Evaluating the socio-economic potential of road development projects around the Aberdare range

A report for Rhino Ark

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Executive Summary

Background: Road development and associated large infrastructure projects have the potential to drive economic growth and poverty reduction in the developing world. However, there is a common misconception among governments and developers that all roads are good, while some may have considerable economic and environmental costs. It is essential to evaluate any new development against other options to ensure governments and investors make decisions that truly benefit people and the economy.

Context: Many road developments are planned in central Kenya. One of the largest is the "Mau-Mau road project" a 30 billion Ksh (280 million USD), a three-year government project to construct over 500km of road on the eastern edge of the Aberdare National Park (ANP) and Aberdare Forest Reserve. There have also been proposals to extend the Mau-Mau road over the Aberdare mountains. No analysis has been done on the costs and benefits of these road building scenarios for the Kenyan people, which is crucial information for development decisions.

This study: We used OpenStreetMap data to evaluate how different road building scenarios perform against well-founded socio-economic measures of good road design, including the number of people living within 2km of a road, and reductions in travel time to and between major towns.

Major finding 1: The new Mau-Mau road will reduce travel times by 1.3 - 6.5% on 11 routes, increase the number of people within 2km of a tarmac road by 177,000, and improve travel times to major towns for over 25,000 people. This suggests the Mau-Mau road will help stimulate economic growth and development in these areas. The Mau-Mau roads do not pass through any natural habitat in either the ANP or Forest Reserve, so they will have a minimal environmental impact in that regard.

Major finding 2: There is almost no socio-economic benefit to building a road over the Aberdare range and through the ANP. There is no evidence that it brings people closer to main roads, or reduces travel time to markets. The only benefit is a slightly reduced travel time, and potentially lower fuel costs, between Nyeri-Naivasha and Nyeri-Gilgil, but this is conditional on the road being upgraded to a secondary road built to allow an average speed of greater than 50 KpH which is most likely unfeasible on the mountainous terrain. These routes also consist of considerable sections of high gradient, which could profoundly impact traffic flow.

Conclusion: Our results clearly show that upgrading roads around the ANP (the current "Mau-Mau road project") benefit more people, and will produce higher economic returns than a road over the top of the Aberdare range. Considering the low socio-economic returns of this development, it appears that its construction is not worth the risk posed to biodiversity and ecosystem services found within the ANP.

Introduction

Road development and associated large infrastructure projects have the potential to drive economic growth and poverty reduction in the developing world. However, there is a common misconception among governments and developers that all roads are good. This is not true - the benefits of roads are only realised when a road is well planned. Poorly planned roads can have substantial negative impacts on the economy, local livelihoods, and the environment. A road is also never built in isolation, there are always several different options to consider, including to improve or upgrade existing infrastructure instead. Given the rapid road-building spree occurring globally (road length is expected to increase by 25 million km^2 worldwide by 2050 which is a 60% increase in current total road length[1]), ensuring roads are well planned and deliver broad societal benefits is crucial - especially in African countries striving to meet ambitious development goals with limited budgets.

What makes a good road?

A well-planned road connects as many people as possible to fundamental services such as schools, hospitals, and markets, and reduces their travel time. Well placed roads can benefit agriculture by improving access to markets, allowing farmers to explore more options for better prices, and improving access to essentials such as fertilizers and machinery. This can lead to increased yields, which is particularly important in Africa where the yield gap is still high, and help transition subsistence agriculture into commercial agriculture[2]. People also congregate along roads, taking advantage of immediate economic opportunities (e.g., selling local produce/products to travelers), which then attracts more people who start increasingly larger businesses, and the economy grows from there. The importance of well-planned roads for development is now well recognized in the United Nations Sustainable Development Goals (SDGs). Specifically, SDG 9.2 which encourages policymakers to increase the share of the rural population living within 2 kilometers of an all-season road to encourage economic development and human well-being.

What makes a bad road?

All new roads drive massive social, environmental, and economic transformations in the regions they go through - and these changes can be for the worse. The most visually apparent negative impact of roads is on the environment. Roads fragment natural habitats and allow human entry into areas that were previously challenging to access. This leads to increases in wildlife crime, such as illegal hunting and deforestation. For example, evidence suggests large animals in Africa quickly disappear along roads due to hunting[3], and in the Amazon, 95% of all deforestation is within 5km of a road[4]. Fragmenting forests also increase the edge area - where considerable changes in the local environment occur. Most concerningly, the vegetation within several hundred metres of a road edge starts to emit substantial amounts of carbon into the atmosphere undermining efforts to halt climate change[5,6]. There are many other effects of new roads, including pollution, increased invasive species spread, and vehicle-wildlife collisions. They are also unsightly and can undermine the nature tourism industry if they compromise areas of high natural beauty. Species such as large carnivores also die out increasingly quickly as habitat patches decrease in size due to fragmentation[7].

Poorly planned roads can also pose a substantial economic burden on governments and investors. For example, roads built in flood-plains or on steep terrain have negative downstream impacts on industries such as agriculture, fisheries, and tourism, leading to net losses in revenue[8]. These costs are rarely accounted for in impact assessments or planning. There is also always a risk that road-building projects prompt land-speculation, corruption, and cost-overruns[9]. In Kenya, there are also examples of roads entrenching and strengthening current power imbalances, further sidelining marginalized people and communities, while elites increasingly prosper[10]. Economically, one of the most significant negatives of a road is when financial resources could have been better spent elsewhere, on other more beneficial roads, or even on entirely different projects that provide much greater development benefits such as hospitals or schools. Upgrading existing infrastructure, for example, through improving road surface quality, is often a far more cost-effective development strategy than building new roads.

