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Economic, Socio-Political and Environmental Risks of Road Development in the Tropics

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It is projected that 25 million km of new paved roads will be developed globally by 2050 — enough to encircle the planet more than 600 times. Roughly 90% of new roads will be built in developing nations, frequently in tropical and subtropical regions with high biodiversity and environmental values. Many developing nations are borrowing from international lenders or negotiating access to their natural resources in order to expand their transportation infrastructure. Given the unprecedented pace and extent of these initiatives, it is vital to thoroughly assess the potential consequences of large-scale road and highway projects. In appropriate contexts and locales, new roads can promote sizeable economic and social benefits. If poorly planned or implemented, however, new roads can provoke serious cost overruns, corruption and environmental impacts, while generating sparse economic benefits and intense social and political conflict. Using examples from developing nations, we identify risks that can hinder road projects in wet and dry tropical environments. Such risks, we assert, are often inadequately considered by project proponents, evaluators and the general public, creating a systematic tendency to overestimate project benefits while understating project risks. A more precautionary approach is needed to reduce risks while maximizing benefits of new road projects in the tropics.

Introduction

Roads are expanding across the globe at an unprecedented rate, both in total length and spatial extent [1,2]. The length of legally sanctioned roads has increased by ~12 million km worldwide since 2000 [3], with a further 25 million km of additional paved roads expected by 2050 [2,3]. To support this dramatic expansion, the G20 industrial nations have asserted that US$70 trillion in funding will be needed by 2030 for new roads and other infrastructure, which would more than double global investments in infrastructure to date [4].

Around 90% of all new infrastructure projects are occurring or expected to occur in developing nations [3], with the tropics emerging as an epicentre of road proliferation (Figure 1) [1–3,5,6]. For instance, China's planned 'Belt and Road' and '21st Century Maritime Silk Road' projects are expected to span 70 nations extending across most of Asia to Europe and Africa [7,8]. In Africa, the 35 major 'development corridors' that are being planned or are progressing would crisscross the continent, collectively exceeding 53,000 km in length [9,10]. A similarly ambitious suite of infrastructure projects is advancing across Latin America, penetrating into many remote regions and key ecosystems [3,8] (Box 1).

The growing populations and aspirations of developing nations are justifiably creating a powerful impetus for road development, yet the tropics also harbor much of the planet's biodiversity [11,12] and provide critical environmental services for humanity and nature alike [13,14]. Roads that are effectively located and constructed can provide positive outcomes for economic growth and social integration, and access to larger urban markets for local producers [15–18]. Roads that are poorly planned or executed, however, can create numerous environmental [9,19–26], economic [27–30], and socio-political [31–33] problems. For example, a proposed 'superhighway' in Nigeria would have cut through much of the remaining habitat for the endangered Cross River Gorilla (*Gorilla gorilla diehli*), allowing the government to seize extensive traditional community-owned lands while providing questionable economic benefits [34].

The positive effects of new roads are often enthusiastically proclaimed by road proponents and stakeholders [15,17,35–38], but their potential risks are frequently downplayed [9,22–24,27,39–41]. Unprecedented sums of money are being invested in road and other infrastructure projects in developing nations [4]. However, the extent of long-term economic risks to which project investors and international lenders are exposed is often not apparent or fully understood [27,42,43]. This arises from inadequate dissemination and public debate of the full array of environmental, economic and socio-political risks of road development, the revelation of which could greatly assist stakeholders in the planning and execution of major projects [44].

Here, we provide a cross-disciplinary synthesis of the environmental, economic and socio-political risks of road building, focusing on wet and dry tropical environments. A fuller appreciation of the relative risks and rewards of roads is ugently needed in the tropics, where roads are playing a pivotal role in many development schemes and in determining the pace and pattern of environmental change [1,5].

Environmental Impacts and Risks

Road building can affect biodiversity both directly, as an immediate consequence of a road and its construction; or

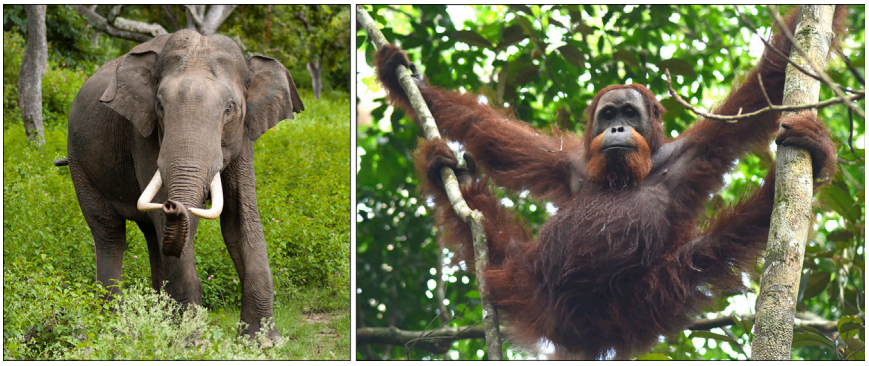

Figure 1. Road risk.
The greater Leuser Ecosystem in northern Sumatra is the last place on Earth where elephants, rhinoceros, tigers and orangutans still survive together, and is threatened by plans for major road expansion. (Elephant photo: William Laurance; orangutan photo: Suprayudi).

indirectly, as a result of human activities that are facilitated by new roads [19,24]. Examples of direct effects include vehicle–wildlife collisions [19,45,46], reduced reproductive capacity of sensitive species as a result of chronic road noise [21,47–51] and behavioural avoidance of roads [19,21,22,52,53]. Roads can also function as barriers to animal movement; for instance, several species of Amazonian understory birds (*Hylophylax* spp. and *Formicarius* spp.) that were experimentally translocated would cross a 75 meter-wide forest clearing but were unwilling to cross a clearing of 250 meter width — even to return to their permanent territory and lifelong mate [54].

Roads increase the amount of abrupt, artificial edge habitat in forested landscapes [55,56]. These forest edges experience varied physical and biotic edge effects that can alter forest microclimates, distributions of specialized plant and animal species, geochemical cycles, and the biomass, structure and composition of forests [24,57,58]. Furthermore, sharply elevated light levels near forest edges lead to a proliferation of disturbance-loving vines, pioneer trees and invasive plants [24,57,59,60]. Forest edges are also more vulnerable to recurring wind shear and turbulence, as well as heavier damage from periodic wind storms [61–63].

As vegetation is cleared along and adjacent to new roads, soil erosion and sediment inputs to water courses can rise sharply (Figure 2), especially in wet regions [64]. For example, in the first two years after construction, logging roads and tracks in Peninsular Malaysia and dirt roads in East Java, Indonesia were found to generate 275 t ha^{-1} yr^{-1} [65] and 73 t ha^{-1} yr^{-1} [66] of sediment, respectively — far more than those from other nearby land uses. Soil erosion from dirt roads was modest (0.84 t ha^{-1} yr^{-1}) in the dry tropics of Puerto Rico but this was still ~15 times higher than in non-road habitats [67]. Road-induced erosion is much greater in steep or dissected terrain, in part because heavier roadworks (more cut-and-fill activities to level the road surface) are needed [64,65,68].

