenance costs, and ultimately makes African goods some of the most expensive in the world. Per the World Bank, “transport prices for most African landlocked countries range from 15 to 20 percent of import costs.” The OECD reports that commodities traded intra-Africa are 30–40 percent more expensive due to higher transport costs. This leads directly to low trade performance. Exceptionally high costs in trade met with disconnected rural and urban regions compound challenges in the economic potential of many African countries.

Three key challenges a new road technology would need to address

1. High costs

The most recent publicly available cross-continental analysis of the unit cost per mile of road construction, from re-graveling to pavement, is 16 years old. Despite the datedness of the data, the high cost it measures remains applicable today. Currently, the cost of paving one kilometer of road ranges from as low as $300,000 in Kenya up to $1 million in Uganda. Even at the low end of the continuum—$300,000—the costs are prohibitive for the region’s governments. For governments and international development agencies, driving down the cost of road pavement, without reducing the structural integrity of the infrastructure, remains a primary objective.

Table. The unit costs of road construction and maintenance (2006 US$)

TYPE	UNIT	LOWER QUARTILE	MEDIAN	UPPER QUARTILE
Construction (paved) <50km	US$/lanekm	349,523	401,646	613,929
Construction (paved) >50km	*US$/lanekm*	*209,427*	*290,639*	*344,135*
Rehabilitation (paved) <50km	*US$/lanekm*	*220,186*	*352,613*	*505,323*
Rehabilitation (paved) >50km	*US$/lanekm*	*194,679*	*299,551*	*457,714*
Periodic maintenance (Paved)	*US$/lanekm*	*81,854*	*158,009*	*235,157*
Regraveling	*US$/lanekm*	*12,835*	*15,625*	*19,490*

Note: Italicized text denotes sample sizes large enough to provide reliable unit-cost predictions
Source: World Bank

2. Resilience to extreme weather and climate change

The changing climate presents even more challenges to keeping roads passable year-round. Heavy rains and unseasonable heat impair existing roads, requiring frequent maintenance at high aggregate costs. The World Bank concludes that "weather extremes will indeed put considerable pressure on Africa's road system. The damage and accelerated ageing of roads caused by climate change will require increased maintenance and more frequent rehabilitation." Countering the damage to African road assets from increased rainfall and the subsequent flooding, along with higher temperatures, is the second important objective for governments.

3. Reduced emissions

The third and final challenge is addressing the contribution of the built environment, including road construction and maintenance, to high emission of greenhouse gases. According to Architecture 2030, 42 percent of annual global CO_2 emissions are a product of the built environment. Carbon-intense road-building materials like steel, cement, and bitumen are large contributors. A recent study of CO_2 emissions associated with asphalt pavement found the two activities that generated the most CO_2 emissions were asphalt laying (49 percent) and material transportation (35 percent). The same report noted that the "life cycle assessment on flexible pavement construction activities showed that it generated twice higher carbon emissions than that of rigid pavement construction activities." As the World Bank puts it, "When it comes to transport, developing countries face a dual challenge: ensuring everyone has access to efficient, safe and affordable mobility, and doing so with a much smaller climate footprint." Driving down the emissions footprint of road construction, even as the network is expanded, is a reasonable objective as each country makes contributions to CO_2 reduction.

This project is therefore seeking a road pavement technology solution that optimally applies state-of-the-art advances in materials, geo-technical mechanisms, pavement design, and other related sub-sectors of engineering to address the three problems outlined above: substantially drive down the unit cost of constructing a paved road per mile, meet or exceed the resilience of current solutions to heat and precipitation, and reduce the emissions footprint of road construction and maintenance.

Volume and potential impact

The optimal product for market-shaping mechanisms has at least two advantages—it addresses an important public good (the US government's Operation Warp Speed targeted a vaccine to end COVID) and it constitutes a large enough market to attract the best competitors (Moderna, Pfizer, Johnson and Johnson all participated in Operation Warp Speed). These two conditions also apply to roadbuilding technologies.

There is a substantial market for a new roadbuilding technology. In FY22, the World Bank approved 40 transport projects with a total value of $8.2 billion. The Bank's current portfolio includes 172 active transport projects with an aggregate value of $34 billion, which is approximately 11 percent of the Bank's lending. While these transport projects also include rail, ports, and water transport projects, roads constitute over 50 percent of all Bank transport projects in sub-Saharan Africa. With up to 90 percent of the region's freight and people movement occurring on roads, road construction and maintenance will remain a substantial portion of government capital outlay over the coming decades. Beyond the World Bank, other multilateral and bilateral lending institutions will also lend substantial resources for road construction, rehabilitation, and maintenance. According to the African Development Bank, to fill the infrastructure gap on the continent spending on infrastructure will require up to $170 billion a year, with transport consuming about 40 percent of that total. In addition to improving social and economic welfare outcomes, the sheer size of the road transport market in Africa presents opportunities for disrupting the current pavement options by driving down price, while improving overall performance.