Accounting for the true costs and benefits of road development is crucial to ensure governments and investors make decisions that truly benefit people and the economy. Such assessments also need to consider many possible alternative options and weigh up the potential economic benefits and the hidden environmental and economic costs.

Central Kenya Case

Kenya’s road network has grown considerably over the last decades, from around 7,000 kilometers of paved and improved roads in 1978 to around 11,000 kilometers of improved and paved roads as of 2017[11]. This is the same across Africa, and many of them cut across PAs. Part of the next phase of road development is to continue to develop a set of roads around the Aberdare range in central Kenya. This consists of the “Mau-Mau road project” a 30 billion Ksh (280 million USD), a three-year, major government project to construct over 500km of road along the eastern edge of the Aberdare National Park and Aberdare Forest Reserve, with several spur and feeder roads connecting various towns. In addition, there have been proposals for extensions of the Mau-Mau road to traverse over the Aberdare range, between Nyeri and Ndunyu Njeru, a proposal previously rejected by the National Environment Management Authority due to its potential impacts on the Aberdare National Park and its important biodiversity and ecosystem services.

Here, we investigated how these scenarios of road development in this region compare against various indicators of successful road design, from a socio-economic perspective: (i) The travel times between major towns; (ii) The travel time for people to major towns; (iii) The number of people within 2km of paved roads and; (iv) The economic trade-offs between road options over and around the Aberdares National Park. We then discuss the benefits of these road designs versus their potential impacts on biodiversity and ecosystem services.

Methods

Study Area

We developed four alternative scenarios of road development around the Aberdare range in central Kenya. The study area was defined from Nakuru as the west boundary (36.05° E), Nairobi as the southern boundary (1.30°S), Nyahururu as the northern boundary (0.04°N) and Makutano junction to the east (37.2° E).

The Aberdare range is at the center of this well-populated region, stretches over 120km long and 40km wide, and is characterized by undulating hills and valleys, peaking at an altitude of 4000m, with a large plateau above 3000m along the central ridge of the Aberdares. The range slopes gently to the east while, in contrast, the western slopes drop rapidly into the Rift Valley. Vegetation in the Aberdares is Afromontane, with three broad vegetation zonations including the montane forest belt at lower altitudes, the subalpine zone at mid-elevation, and the alpine zone at the summit. Administratively, this forest is managed in two parts: Aberdare National Park, managed by Kenya Wildlife Service (KWS), and the Aberdare forest reserve, governed by Kenya Forest Service (KFS). The forest is important for both its biodiversity and ecosystem services. This includes 63 endemic plants, an important bird area which includes several endemics, 1500 endangered African Elephants, the largest remaining population of critically endangered Eastern Mountain Bongo, and a small population of endangered black rhino. The forest is also an important water catchment area for several million people, including Kenya's capital, Nairobi. Because of its importance, the forest has now been wholly fenced to preserve its intact Afromontane habitat.

Analysis

We generated a database of highway data for the study area from OpenStreetMap (www.openstreetmap.org), accessed on 28/01/2020. OSM provides an open-source and comprehensive spatial database, continually updated, for services and infrastructure across the planet. OSM is widely used in the assessment of infrastructure on human health, the environment, disaster response, etc. In this OSM database, highways are predominantly categorised as being either: primary, secondary, tertiary, trunk, or residential. In addition, the surface of the road may also be classified, with multiple options available, such as: tarmac, paved, unpaved, dirt, sand or unknown. We used this data to build four scenarios of road development (Figure 1). To create our scenarios, we edited the OSM data using Java OpenStreetMap Editor (JOSM:josm.openstreetmap.de):

- **Scenario 1 - "Current state" -** uses the OSM data to represent the current state of the Kenyan road network.
- **Scenario 2** - **"Mau-mau road"** - with a network of roads along the eastern edge of the Aberdares upgraded, and the Thika-Njabini-Naivasha road tarmacked, according to government tenders and plans gathered from the KENHA website (www.kenha.co.ke). The main Mau-Mau road was designated as primary road, and the spur roads designated

as secondary roads, including the upgrade of the Naivasha-Njabini-Kimakia-Gatura road. We labeled the surface of all roads that were upgraded as tarmac.

- **Scenario 3 - "Aberdare road minor" -** this is scenario 2 with the additional road over the Aberdares upgraded according to government plans. Due to the nature of the road passing through the park, which could include the need for speed bumps to protect wildlife, we labeled this road as a tertiary road.
- **Scenario 4 - "Aberdare road major" -** this is scenario 3, but assuming there is no regulation on the Aberdare roads, with the road upgraded to a secondary road.

1. Number of people within 2km of a paved road

We used the data from the four different scenarios to calculate the number of people within 2km of a paved road (SDG indicator 9.1.1). We used any road that was classified as a primary, secondary, or trunk road and any road that was paved, tarmac, asphalt, or concrete. We included only tertiary roads that had explicitly stated that they are paved, tarmac, asphalt, or concrete surfaces. For each scenario, we extracted the number of people living within 2km of the paved road network using 100m human population raster adjusted for the year 2015 from https://www.worldpop.org.