In wet tropical regions, rapid erosion from roads and the resulting heavy pulses of sediment into streams and rivers elevate water turbidity and temperature, reduce dissolved oxygen content, and alter natural flow regimes [69,70]. Silt and nutrient inputs into freshwater ecosystems can also promote eutrophication, which can kill sensitive fish and freshwater invertebrates [19] and reduce water quality for humans and livestock [71,72]. Rapid surface flows from roads increase both local and downstream flooding. Few roads in high-rainfall zones have sufficient culverts, bridges or other drainage structures to divert water through or around the roads. The recurring impediment of water causes localized flooding and vegetation mortality, peaking during periods of intense rainfall [19,69,70].

Road construction in mountainous areas also increases the risk of landslides [26,68,73,74]. In montane forests of Southeast Asia, landslides were two to three times more frequent in terrain with roads than without roads [68]. In a mountainous region of Puerto Rico, landslides were 4–13 times more frequent near roads (<80 m from the road) than in comparable sites with agriculture or forest cover [73,74].

In forested regions, new roads sharply increase human accessibility [75], fundamentally transforming economic and social dynamics and increasing migration into forest frontiers. The environmental impacts of forest colonization can be diverse, including increased fires [76], land speculation, illegal mining, poaching, timber theft and forest clearing for illicit drug production [76–78]. Roads profoundly influence the spatial patterns of deforestation. In Brazilian Amazonia, 95% of all deforestation occurs within 5.5 km of a paved or unpaved road [75]. Similar trends are evident in Cambodia [39], Sumatra [78], Thailand [79] and Panama [80] and occur even inside some legally protected areas [81].

Forest roads greatly increase physical access for poachers and hunters [22,41,82]. In Peninsular Malaysia, a systematic survey revealed that ~90% of snares and poaching camps were located within 5 km of a paved road [39]. Road expansion in the Congo Basin has sharply increased commercial and subsistence hunting, intensifying pressures on a range of larger (>1 kg) wildlife species [41]. Over the past decade, about two-thirds of all Africa's forest elephants have been slaughtered for their valuable ivory tusks [9].

In many developing nations, illegal or unofficial roads are more prevalent than legal roads, often because of widespread illegal logging [1,9,24,83]. In Brazilian Amazonia, for example, nearly 3 km of illegal or unofficial roads exist for every 1 km of legal road [84]. Paved roads that penetrate into remote forested areas play a pivotal role in increasing forest vulnerability to human pressures, because they provide year-round access to forests even during the wet season, when many unpaved roads become impassable [24]. Illegal secondary roads can proliferate like a 'spider web' around such paved roads, greatly increasing the spatial extent of habitat disruption. For these reasons, 'avoiding the first cut' — halting the penetration of permanent roads into intact habitats — is the most urgently needed means to limit the scale and pace of environmental degradation in the tropics [1,2]. It is also among the most cost-effective of all conservation strategies [2,24].

Box 1. Explosive road expansion in the tropics.

We are currently witnessing the most dramatic era of road expansion in human history. In Equatorial Africa, more than 50,000 km of logging roads were constructed from 1976 to 2003 [146,147], with much logging expansion occurring since then [118]. Meanwhile, China alone is currently investing ~US$100 billion annually in Africa for extractive mineral industries and associated transportation and energy infrastructure [148]. Many of these developments form part of the planned or existing 'development corridors' in Sub-Saharan Africa, which if completed would total more than 53,000 km in length [9,10]. In many instances, these corridors would penetrate into remote areas, threatening some of the continent's last remaining intact ecosystems [2,10,149].

In South America, some 335 infrastructure projects are being advanced under the IIRSA program (Initiative for Integration of Regional Infrastructure of South America) [150,151]. In the Amazon basin alone, new and proposed infrastructure would sharply accelerate the spatial scale of forest loss, fragmentation and degradation [57,150,152]. China's growing investments in Latin America are heavily weighted toward infrastructure and natural-resource exploitation. For example, a planned Chinese-funded railroad would total more than 5,000 km in length and completely bisect the continent from East to West [153].

Across Asia, the total length of paved roads in developing nations is expected to double by 2020 [154]. A constellation of roads and other transportation projects under the aegis of China's massive "Belt and Road" and "21st Century Silk Road" projects will link China to Southeast Asia, Central Asia, Europe, and Africa. Indonesia plans to invest US$2.6 billion in six massive 'Economic Corridors' that will cut across the islands of Sumatra, Java, Kalimantan, Sulawesi, New Guinea, and the island chain extending from Bali to East Timor [35]. In Malaysia, the road network expanded by 68% in length (an additional 93,000 km) from 2010 to 2015 [155,156]. Further, the planned Pan-Borneo Highway and its feeder roads will crisscross forested areas of Sarawak and Sabah, imperiling some of Malaysia's most important wildlife habitats [157].

Challenges for Building and Maintaining Tropical Roads

Roads are expensive to construct in steep, dissected or swampy terrain. These higher costs arise from a need for more bridges, tunnels, culverts and cut-and-fill operations, along with an increase in the complexity of construction techniques. Roads in bogs, swamps and peatlands are also expensive because a high road base is needed to maintain the road surface above seasonally fluctuating water levels, along with sufficient culverts or drainage structures to avoid impeding aboveground water movement [68–70]. Our extensive observations (spanning ~160 person-years in Latin America, the Asia-Pacific and Africa) suggest that few roads in the tropics are adequately constructed to withstand the effects of heavy rainfall — especially the intense bursts associated with tropical air depressions or hurricanes, when up to a metre of rain can fall in just a few days. A common sign of inadequate drainage is pronounced flooding along one side of a road that has killed numerous trees and other plants [24].

Maintenance costs for roads can be very high in wet tropical environments. Localized floods or surface flows promote potholes and rutting [68–70], whereas subsurface water flow causes soil slumping [85], undermining and fracturing the road surface. Such road-surface damage sharply reduces mean vehicle speeds while increasing traffic bottlenecks and accident risk, depressing the economic potential of the road investment (Figure 3). In many developing nations, too much funding is being devoted to ambitious road-expansion schemes and too little funding allocated to maintain and repair roads in the years following construction [70,86–93]. Rapid road deterioration and a failure to generate expected economic and social benefits appears especially likely when initial road-construction costs are met by foreign lenders, donors or investors, but ongoing maintenance is left to local and national governments. In the wet tropics and in challenging topographies, major road investments can easily be squandered [70,86,94].

Road projects are also highly vulnerable to poor governance. Major infrastructure ventures — which necessarily involve large budgets and myriad interactions among government decision-makers, road proponents, local stakeholders and construction contractors — are highly exposed to such challenges. Poor governance is especially problematic in low- to middle-income nations, for which corruption (in its many guises) is a greater daily economic impediment than in wealthier nations (Figure 4) [43,95]. A study of 500 World Bank-financed projects (2000–2010) with a road component concluded that one quarter of all projects in low- to middle-income countries had serious allegations of fraud, corruption and collusion, collectively tainting US$14 billion in investments [27]. On average, per-unit road-development costs were ~30% higher in countries with political conflicts than in those without conflicts. Corruption generates multiplying inefficiencies, with each 1% increase in corruption (as a proportion of the project budget) resulting in an increase of up to 7% in total project costs [27].