Target unit cost

This wide variation in road construction costs across the region precludes a singular target for all 49 markets in the target area. Target price per country will be evaluated against the most competitive price of existing pavement options (cement and asphalt). A winning target production will thus compete directly in quality and performance with the aforementioned existing solutions. The goal is to drive costs down while, at worst, keeping performance comparable to competitor pavement and at best, exceeding the performance of competitors. Pavement materials—asphalt and cement—are the most expensive parts of road pavement. Any solution which targets this cost along a band of 15 to 30 percent cost reduction across the life cycle of the pavement shall be considered competitive.

Performance criteria

A competitive target product (TP) is expected, as noted above, to equal or exceed comparable performance with asphalt or concrete, given similar conditions on, a) lifecycle costs, b) environmental impact (use of local materials and emissions), and c) resilience to the impact of high temperatures, high rainfall, and flooding. Performance on lifecycle costs and resilience to climatic changes will be weighted higher. The TP will also be subject to the same performance criteria as existing paved roads such as durability, sulfate, and abrasion resistance; rutting, faulting, and cracking percentage; materials loss and erodibility.

Traffic load

Roads using the TP for surface treatment should support an Annual Average Daily Traffic of at worst 200 and up to 400. In the contexts where the TP will see most application, axle load control and monitoring is either in infant stages or non-existing. This means that the occasional light truck or heavy truck will ply roads designed for lighter fare. Innovators are encouraged to design with this context in mind.

Soils

Variability in soils across the world and across regions might preclude a single high performing material for every region. TPs must, like existing comparators, strive to be adaptable to variable soil conditions. TPs must target design parameters that enable application, for example, in laterite soils (prevalent in West and Central Africa) some of which strengthen when soaked. TPs must be equally applicable to black cotton soil (found in East Africa) which is not a stable engineering material due to its strong swelling potential. A TP that performs comparatively well in any one region, however, will be considered competitive.

Materials

TPs will be evaluated with comparator materials on safety (friction and texture), permeability, strength and swelling potential. TPs incorporating in situ, waste, or marginal materials will rank higher. Competitive TPs will minimize the need for specialized training or bespoke specialized equipment. TPs will seek to simplify their introduction by incorporating existing pavement methods and equipment.

CO_2 emissions

Globally, there are two primary materials to pave roads, concrete cement and asphalt cement. Across a road's life cycle, the construction phase emits the highest rates of CO_2 emissions (Huisingh et al, Barandica et al). Concrete, which generates more CO_2 emissions than asphalt, is the most used man-made material in the world with a utilization rate of 4.1 billion tons annually. Concrete accounts for 8 percent of global anthropogenic CO_2 emissions and is projected to grow in production at 12–23 percent. Ultimately, concrete emits 144 kg CO_2 per ton in comparison to asphalt's 61 kg CO_2 per ton. A competitive target product will target the CO_2 emissions rate of flexible pavement like asphalt or even less.

Local standards

The outsized role of development finance institutions in funding road infrastructure across the developing world dictates that the TP must pass their criteria as acceptable pavement criteria. For African countries seeking development finance for road pavement, standards are usually based on American Association of State Highway and Transportation Officials (AASHTO) or European equivalents adapted to the local context. Target products are expected to perform under these standards.

Conclusion

Target product profiles have not been extensively used outside the health sector and our project is very likely the first application to road infrastructure. The process will thus be iterative. These guiding criteria will thus remain dynamic and open to feedback from as broad a pool of stakeholders as possible. They will be updated regularly as required as the sector expands and in response to innovators' feedback.

The performance criteria outlined in this TPP are not intended to be final procurement specifications. They are left sufficiently broad to ensure that prospective competitors are technology and material-neutral, but the criteria are also narrow enough to guide innovators in targeting products to perform under clear conditions.

Target product profile criteria for new pavement material

PRODUCT TARGETS	MINIMAL ACCEPTABLE RESULT	IDEAL RESULT
Target unit cost	At least a 15 percent cost reduction across the life cycle when compared to existing commercial concrete and asphalt	Up to a 30 percent cost reduction across the life cycle when compared to existing commercial concrete and asphalt
Climate resilience	Higher threshold of tolerance of extreme heat, flooding, and freezing than flexible pavement	
Performance criteria	Of equal or exceeding comparable performance with asphalt or concrete, given similar conditions. The TP will also be subject to the same performance criteria as existing paved roads: durability, sulfate, and abrasion resistance, IRI, rutting, faulting, and cracking percentage, and materials loss/erodibility	Performance on lifecycle costs and resilience to climatic changes will be weighted higher
Traffic load	Annual Average Daily Traffic of 200	Annual Average Daily Traffic up to 400
Soils	Performs comparatively well in any one region	Must be applicable in laterite soils (prevalent in West and Central Africa) and in black cotton soil (found in East Africa)
Materials	Evaluated on safety (friction and texture), permeability, strength and swelling potential.	TPs incorporating in-situ, waste or marginal materials and will minimize the need for specialized training or bespoke specialized equipment will rank higher
CO_2 emissions	Should target 61 kg CO_2 per ton in emissions rate of flexible pavement like asphalt or even less	
Local standards	Must meet building standards of American Association of State Highway and Transportation Officials and/or European equivalent	

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