2. Travel Times to and between towns

We calculated the travel times between major towns and travel time to major towns using the Open Source Routing Machine (OSRM), which is a high-performance routing engine for the shortest paths in road networks. We established our own server and gave it access to the four different scenarios generated from OSM. OSRM uses sophisticated algorithms to optimize the routing along transport networks for speed and road network, in our case we optimized the routing using the in-built profile for cars, which also accounts for speed limits based on road surface quality and classification of the road (https://github.com/Project-OSRM/osrm-backend/blob/master/profiles/car.lua).

We selected twelve of the largest towns in the region, which are critical hubs for agriculture, commerce, and travel, and georeferenced them using the *googleway* package in R 3.6.1[12]. We used the package *osrm* to query the OSRM server to establish:

1) The preferred route, its length, and duration between each combination of towns under the four different scenarios.
2) Travel time to every town, under every scenario.
3) We then used this information to estimate the travel time to any major market across a 100m grid covering the entire study area, and using the 100m human population raster adjusted for the year 2015 from https://www.worldpop.org; we estimated the change in travel times to major towns for people under the different scenarios

3. Route choices and Fuel Efficiency

We looked at the routes between towns that may benefit from an improved road over the Aberdares and through the National Park. Using elevation data from the Mapzen Terrain Service using the *elevatr* package, we compared different routing options and their elevation profiles, gradients, and the distance of different routes. We then used data on fuel efficiency at different gradients of the road (https://afdc.energy.gov/data/10601) to interpolate the fuel usage for an SUV on these different routes, using a simple Generalized Additive Model (GAM), fit using the package *mgcv.*

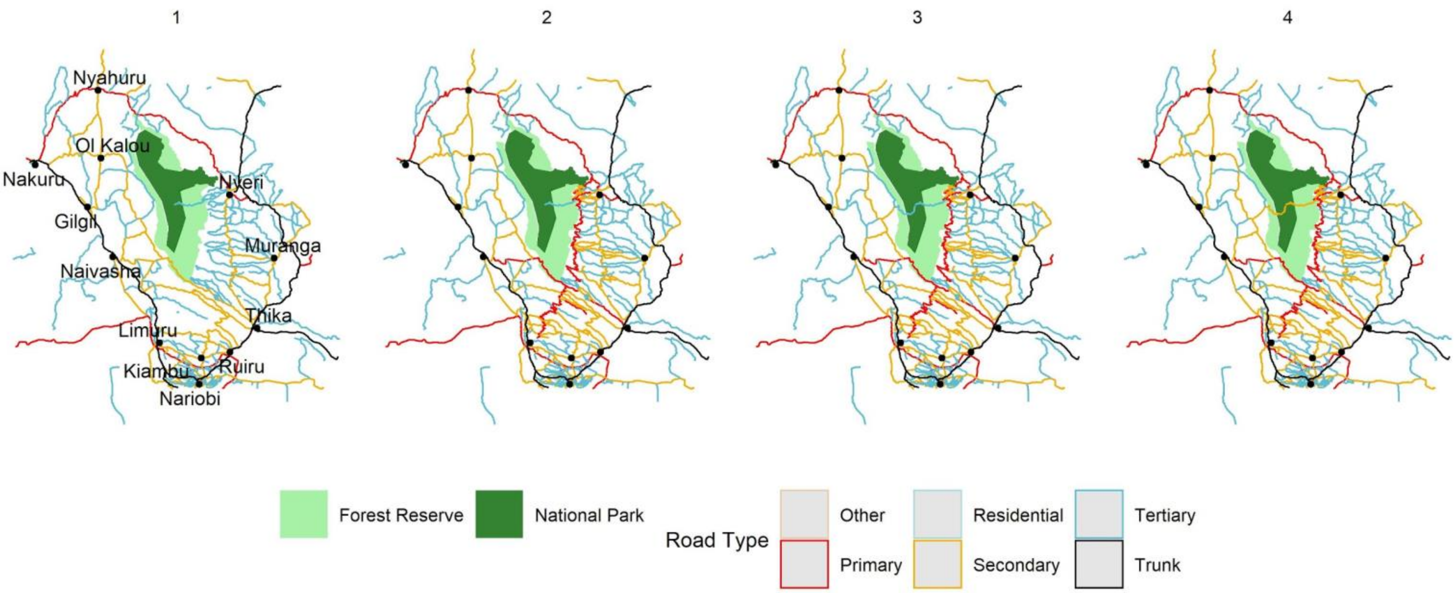


Fig 1. The four future road development scenarios. Only paved roads are displayed for clarity. The four scenarios include; (Scenario 1) the "current state" showing the road layout in early 2020 (data acquired from Open Street Maps); (Scenario 2) the "Mau-Mau road" where the planned Mau-Mau road is designated as a primary road, and the spur roads designated as secondary roads, including the upgrade of the Naivasha-Njabini-Kimakia-Gatura road. (Scenario 3) "Aberdare road minor" where the "Mau-Mau road" (Scenario 2) goes ahead, with the addition of an upgraded tertiary road through the Aberdare National Park; and (Scenario 4) "Aberdare road major", where the "Mau-Mau road" (Scenario 2) goes ahead, with the addition of an upgraded secondary road through the Aberdare National Park with a higher speed limit. Major towns in the analysis are shown, as are the Aberdare Forest Reserve and Aberdare National Park.