According to the World Bank, the estimated 'tax' of collusion and cartel influences on road-related projects ranges from 8–60% of total project costs [28]. In Bangladesh, it was estimated that companies involved in World Bank-funded infrastructure projects were required to pay 15% of the total contract value to government officials in exchange for the awarding of a contract [28]. In Africa, an estimated 15–20% of the total bid price of World Bank-funded roads was allocated to fraudulent components such as nonexistent cement and reduced road base [28]. In Indonesia, a study of 600 road projects reported that, on average, 24% of the total project costs could not be explained [96]. Thus, a sizeable fraction of the road-related investment boom in tropical nations can be squandered by lost revenues and shoddy construction practices. Because World Bank-financed projects might have greater oversight and control than do those funded from the private sector [97], the analyses of road-related corruption cited here might actually be underestimates.

Financial Risks of Road Projects

Many trillions of dollars are currently being invested in road and other infrastructure projects in developing nations [4]. However,

Figure 2. High sediment load in a tropical river.
Satellite images showing pre-logging (top, c. 2011) and post-logging (bottom, c. 2016) sediment levels in a rainforest river in the hills near Lake Kenyir, Peninsular Malaysia. The arrow highlights a river with particularly high sediment loads. (Top image: ASTER satellite; bottom image: Landsat 8 satellite.)

Figure 3. Potholes and slumping in tropical roads.
Large potholes (top) can substantially reduce road efficacy. Sloping terrain (bottom) in wet tropical environments is particularly prone to slumping, leading to large cracks or a collapse of the road surface. (Photos: William Laurance.)

the long-term economic risks to which project investors and international lenders are exposed is rarely apparent, understood or presented transparently [27,42,43]. Government planners have often seen road expansion as a cost-effective means to accelerate economic growth and social integration, but the magnitude of such benefits is highly variable and sensitive to local context [16,98,99]. New or improved roads appear particularly beneficial when they link rural farming populations to urban markets, allowing farmers to gain higher crop prices, improved agricultural technologies and other livelihood benefits (such as improved access to health and educational services), while meeting growing urban food demand [2,16,100–102].

In other settings, however, the benefits of new roads seem more far precarious [99]. The World Bank has characterized infrastructure projects such as major roads as a "blunt instrument" for aiding the poor [98]. Strategies for driving economic growth via road expansion can be plagued by a wide range of hazards [99,103], many of which are poorly discussed or debated before project approval. For example, road building in high-risk topographic locations, such as floodplains or steep terrain, can cost governments and investors billions of dollars in lost revenue due to cascading impacts on other sectors of the economy [70]. Impacts on downstream fisheries, agriculture, recreation, aesthetics and the costs of ecological restoration can all be considerable. Via its impacts on water quality and fish-breeding sites, planned road expansion in the Lower Mekong Basin could negatively impact fisheries [69,70] worth an estimated US$2 billion per year [104]. In Indonesia, deforestation caused by forest-road building in Aceh state has increased

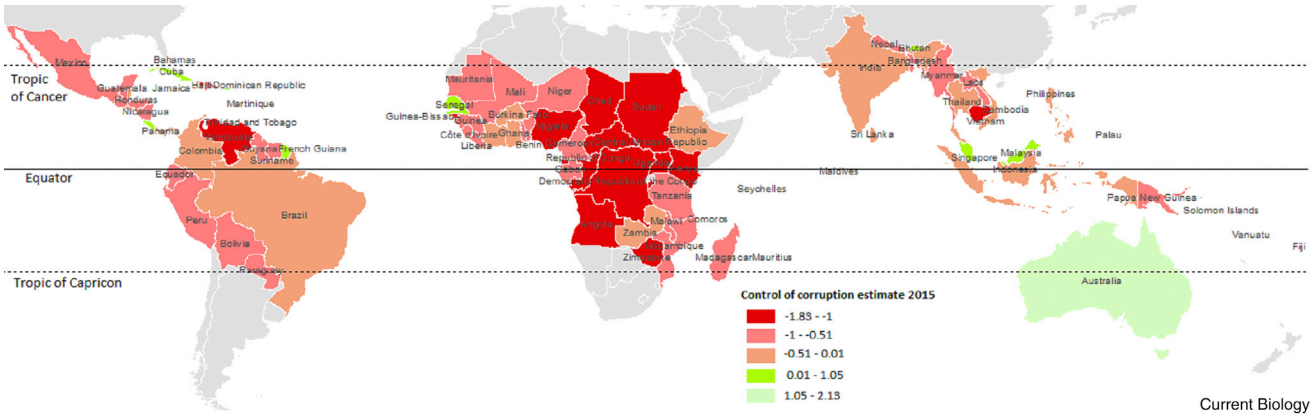

Figure 4. Governance in tropical nations.
'Control of corruption' values for tropical nations in 2015. Values that are strongly negative (dark red) indicate greater corruption (Worldwide Governance Indicators database; http://info.worldbank.org/governance/wgi/index.aspx#home).

downstream flooding, requiring ~US$15 million per year in flood-prevention measures [105]. Efforts to establish ecological-corridor networks in roaded landscapes can be expensive and of uncertain effectiveness for maintaining wildlife movements [106].

Cost-benefit analyses for road investments often fail to include key factors, such as the effects of inflation, the expense of servicing project debt, and long-term environmental and social impacts [107,108]. The costs of road maintenance, ecological restoration and unexpected outlays from corruption, political instability or labor disputes [109] can easily exceed expected project returns [70]. For example, restoration costs for oil-palm and wood-pulp plantations in tropical peatlands, which contain massive stocks of belowground carbon [110], could outstrip the long-term economic gains of peatland exploitation [111]. Major road projects in wet, steep terrain, such as the Trans-Papuan Highway in Indonesia and Trans-Borneo Highway in Malaysia, face daunting risks from landslides, flooding and road collapse. The precautionary lessons of high-risk infrastructure projects need to be considered *before* nations barter away access to their natural resources or incur heavy foreign debts for development.

A key concern is that the meteoric rise of major financial institutions, such as the Asian Infrastructure Investment Bank, Chinese Import-Export Bank, and Brazilian Development Bank (BNDES), could increase the risk of unwise infrastructure investments. These institutions have 'streamlined' environmental and social guidelines to reduce paperwork and accelerate project approvals [112]. To remain economically competitive with the new lenders, the World Bank announced in 2016 a similarly diluted approach to its project safeguards [113,114]. This has provoked anxieties about a potential 'race to the bottom' by large-scale infrastructure lenders [115]. The World Bank's shift from a rules-based compliance system towards one of unprecedented flexibility—favouring a borrower's national laws and policies in lieu of its traditional safeguards—is particularly worrisome [116].

In addition to multilateral and bilateral lenders, private capital is a growing driver of infrastructure expansion [117]. It is far from certain, however, whether private financiers will support projects that seek to balance environmental and social criteria with profitability. Most investors remain strongly profit-oriented, although there is growing interest in projects that can compete financially with traditional infrastructure schemes while reducing their long-term environmental and social risks [117]. There is a dire need for novel mechanisms to attract major private funds for sustainable infrastructure projects.

Socio-political Risks of Road Projects

Road proponents frequently portray their proposed projects as a panacea for many social aspirations [2,15,16]. However, the broad societal risks that new roads can create are rarely identified or weighted adequately [118,119]. Road development in remote areas, for example, can lead to increases in illicit logging, mining, poaching, smuggling and drug production [41,120–122]. Such practices can exacerbate environmental and social problems, defraud governments of tax and royalty revenues, and require increased expenditures for monitoring and law enforcement [120,121].