Results

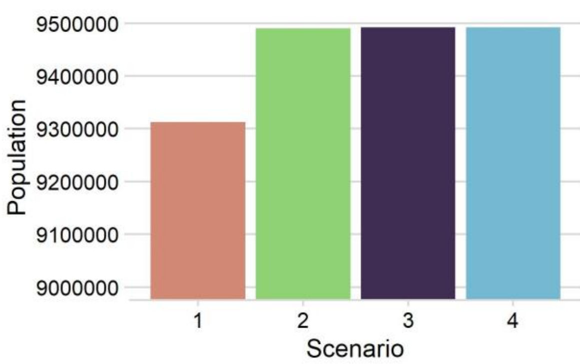


Figure 2. The number of people living within 2km of a paved road under the four different scenarios. In the study area, 9,313,133 people currently live within 2km of a paved road. Scenario 2 (Mau-Mau road) increases the number of people by 177,188 (1.9% increase). In comparison, the improvement of the road over the Aberdares (Scenario 2 and 3) may add only a negligible extra 2,157 people (0.02% increase from Mau-Mau road).

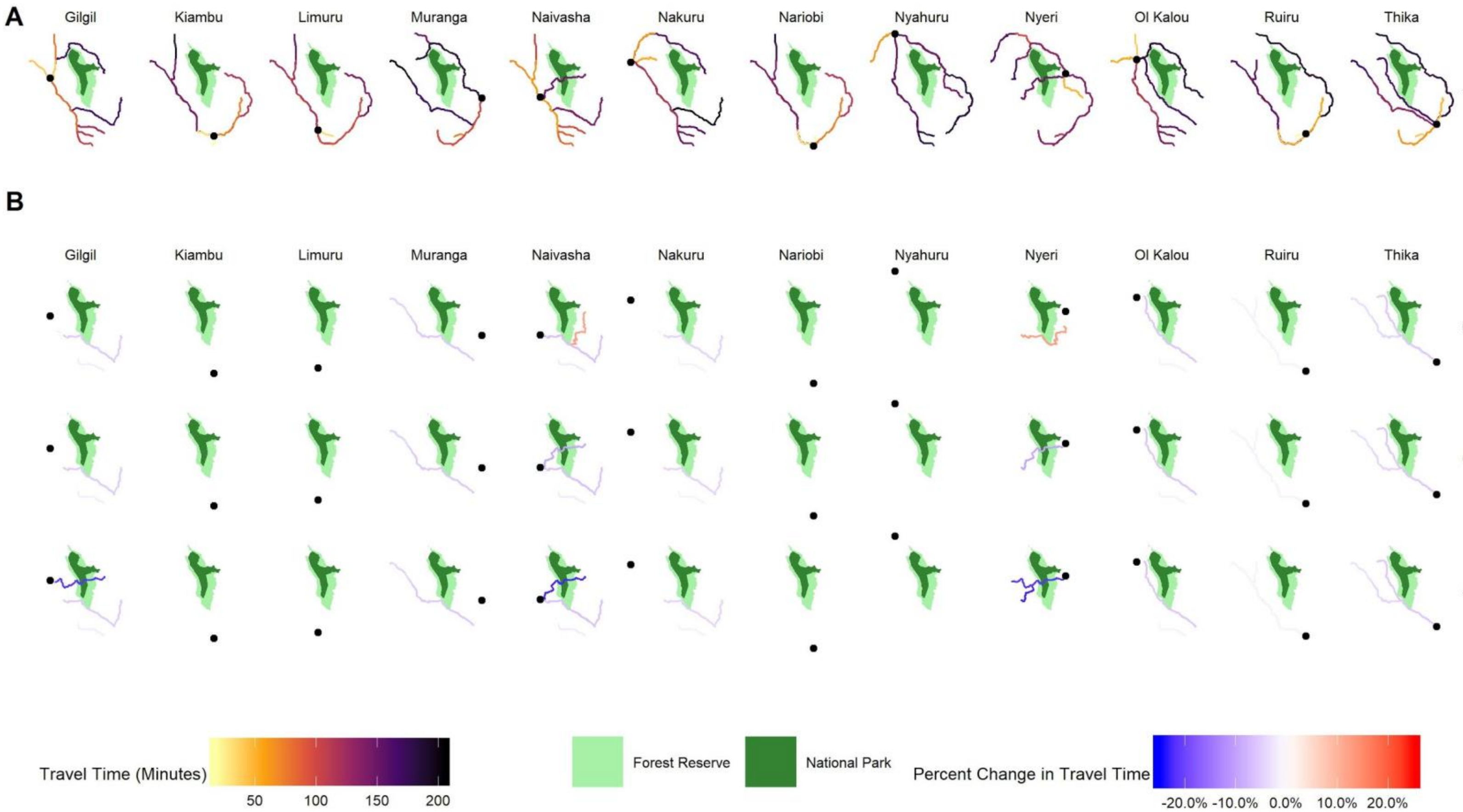
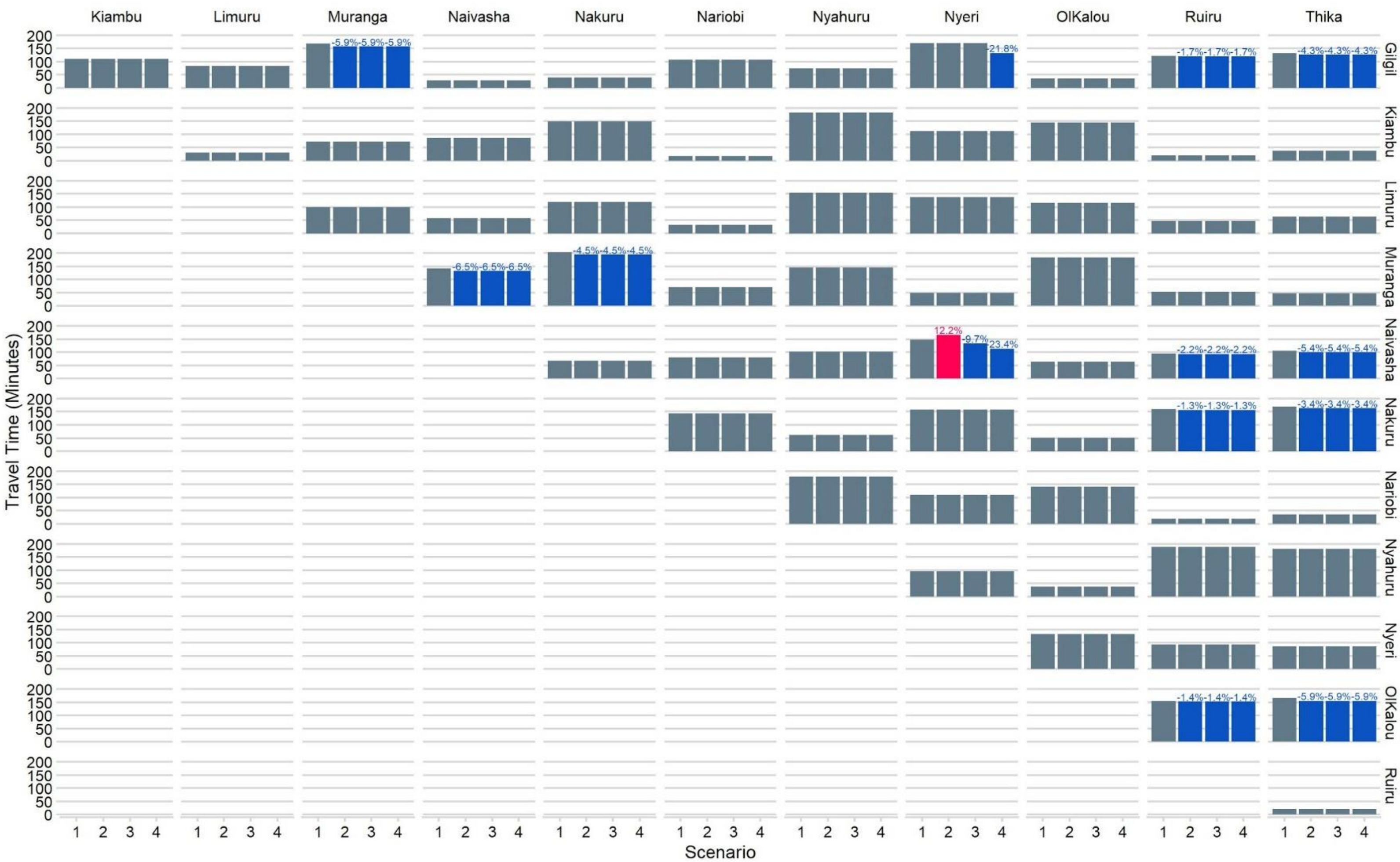


Figure 3. The impact of future road development on estimated travel times between twelve major towns around the Aberdare range. A) The preferred routing and current estimated travel times in minutes between the towns (Scenario 1 "current state"). B) The percentage change in travel times between the major towns under the three new scenarios. Those routes with little change are white and hence are not shown. The most considerable decrease in travel time under the different scenarios is between Gilgil - Nyeri, and Naivasha - Nyeri under Scenario 4 (blue color), and are the only scenarios which pass through Aberdare National Park. In most scenarios, there is little change in travel times. See Figure 4.

Figure 4. Travel times between the twelve major towns under the four scenarios. Those routes with a change in travel time between scenarios are highlighted and labeled with the percentage change in travel time; pink is an increase in travel time, and blue a decrease in travel time relative to Scenario 1. **Figure 4. Travel times between the twelve major towns under the four scenarios.** Those routes with a change in travel time between scenarios are highlighted and labelled with the percentage change in travel time; pink is an increase in travel time and blue a decrease in travel time relative to Scenario 1.



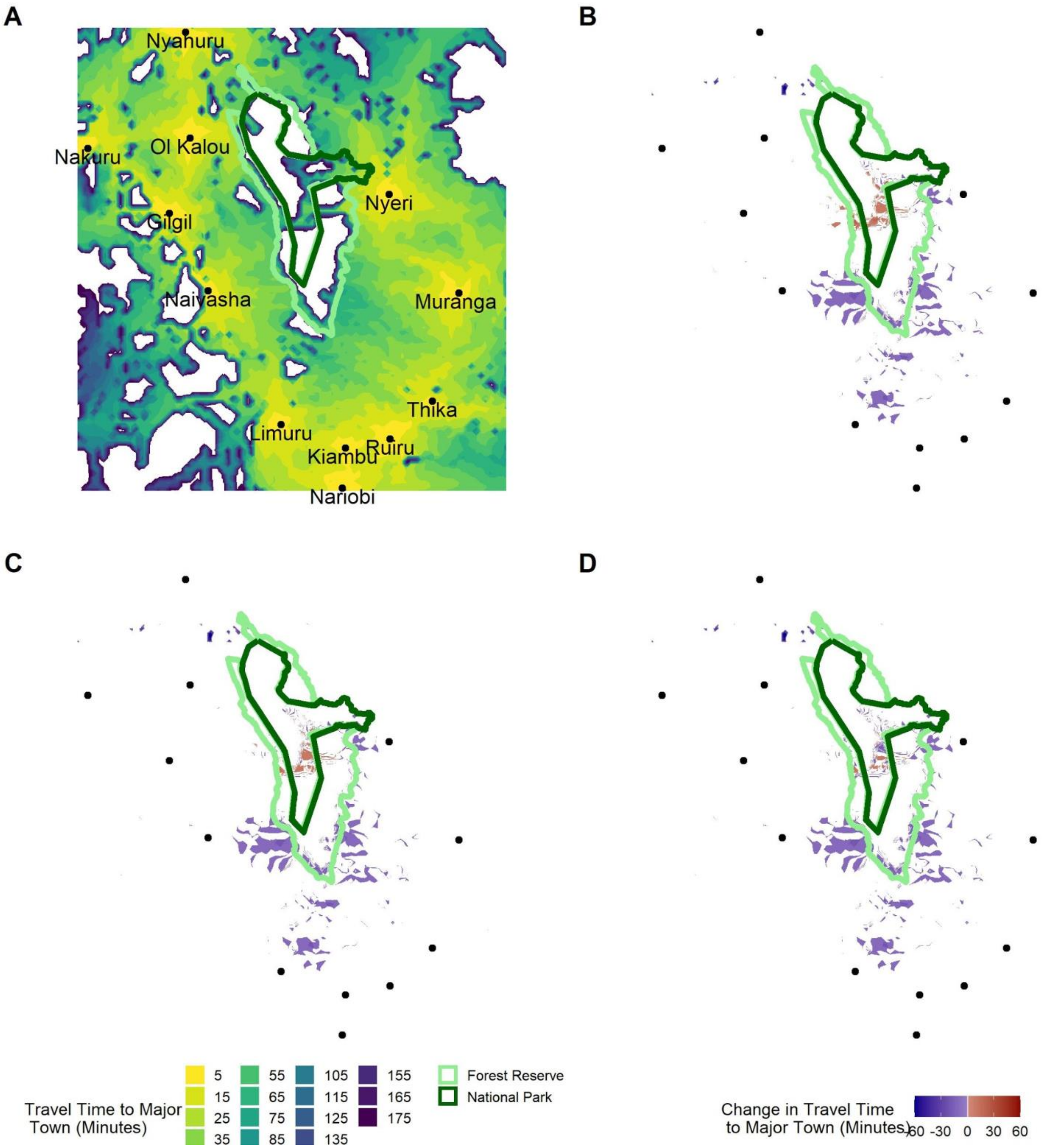
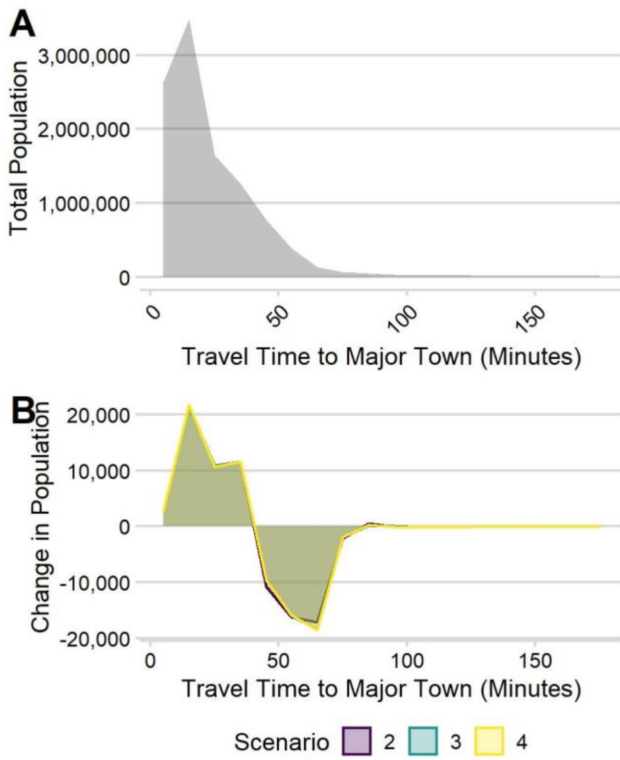


Figure 5. **Changes in travel times to any major town on a 1x1km resolution grid**. A)Travel time to any major town under Scenario 1, with the centre minute of the group travel times displayed in the legend; B-C) The respective changes in travel time to any major town, compared to the original scenario (A), for Scenarios 2-4.

Figure 6. The number of people (from worldpop.org), who live within different travel times from major towns (Figure 5). This increases the most under Scenario 2 (Mau-Mau Road), and there is little additional benefit from Scenario 3 and 4 (Aberdare Minor and Major roads). A) An area chart of the total number of people within different travel times from major towns for Scenario 1 (Current State); B) An overlapping area chart of the absolute change in human population within the different distance categories for Scenarios 1-4.