Some road projects instigate serious social unrest (Figure 5) [123,124]. During the initial phases of development, real or perceived inadequacies in community consultation or forced land reclamations can be flash-points for conflict. Community dissatisfaction may be aroused if benefits from roads are distributed inequitably, such as via a lack of employment opportunities for local residents or perceived government corruption. Road projects in frontier areas commonly lead to an influx of migrant workers or colonists, with potentially adverse impacts on local inhabitants [24,122,123]. Among the undesirable effects are increased demands for 'immoral' services such as prostitution and black-market products [39], an increase in sexually transmitted infections [125] and an erosion of traditional social structures [123]. Such challenges can provoke community conflict, potentially delaying road development or increasing its economic costs. Some frontier communities living in the aftermath of new roads are highly polarized between 'locals' and 'migrants' [123,126].

Social risks do not end once a road project has been completed. For instance, vehicle crashes have substantial socio-economic impacts, averaging 3.3% of total GDP in high-income

Figure 5. Protests against roads.
A mining road in old-growth rainforest in Panama that generated heated public debate (Photo: Susan Laurance). Inset above: Protest against a government-approved highway that will cut through indigenous and protected areas in Bolivia (Photo: Szymon Kochański/Wikimedia Commons). Inset below: Protest against a planned highway in indigenous lands in Arizona, USA (Photo: © Reuters/Kevork Djansezian).

countries and at least 1.1 to 2.9% of total GDP in lower-income countries [32]. New roads act as invasion corridors, facilitating incursions of human and animal pathogens and disease vectors [24]. In Ecuador, infection rates of human enteric pathogens were 2-8 times higher in villages near roads than in remote villages [127]. People living near roads in India, Brazil, and Uganda have reported increased incidences of dengue fever, malaria and HIV, respectively [125,128,129]. Exotic plants and animals, including many species deleterious to humans or agriculture, often use road verges to invade new lands. Little fire ants (*Wasmannia auropunctata*), for example, invade ~60 times faster along logging roads in African rainforests than in undisturbed forests; the intense stings from this species repel and even kill livestock, wildlife and people [130]. For such reasons, cost-benefit analysis of roads must consider not only their immediate prospective benefits, but also their longer-term socioeconomic and environmental risks.

For indigenous groups in remote areas, new roads can have irrevocable effects [126]. Roads have decimated some indigenous populations via introduced diseases and forced or voluntary migration [131]. In the 1970s, the construction of the TransAmazon Highway led to the deaths of 45% of one indigenous group in a single year [132]. Roads penetrating into tribal territories can lead to an influx of non-indigenous squatters and land speculators seeking to appropriate land titles. Additional impacts such as alcohol abuse, prostitution, illegal mining and social domination by colonists can arise [133–135]. In Sumatra, Indonesia, heavy environmental degradation accompanying the Pekanbaru-Dumai road was blamed on a lack of social responsibility among new migrants, whose incursions followed new road construction [126]. Roads penetrating into remote areas are often perceived as a driver of increased aggression, lawlessness and other 'frontier society' behaviours [120,121,126]. In Peninsular Malaysia, indigenous communities living in remote areas have cited such concerns as reasons for opposing new roads in their vicinity [136].

Environmental Impact Assessments

Environmental impact assessments (EIAs) are intended to identify many of the risks and potential liabilities of infrastructure projects, and to minimize such risks with suitable mitigation and offset measures. However, relatively few EIAs are considered sufficiently robust or adequate in scope [118,137]. For example, requirements and approvals for EIAs are typically determined by local or national jurisdictions. As such, the EIA depends upon the enforcement capacity, willingness and predilections (e.g. pro-development or not) of the jurisdiction. EIAs often lack consistency across local or national political boundaries, limiting their utility and comparability [138].

EIAs can suffer from a range of structural problems. For instance, EIAs for road projects may be performed at narrow spatial scales that fail to identify impacts on wide-ranging wildlife, whose large home ranges may overlap with planned road locations [139]. Few EIAs effectively assess a project's indirect or induced effects — such as when a road opens a forested region to subsequent encroachment, poaching and habitat fragmentation [2,138]. Importantly, most EIAs are funded by the project proponent, creating potential conflicts of interest [2,9]. For instance, a consultancy firm might hesitate to conduct a stringent EIA if it believes it could be black-balled by other project proponents in the future [118,138]. Finally, EIA processes effectively place the burden of proof on road opponents [119,140], who rarely have detailed information on rare species, biological resources and ecosystem services [141] needed to determine the actual environmental costs of roads.

Such deficiencies of EIAs increase the risk of environmental damage, social conflicts and litigation. This can lead to project delays, cost overruns or even project cancellation [118,119,137]. Some structural deficiencies of EIAs are addressed by strategic environmental assessments (SEAs) and social cost-benefit analyses, which attempt to evaluate the wider geographic context of projects as well as their various indirect or induced effects [1,137]. Unfortunately, SEAs and social-oriented analyses are expensive and therefore applied to only a minority of road projects. Such limitations underscore a key need to augment EIAs or SEAs with more broadly-based, strategic approaches to infrastructure and land-use planning [1,2,9,25].

Conclusions

The tropics are experiencing an unprecedented boom in new roads and other infrastructure. It is vital, given the transformative effects of such projects on economies, societies and environments, that their potential rewards and risks be fully disclosed and considered publicly. It is incumbent upon scientists to broaden the discourse, especially for high-risk projects (Box 2).

We emphasize four key conclusions. First, status quo procedures for evaluating roads can create a potent bias in favor of project approval. Cost-benefit analyses frequently fail to incorporate key factors that affect project profitability and risks [70,107,108]. Further, corrupt practices can generate perverse incentives in favor of ill-advised projects, rewarding decision makers who approve new roads despite unfavorable conditions

Box 2. Rationale for opposing ill-advised infrastructure projects.

There are strong reasons and effective strategies for challenging high-risk infrastructure projects:
Many planned projects do not ultimately proceed, as a result of shifting economic factors, political priorities or growing public disapproval. Hence, opposition to such projects is far from hopeless, because many are halted or substantially modified.
When a high-risk infrastructure project is proposed, it is essential to act immediately to advance a public narrative that highlights the key risks and weaknesses of the project. Ill-advised projects are much more difficult to stop if they have received required legal approvals or if project proponents have been allowed to dominate public discourse.
Sustained opposition is effective because many project proponents, such as corporations or governments, have short-term goals for profits or fixed political terms that have limited tolerance for project delays.
Few people — including decision-makers and project investors — understand the diverse suite of economic, social and environmental risks associated with major infrastructure projects. Cost-benefit analyses are frequently biased to favor project approval.
Some members of the public incorrectly believe that any proposed development is inherently desirable, as it will generate jobs and economic growth. This misperception must be actively addressed because some projects become major money-losers — creating large public debts, the costs of which must ultimately be borne by taxpayers.
In most nations, corruption and other undocumented inducements to decision-makers by project proponents creates a systematic bias in favor of project approval. Politically connected individuals and land speculators can acquire great wealth, whereas the majority of the public receives little advantage or even suffers financially from growing public debt and inflated living costs.

and risks [27,28,95]. Even if one disregards their environmental effects, new roads can have such large economic, social and political ramifications that no major project should be accepted uncritically.