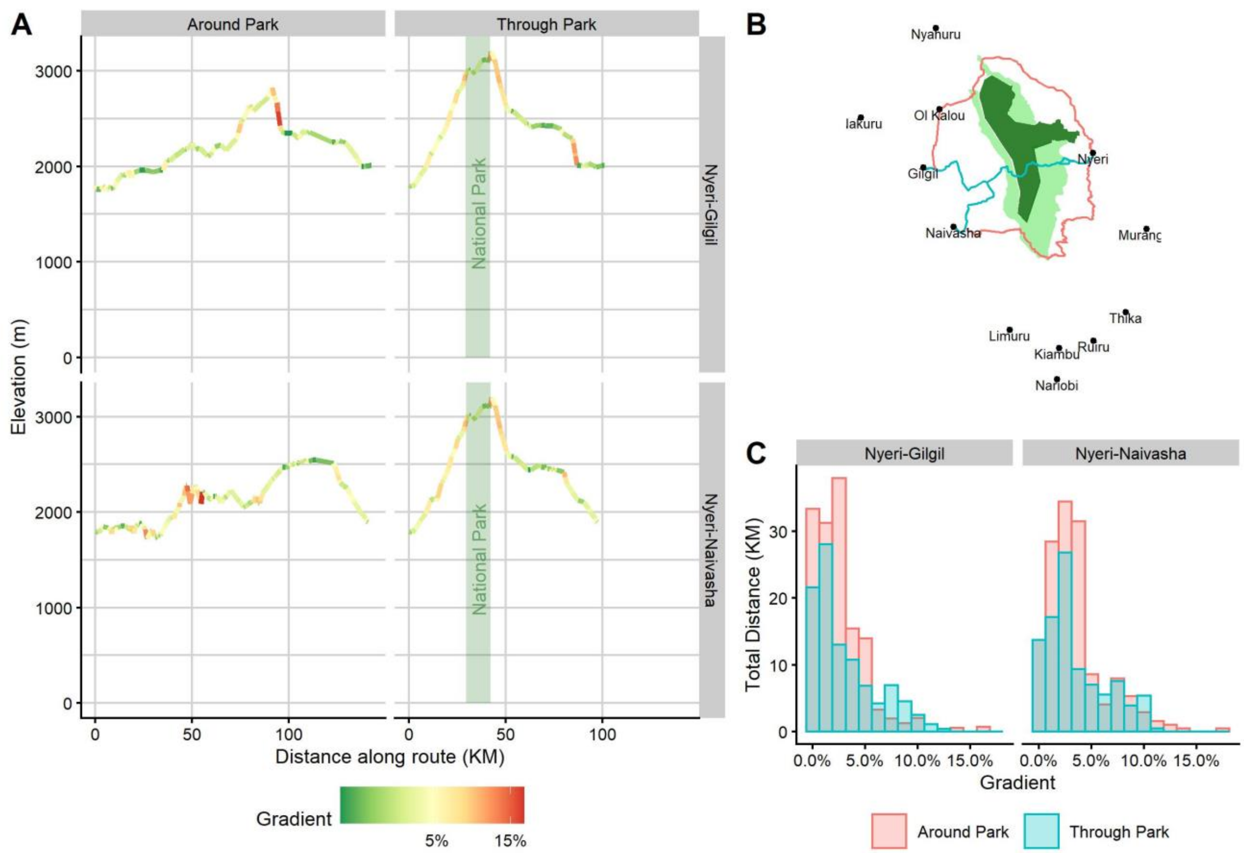


Figure 7. Comparison of the routing, elevation profile, gradient, and distance of different routes between Nyeri to Naivasha and Gilgil around and through the National Park (NP) found during our analysis (Figure 3). A) The elevation profiles of the routes, including the gradient for each segment of the road. Those routes through the NP - green shading - must climb to over 3200m to cross the Aberdares, with continuous gradients >5%. B) Map of the four routes showing their pathing through or around the NP. C) A frequency plot of the road gradient and the total length of the road within each gradient bin for the four alternative routes. For Nyeri-Gilgil, the route through the park has longer sections of road with a gradient higher than >5%, and with more road length <5%. Going around the NP on the Nyeri-Naivasha route has a greater length in the range of 2-5% gradient, with slightly less length in the 5-10% bracket, but several short sections of road >10%.

Route	Option	Average Gradient per Segment (%)	Total Elevation Change (m)	Overall Distance (km)	Approximate Fuel Use for an SUV in Both Directions (Litres)
Nyeri-Gilgil	Around Park	2.94%	3190	143	16.7-16.3
	Through Park	3.77%	2962	101	12.2-11.9
Nyeri-Naivasha	Around Park	3.83%	4279	141	17.2-17.6
	Through Park	3.84%	3117	97	11.4-12.7

Table 1. Comparison of the different routes between Nyeri to Naivasha and Gilgil around and through the National Park (NP) from our analysis (Figure 7).

Mau-Mau road increases people’s access to good roads

Under Scenario 2, the construction of the new Mau-Mau road along the edge of the Aberdares, and upgrading the Thika-Njabini-Naivasha road, add an extra 572 km of paved roads. An extra 177,000 people, a 1.9% increase, will now live within 2km of a paved road (Figure 2). This road improvement also decreases the travel time to major towns with an additional 46,569 people (0.5% increase from 9,026,974 in Scenario 1) people <40 minutes from a major town (Figure 6).