Second, prevailing strategies for evaluating the environmental, social and economic impacts of major road projects, such as EIAs and SEAs, are necessary but insufficient for assessing the full costs of projects. For instance, the terms of reference for EIAs rarely consider the wider effects of other concurrent developments or environmental changes [118]. This underscores a dire need for strategic approaches for planning and prioritizing infrastructure projects — such as the 'global-roadmapping' (http://www.global-roadmap.org) scheme [1,2,5,9] that can be used to zone any geographic region to maximize the socio-economic benefits and minimize the environmental costs of new developments.

Third, there is great scope to increase private and public investment in sustainable development. At present, 'green bonds' for development projects constitute less than 0.6% of all debt securities [142], and less than 0.2% of all banking assets are held by institutions that have pledged to promote positive change in the banking industry (http://www.gabv.org) [143]. A key challenge is making sustainable investments more profitable and competitive with other investment options, such as by incorporating long-term social and environmental costs that are typically undervalued in investment decisions.

Finally, some environmental and social mitigation efforts for roads and other developments are little more than window-dressing [144]. This creates a false sense of security while understating the inherent risks of such projects. Investors are accustomed to risk-reward frameworks in which higher risk translates into larger profits, and vice-versa. Such frameworks, however, presuppose that investors have full and accurate information on which to base their decisions [145]. As we have argued here, many infrastructure projects have diverse and obscure arrays of risks. This creates a dangerous gauntlet for investors who fund poorly conceived projects, but great opportunities for those advancing 'smart infrastructure' that strives to be truly sustainable.

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REFERENCES

1. Laurance, W.F., and Balmford, A. (2013). A global map for road building. Nature *495*, 308–309.
2. Laurance, W.F., Clements, G.R., Sloan, S., O'Connell, C.S., Mueller, N.D., Goosem, M., Venter, O., Edwards, D.P., Phalan, B., Balmford, A., *et al*. (2014). A global strategy for road building. Nature *513*, 229–232.
3. Dulac, J. (2013). Global land transport infrastructure requirements: Estimating road and railway infrastructure capacity and costs to 2050 (Paris, France: International Energy Agency), p. 50.
4. Alexander, N. (2014). The emerging multi-polar world order: its unprecedented consensus on a new model for financing infrastructure investment and development (Washington, DC: Heinrich Böll Foundation North America).
5. Balmford, A., Chen, H., Phalan, B., Wang, M., O'Connell, C., Tayleur, C., and Xu, J. (2016). Getting road expansion on the right track: a framework for smart infrastructure planning in the Mekong. PLoS Biol. *14*, e2000266.
6. Caro, T., Dobson, A., Marshall, A.J., and Peres, C.A. (2014). Compromise solutions between conservation and road building in the tropics. Curr. Biol. *24*, R722–R725.
7. Honjiang, C. (2016). The Belt and Road Initiative and its impact on Asia-Europe connectivity (Beijing, PR China: China Institute of International Studies).
8. Laurance, W. (2017). The dark legacy of China's drive for global resources. In Yale Environment 360 (Yale School of Forestry & Environmental Studies).
9. Laurance, W.F., Sloan, S., Weng, L., and Sayer, J.A. (2015). Estimating the environmental costs of Africa's massive "Development Corridors". Curr. Biol. *25*, 3202–3208.
10. Weng, L., Boedhihartono, A.K., Dirks, P.H.G.M., Dixon, J., Lubis, M.I., and Sayer, J.A. (2013). Mineral industries, growth corridors and agricultural development in Africa. Glob. Food Secur. *2*, 195–202.
11. Myers, N., Mittermeier, R.A., Mittermeier, C.G., da Fonseca, G.A.B., and Kent, J. (2000). Biodiversity hotspots for conservation priorities. Nature *403*, 853–858.

12. Sodhi, N.S., Koh, L.P., Brook, B.W., and Ng, P.K.L. (2004). Southeast Asian biodiversity: an impending disaster. Trends Ecol. Evol. *19*, 654–660.

13. Pan, Y., Birdsey, R.A., Fang, J., Houghton, R., Kauppi, P.E., Kurz, W.A., Phillips, O.L., Shvidenko, A., Lewis, S.L., Canadell, J.G., *et al*. (2011). A large and persistent carbon sink in the World's Forests. Science *333*, 988–993.

14. Watson, J.E.M., Shanahan, D.F., Di Marco, M., Allan, J., Laurance, W.F., Sanderson, E.W., Mackey, B., and Venter, O. (2016). Catastrophic declines in wilderness areas undermine global environment targets. Curr. Biol. *26*, 2929–2934.

15. Hettige, H. (2006). When do rural roads benefit the poor and how? An in-depth analysis (Manila, Philippines: Asian Development Bank), p. 95.

16. Weinhold, D., and Reis, E. (2008). Transportation costs and the spatial distribution of land use in the Brazilian Amazon. Glob. Environ. Change *18*, 54–68.

17. Asian Development Bank (2016). Key indicators for Asia and the Pacific 2016 (Manila, Philippines: Asian Development Bank), p. 359.

18. Bryceson, D.F., Bradbury, A., and Bradbury, T. (2008). Roads to poverty reduction? Exploring rural roads' impact on mobility in Africa and Asia. Dev. Policy Rev. *26*, 459–482.

19. Trombulak, S.C., and Frissell, C.A. (2000). Review of ecological effects of roads on terrestrial and aquatic communities. Conserv. Biol. *14*, 18–30.

20. Coffin, A.W. (2007). From roadkill to road ecology: a review of the ecological effects of roads. J. Transp. Geogr. *15*, 396–406.

21. Kociolek, A.V., Clevenger, A.P., St. Clair, C.C., and Proppe, D.S. (2011). Effects of road networks on bird populations. Conserv. Biol. *25*, 241–249.

22. Laurance, W.F., Croes, B.M., Tchignoumba, L., Lahm, S.A., Alonso, A., Lee, M.E., Campbell, P., and Ondzeano, C. (2006). Impacts of roads and hunting on Central African rainforest mammals. Conserv. Biol. *20*, 1251–1261.

23. Laurance, S.G.W., Stouffer, P.C., and Laurance, W.F. (2004). Effects of road clearings on movement patterns of understory rainforest birds in Central Amazonia. Conserv. Biol. *18*, 1099–1109.

24. Laurance, W.F., Goosem, M., and Laurance, S.G.W. (2009). Impacts of roads and linear clearings on tropical forests. Trends Ecol. Evol. *24*, 659–669.

25. Campbell, M., Alamgir, M., and Laurance, W. (2017). Roads to ruin. In Australasian Science, Volume 38. (Australia: Australia's Authority on Science), pp. 40–41.

26. Leshchinsky, B., Olsen, M.J., Mohney, C., Glover-Cutter, K., Crook, G., Allan, J., Bunn, M., O'Banion, M., and Mathews, N. (2017). Mitigating coastal landslide damage. Science *357*, 981–982.27.

27. Collier, P., Kirchberger, M., and Sonderbom, M. (2015). The cost of road infrastructure in low and middle income countries (Washington, DC: World Bank), p. 37.

28. Messick, R. (2011). Curbing fraud, corruption and collusion in the roads sector (Washington, DC: World Bank), p. 46.

29. Kenley, R., Harfield, T., and Bedggood, J. (2014). Road asset management: the role of location in mitigating extreme flood maintenance. Procedia Economics and Finance *18*, 198–205.

30. Garcia, L.C., Ribeiro, D.B., de Oliveira Roque, F., Ochoa-Quintero, J.M., and Laurance, W.F. (2016). Brazil's worst mining disaster: corporations must be compelled to pay the actual environmental costs. Ecol. Appl. *27*, 5–9.

31. Cousins, J.A., Evans, J., and Sadler, J.P. (2009). 'I've paid to observe lions, not map roads!' – An emotional journey with conservation volunteers in South Africa. Geoforum *40*, 1069–1080.

32. Wijnen, W., and Stipdonk, H. (2016). Social costs of road crashes: an international analysis. Accid. Anal. Prev. *94*, 97–106.

33. Bambach, M.R., and Mitchell, R.J. (2015). Estimating the human recovery costs of seriously injured road crash casualties. Accid. Anal. Prev. *85*, 177–185.

34. Mahmoud, M.I., Sloan, S., Campbell, M.J., Alamgir, M., Imong, I., Odigha, O., Chapman, H.M., Dunn, A., and Laurance, W.F. (2017). Alternative routes for a proposed Nigerian Superhighway to limit damage to rare ecosystems and wildlife. Trop. Conserv. Sci. *10*, 1–10.

35. Strategic Asia (2012). Implementing Indonesia's Economic Master Plan (MP3EI): challenges, limitations and corridor specific differences. (Strategic Asia), 87 pp.

36. OECD (2014). Southeast Asia investment policy perspectives (Paris, France: The Organisation for Economic Co-operation and Development), p. 92.

37. African Development Bank (2014). Study on road infrastructure costs: analysis of unit costs and cost overruns of road infrastructure projects in Africa (Abidjan, Côte d'Ivoire: African Development Bank), p. 40.

38. African Development Bank (2014). Study on quality of Bank financed road projects (Abidjan, Côte d'Ivoire: African Development Bank), p. 318.

39. Clements, G.R., Lynam, A.J., Gaveau, D., Yap, W.L., Lhota, S., Goosem, M., Laurance, S., and Laurance, W.F. (2014). Where and how are roads endangering mammals in Southeast Asia's Forests? PLoS ONE *9*, e115376.

40. Perz, S.G., Caldas, M.M., Arima, E., and Walker, R.J. (2007). Unofficial road building in the Amazon: socioeconomic and biophysical explanations. Dev. Change *38*, 529–551.

41. Wilkie, D., Shaw, E., Rotberg, F., Morelli, G., and Auzel, P. (2000). Roads, development, and conservation in the Congo Basin. Conserv. Biol. *14*, 1614–1622.

42. Corlett, R.T. (2014). The Ecology of Tropical East Asia, Second Edition (Oxford, UK: Oxford University Press).

43. World Bank. (2016). Worldwide governance indicators (Washington, DC: World Bank). http://info.worldbank.org/governance/wgi/index.aspx#home.

44. Bettinger, K. (2014). Death by 1,000 cuts: road politics at Sumatra's Kerinci Seblat National Park. Conservat. Soc. *12*, 280–293.

45. Clevenger, A.P., Chruszcz, B., and Gunson, K.E. (2003). Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. Biol. Conserv. *109*, 15–26.

46. Fahrig, L., Pedlar, J.H., Pope, S.E., Taylor, P.D., and Wegner, J.F. (1995). Effect of road traffic on amphibian density. Biol. Conserv. *73*, 177–182.

47. Qin, Z., Wei, X., and Qing, Y. (2014). Study on environmental protection of highway construction on birds nature reserve. Nat. Env. Poll. Tech. *13*, 831–834.

48. Kerley, L.L., Goodrich, J.M., Miquelle, D.G., Smirnov, E.N., Quigley, H.B., and Hornocker, M.G. (2002). Effects of roads and human disturbance on Amur Tigers. Conserv. Biol. *16*, 97–108.

49. Hoskin, C.J., and Goosem, M.W. (2010). Road impacts on abundance, call traits, and body size of rainforest frogs in Northeast Australia. Ecol. Soc. *15*, 15.

50. Slabbekoorn, H., and Halfwerk, W. (2009). Behavioural ecology: noise annoys at community level. Curr. Biol. *19*, R693–R695.

51. Francis, C.D., Ortega, C.P., and Cruz, A. (2009). Noise pollution changes avian communities and species interactions. Curr. Biol. *19*, 1415–1419.

52. Whitworth, A., Beirne, C., Rowe, J., Ross, F., Acton, C., Burdekin, O., and Brown, P. (2015). The response of faunal biodiversity to an unmarked road in the Western Amazon. Biodivers. Conserv. *24*, 1657–1670.

53. Hockings, K.J., Anderson, J.R., and Matsuzawa, T. (2006). Road crossing in chimpanzees: a risky business. Curr. Biol. *16*, R668–R670.

54. Laurance, S.G.W., and Gomez, M.S. (2005). Clearing width and movements of understory rainforest birds. Biotropica *37*, 149–152.

55. McGarigal, K., Romme, W.H., Crist, M., and Roworth, E. (2001). Cumulative effects of roads and logging on landscape structure in the San Juan Mountains, Colorado (USA). Landscape Ecol. *16*, 327–349.

56. Reed, R.A., Johnson-Barnard, J., and Baker, W.L. (1996). Contribution of roads to forest fragmentation in the rocky mountains. Conserv. Biol. *10*, 1098–1106.

57. Laurance, W.F., Camargo, J.L.C., Luizão, R.C.C., Laurance, S.G., Pimm, S.L., Bruna, E.M., Stouffer, P.C., Bruce Williamson, G., Benítez-Malvido, J., Vasconcelos, H.L., *et al*. (2011). The fate of Amazonian forest fragments: a 32-year investigation. Biol. Conserv. *144*, 56–67.

58. Laurance, W.F., Laurance, S.G., Ferreira, L.V., Rankin-de Merona, J.M., Gascon, C., and Lovejoy, T.E. (1997). Biomass collapse in Amazonian forest fragments. Science *278*, 1117–1118.

59. Laurance, W.F., Nascimento, H.E.M., Laurance, S.G., Andrade, A.C., Fearnside, P.M., Ribeiro, J.E.L., and Capretz, R.L. (2006). Rain forest fragmentation and the proliferation of successional trees. Ecology *87*, 469–482.

60. Campbell, M., Laurance, W.F., and Magrach, A. (2015). Ecological effects of lianas in fragmented forests. In Ecology of Lianas, S.A. Schnitzer, F. Bongers, R.J. Burnham, and F.E. Putz, eds. (Oxford, UK: Willey Blackwell), pp. 443–450.

61. Turton, S.M., and Alamgir, M. (2015). Ecological effects of strong winds on forests. In Handbook of Forest Ecology, K. Peh, R. Corlett, and Y. Bergeron, eds. (Abingdon, UK: Earthscan), pp. 127–140.