Under Scenario 2 several routes between towns may see a minor reduction in travel time between Gilgil-Muranga, Gilgil-Ruiru, Gilgil-Thika, Muranga-Nakuru, Muranga-Naivasha, Naivasha-Ruiru, Naivasha-Thika, Nakuru-Ruiru, Nakuru-Thika, and Ol Kalu-Ruiru, and Ol Kalou-Thika (Figure 4). All of these savings relied on the improvement of the Thika-Njabini-Naivasha road (Figure 3). Only one route increased in travel time, with the routing engine for the Nyeri-Naivasha route preferring the routing on the higher quality Thika-Njabini-Naivasha around the south side of the Aberdare Range (Figure 3&4).

Aberdare Road improvements serve few people

The Aberdare Major and Minor Road scenarios, has only minor increases in the number of people living within 2km of the new road over the top of the Aberdares, primarily because the road traverses through the park, which is devoid of people (Figure 2). In addition, these two scenarios did not majorly change the travel time to major towns for the majority of people (Figure 6). Scenario 3 shows a slight decrease in travel time over the top of the Aberdares between Nyeri - Naivasha. However, the routing engine still routed to the north side of the Aberdares to reach Gilgil. Scenario 4 shows the largest decreases in travel times between Nyeri-Gilgil and Nyeri-Naivasha (23.4% and 21% decreases from Scenario 1, respectively). Both of these routes pass through the Aberdare National Park (Figure 7), and climb up a continuous gradient to the peak altitude of 3200m. For the Nyeri-Gilgil route, the option around the park has significantly less gradient on average and spends no time in the National Park (Table 1 and Figure 7). The route between Nyeri-Naivasha has a similar average gradient using either route. However, the route through the NP climbs higher, spends longer in the NP, but is significantly shorter, has a smaller overall gradient change, and if more fuel-efficient (Table 1), due to the large valleys in the proposed Mau-Mau road alternatives (Figure 7).

Discussion

We have analyzed four scenarios of road development around the Aberdare range in Kenya, investigating how each performs against well-founded socio-economic measures of good road design, including the number of people living within 2km of a road, and reductions in travel time to and between major towns. Our analysis demonstrates that the new Mau-Mau road (analysed in scenario 2) will reduce travel times by 1.3 - 6.5% on 11 routes, and increase the number of people within 2km of a tarmac road by 177,000. This suggests the Mau-Mau road will help stimulate economic growth and development in these areas and will connect agricultural communities around the Aberdare National Park. The Mau-Mau roads do not pass through any natural habitat in either the Aberdare National Park or Forest Reserve, so they will have a minimal environmental impact in that regard. Despite the proximity of the road to the forest boundary, it is unlikely that spill-over development from road construction will enter into the park due to the presence of a well-maintained electric fence.

Our results show that there is almost no socio-economic benefit to building a road over the Aberdare mountains through the Aberdare National Park. There is no evidence that it brings people closer to main roads, or reduces travel time to markets. The only benefit is a slightly reduced travel time, and potentially lower fuel costs, between Nyeri-Naivasha and Nyeri-Gilgil, but this is conditional on the road being upgraded to a secondary road built to allow an average speed of greater than 50 KpH. We caution that, in reality, an average speed higher than 50 kph across the Aberdare range is likely infeasible. Vehicles must climb to an altitude of 3200m, where there is extra pressure due to the cold, fog, and isolation. The current roads either side of the ANP are narrow, winding and steep, and are likely to cause traffic jams, especially if used by freight. It could be expected that due to the steep, tight nature of this road that the majority of freight will be expected to use the current routes outside of the Aberdare National Park, rendering this road even less economically beneficial than modeled here. Building roads in bogs, swamps and peatlands (found at the top of the Aberdares) is also more expensive than in other habitats because a high road base is needed to ensure that the road surface is high enough above fluctuating water levels, along with sufficient culverts to ensure adequate drainage.

We also caution that a major road over the Aberdares that could support traffic at an average speed >50kmh would have significant environmental impacts that outweigh the marginal reduction in travel time. The road would damage endemic plant species, which have their highest species richness at the highest elevations, and could increase degradation and pollution of natural habitats. The road would also provide an improved avenue for illegal exploitation of natural resources - including bushmeat, illegal wildlife trade, and logging. The Aberdares is also home to the critically endangered mountain bongo, which is incredibly sensitive to human disturbance and moves away from areas where people or vehicles are active.

Our results clearly show that upgrading roads around the National Park benefit more people than a road over the top of the Aberdare range. This is an important finding because this information can help guide the Kenyan government and development organizations' decisions so that they invest in projects with the most substantial socio-economic benefits for the people of Kenya. Given Kenya's limited development budgets and reliance on international aid and loans, developments such as new roads must yield the highest possible economic returns. Considering the low socio-economic returns of this development, it appears that its construction is not worth the risk posed to biodiversity and ecosystem services found within the National Park. Improving road infrastructure around the Aberdares (Scenario 2) best meets these objectives. This analysis is designed to support sustainable development and will help ensure Kenya builds roads to prosperity, not roads to nowhere.

Conflict of Interest Statement

PT and JA declare no personal or financial conflict of interest in preparing this report. This report received no funding, and both authors worked on this independent of any interested parties.

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