62. Lugo, A.E. (2008). Visible and invisible effects of hurricanes on forest ecosystems: an international review. Austral Ecol. *33*, 368–398.

63. Laurance, W.F., and Curran, T.J. (2008). Impacts of wind disturbance on fragmented tropical forests: a review and synthesis. Austral Ecol. *33*, 399–408.

64. Sidle, R.C., and Ziegler, A.D. (2012). The dilemma of mountain roads. Nat. Geosci. *5*, 437–438.

65. Sidle, R.C., Sasaki, S., Otsuki, M., Noguchi, S., and Rahim Nik, A. (2004). Sediment pathways in a tropical forest: effects of logging roads and skid trails. Hydrol. Process. *18*, 703–720.

66. Rijsdijk, A., Bruijnzeel, L.A.S., and Sutoto, C.K. (2007). Runoff and sediment yield from rural roads, trails and settlements in the upper Konto catchment, East Java, Indonesia. Geomorphology *87*, 28–37.

67. Scharrón, C.E.R. (2010). Sediment production from unpaved roads in a sub-tropical dry setting — Southwestern Puerto Rico. Catena *82*, 146–158.

68. Sidle, R.C., Ziegler, A.D., Negishi, J.N., Nik, A.R., Siew, R., and Turkelboom, F. (2006). Erosion processes in steep terrain—truths, myths, and uncertainties related to forest management in Southeast Asia. For. Ecol. Manage. *224*, 199–225.

69. Beevers, L., Douven, W., Lazuardi, H., and Verheij, H. (2012). Cumulative impacts of road developments in floodplains. Transport. Res. D- Tr. E. *17*, 398–404.

70. Douven, W., and Buurman, J. (2013). Planning practice in support of economically and environmentally sustainable roads in floodplains: the case of the Mekong delta floodplains. J. Environ. Manage. *128*, 161–168.

71. Foley, J.A., Asner, G.P., Costa, M.H., Coe, M.T., DeFries, R., Gibbs, H.K., Howard, E.A., Olson, S., Patz, J., Ramankutty, N., *et al*. (2007). Amazonia revealed: Forest degradation and loss of ecosystem goods and services in the Amazon Basin. Front. Ecol. Environ. *5*, 25–32.

72. Mandle, L., Tallis, H., Sotomayor, L., and Vogl, A.L. (2015). Who loses? Tracking ecosystem service redistribution from road development and mitigation in the Peruvian Amazon. Front. Ecol. Environ. *13*, 309–315.

73. Larsen, M.C., and Parks, J.E. (1997). How wide is a road? The association of roads and mass-wasting in a forested montane environment. Earth Surf. Proc. Land. *22*, 835–848.

74. Larsen, M.C., and Torres-Sánchez, A.J. (1998). The frequency and distribution of recent landslides in three montane tropical regions of Puerto Rico. Geomorphology *24*, 309–331.

75. Laurance, W.F., Albernaz, A.K.M., Schroth, G., Fearnside, P.M., Bergen, S., Venticinque, E.M., and Da Costa, C. (2002). Predictors of deforestation in the Brazilian Amazon. J. Biogeogr. *29*, 737–748.

76. Nepstad, D., Carvalho, G., Cristina Barros, A., Alencar, A., Paulo Capobianco, J., Bishop, J., Moutinho, P., Lefebvre, P., Lopes Silva, U., Jr., and Prins, E. (2001). Road paving, fire regime feedbacks, and the future of Amazon forests. For. Ecol. Manage. *154*, 395–407.

77. Freitas, S.R., Hawbaker, T.J., and Metzger, J.P. (2010). Effects of roads, topography, and land use on forest cover dynamics in the Brazilian Atlantic Forest. For. Ecol. Manage. *259*, 410–417.

78. Miyamoto, M. (2006). Forest conversion to rubber around Sumatran villages in Indonesia: comparing the impacts of road construction, transmigration projects and population. Forest Policy Econ. *9*, 1–12.

79. Cropper, M., Puri, J., and Griffiths, C. (2001). Predicting the location of deforestation: The role of roads and protected areas in North Thailand. Land Econ. *77*, 172–186.

80. Sloan, S., and Pelletier, J. (2012). How accurately may we project tropical forest-cover change? A validation of a forward-looking baseline for REDD. Glob. Environ. Change *22*, 440–453.

81. Aldwaik, S.Z., and Pontius, R.G., Jr. (2012). Intensity analysis to unify measurements of size and stationarity of land changes by interval, category, and transition. Landsc. Urban Plan *106*, 103–114.

82. Poulsen, J.R., Koerner, S.E., Moore, S., Medjibe, V.P., Blake, S., Clark, C.J., Akou, M.E., Fay, M., Meier, A., Okouyi, J., *et al*. (2017). Poaching empties critical Central African wilderness of forest elephants. Curr. Biol. *27*, R134–R135.

83. Perz, S., Brilhante, S., Brown, F., Caldas, M., Ikeda, S., Mendoza, E., Overdevest, C., Reis, V., Reyes, J.F., Rojas, D., *et al*. (2008). Road building, land use and climate change: prospects for environmental governance in the Amazon. Philos. Trans. R. Soc. Lond. B Biol. Sci. *363*, 1889–1895.

84. Barber, C.P., Cochrane, M.A., Souza, C.M., Jr., and Laurance, W.F. (2014). Roads, deforestation, and the mitigating effect of protected areas in the Amazon. Biol. Conserv. *177*, 203–209.

85. Chauvel, A., Lucas, Y., and Boulet, R. (1987). On the genesis of the soil mantle of the region of Manaus, Central Amazonia, Brazil. Experientia *43*, 234–240.

86. Sultana, M., Chai, G., Chowdhury, S., and Martin, T. (2016). Deterioration of flood affected Queensland roads – an investigative study. Int. J. Pavement Res. Technol. *9*, 424–435.

87. Asian Development Bank (2017). Projects and tenders. https://www.adb.org/projects/country/vie/sector/transport-1064?terms=Road.

88. Fannin, R.J., and Lorbach, J. (2007). Guide to forest road engineering in mountainous terrain (Rome, Italy: FAO), p. 88.

89. BBC (2016). BBC Trending: Thai women take dip in the road in pothole protest. http://www.bbc.com/news/blogs-trending-37485461.

90. Galve, J.P., Gutiérrez, F., Guerrero, J., Alonso, J., and Diego, I. (2012). Optimizing the application of geosynthetics to roads in sinkhole-prone areas on the basis of hazard models and cost-benefit analyses. Geotext. Geomembranes *34*, 80–92.

91. Galve, J.P., Gutiérrez, F., Guerrero, J., Alonso, J., and Diego, I. (2012). Application of risk, cost–benefit and acceptability analyses to identify the most appropriate geosynthetic solution to mitigate sinkhole damage on roads. Eng. Geol. *145–146*, 65–77.

92. Johnson, R., and Reyes, R. (2010). Cost of plant city sinkhole repairs rises to $7 Million. In The Tampa Tribune. http://plantcity2.tbo.com/content/2010/may/11/111126/cost-plant-city-sinkhole-repairs-rises-7-million/.

93. Hayat, E., and Amaratunga, D. (2014). The impact of the local political and socio-economic condition to the capacity of the local governments in the maintenance of post-disaster road infrastructure reconstruction assets. Procedia Economics and Finance *18*, 718–726.

94. Kaliba, C., Muya, M., and Mumba, K. (2009). Cost escalation and schedule delays in road construction projects in Zambia. Int. J. Proj. Manag. *27*, 522–531.

95. Laurance, W.F. (2004). The perils of payoff: corruption as a threat to global biodiversity. Trends Ecol. Evol. *19*, 399–401.

96. Olken, B.A. (2007). Monitoring corruption: evidence from a field experiment in Indonesia. J. Polit. Econ. *115*, 200–249.

97. Kenny, C. (2006). Measuring and reducing the impact of corruption in infrastructure (Washington, DC: World Bank), p. 42.

98. World Bank (1994). World development report: Infrastructure for development. (New York), 80 pp.

99. Turner, M. (2013). Roads as economic development. In Property and Environment Research Center. https://www.perc.org/blog/roads-economic-development.

100. Jacoby, H.C. (2000). Access to markets and the benefits of rural roads. Econ. J. (London) *110*, 713–737.

101. Van de Walle, M. (2002). Choosing rural road investments to help reduce poverty. World Dev. *30*, 575–589.

102. Stifel, D., Minten, B., and Koru, B. (2016). Economic benefits of rural feeder roads: evidence from Ethiopia. J. Dev. Stud. *52*, 1335–1356.

103. Burgués, I., Brunner, A., Barr, R., Malky, A., Mazosera, A.B., and Reid, J. (2015). Making the economic case to promote avoidance in infrastructure development. In 35th Annual Conference of the International Association for Impact Assessment. (Firenze, Italy).

104. Baran, E., Jantunen, T., and Chong, C.K. (2007). Values of inland fisheries in the Mekong River Basin (Phnom Penh, Cambodia: WorldFish Center), p. 76.

105. Cochard, R. (2017). Degradation and biodiversity losses in Aceh Province, Sumatra. In Redefining Diversity and Dynamics of Natural Resources Management in Asia, *Volume 1*, G. Shivakoti, U. Pradhan, and H. Helmi, eds. (Amsterdam: Elsevier), pp. 231–271.

106. Holzgang, O. (2001). Corridors for wild animals in Switzerland: the basis for regional networking of habitats (Switzerland: Federal Office for the Environment, Forests and Landscape (SAEFL)), p. 326.

107. Flyvbjerg, B. (2009). Survival of the unfittest: why the worst infrastructure gets built—and what we can do about it. Oxford Rev. Econ. Pol. *25*, 344–367.

108. Ansar, A., Flyvbjerg, B., Budzier, A., and Lunn, D. (2014). Should we build more large dams? The actual costs of hydropower megaproject development. Energy Policy *69*, 43.

109. Laurance, W.F., Croes, B.M., Guissouegou, N., Buij, R., Dethier, M., and Alonso, A. (2008). Impacts of roads, hunting, and habitat alteration on nocturnal mammals in African rainforests. Conserv. Biol. *22*, 721–732.

110. Bonn, A., Allott, T., Evans, M., and Stoneman, R. (2016). Peatland Restoration and Ecosystem services - Science, Policy and Practice (Cambridge, UK: Cambridge University Press).

111. Morel, A., Friedman, R., Tulloch, D.J., and Caldecott, B. (2016). Stranded assets in palm oil production: a case study of Indonesia (UK: Smith School of Enterprise and Environment, University of Oxford), p. 77.

112. Humphrey, C., Griffith-Jones, S., Xu, J., Carey, R., and Prizzon, A. (2015). Multilateral Development Banks in the 21st Century: Three Perspectives on China and the Asian Infrastructure Investment Bank (London: Overseas Development Institute), p. 16.

113. World Bank (2016). The new environmental and social framework (Washington, DC: World Bank), p. 106.

114. Asian Infrastructure Investment Bank (2016). Environmental and social framework (Beijing, PR China: Asian Infrastructure Investment Bank), p. 54.

115. CEE (2015). New Beijing-backed Asian Infrastructure Investment Bank struggles to convince on environment and sustainability issues. In Bankwatch Mail, *Volume 63* (Czech Republic: CEE Bankwatch Network), p. 3.

116. Bank Information Center (2016). World Bank's updated safeguards a missed opportunity to raise the bar for development policy (Washington DC: Bank Information Center).

117. Weber, B., Staub-Bisang, M., and Alfen, H.W. (2016). Infrastructure as an Asset Class (New York: Wiley Publishers).

118. Laurance, W.F., Peletier-Jellema, A., Geenen, B., Koster, H., Verweij, P., Van Dijck, P., Lovejoy, T.E., Schleicher, J., and Van Kuijk, M. (2015). Reducing the global environmental impacts of rapid infrastructure expansion. Curr. Biol. *25*, R259–R262.

119. Laurance, W.F. (2007). Road to ruin. Himalayan J. Sci. *4*, 9.

120. McSweeney, K., Nielsen, E.A., Taylor, M.J., Wrathall, D.J., Pearson, Z., Wang, O., and Plumb, S.T. (2014). Drug policy as conservation policy: narco-deforestation. Science *343*, 489–490.

121. Asner, G.P., Llactayo, W., Tupayachi, R., and Luna, E.R. (2013). Elevated rates of gold mining in the Amazon revealed through high-resolution monitoring. Proc. Natl. Acad. Sci. USA *110*, 18454–18459.

122. Suárez, E., Morales, M., Cueva, R., Bucheli, V.U., Zapata-Ríos, G., Toral, E., Torres, J., Prado, W., and Olalla, J.V. (2009). Oil industry, wild meat trade and roads: indirect effects of oil extraction activities in a protected area in north-eastern Ecuador. Anim. Conserv. *12*, 364–373.

123. Rudel, T.K. (2005). Tropical Forests: Regional Paths of Destruction and Regeneration in the Late 20th Century (New York: Columbia University Press).

124. Rudel, T.K. (1983). Roads, speculators, and colonization in the Ecuadorian Amazon. Hum. Eco. *11*, 385–403.

125. Carswell, J.W. (1987). HIV infection in healthy persons in Uganda. AIDS *1*, 223–227.

126. Colombijn, F. (2002). Introduction: on the road. J. Humanities Social Sci. Southeast Asia *158*, 595–617.

127. Eisenberg, J.N.S., Cevallos, W., Ponce, K., Levy, K., Bates, S.J., Scott, J.C., Hubbard, A., Vieira, N., Endara, P., Espinel, M., *et al*. (2006). Environmental change and infectious disease: how new roads affect the transmission of diarrheal pathogens in rural Ecuador. Proc. Natl. Acad. Sci. USA *103*, 19460–19465.

128. Dutta, P., Khan, S.A., Sharma, C.K., Doloi, P., Hazarika, N.C., and Mahanta, J. (1998). Distribution of potential dengue vectors in major townships along the national highways and trunk roads of Northeast India. Southeast Asian J. Trop. Med. Public Health *29*, 173–176.

129. Hayes, J., and Ferraroni, J. (1981). Malaria along pioneer highways in the Brazilian Amazon (Ciencia e cultura-Sociedade Brasileira para o Progresso da Ciencia).

130. Walsh, P.D., Henschel, P., Abernethy, K.A., Tutin, C.E.G., Telfer, P., and Lahm, S.A. (2004). Logging speeds Little Red Fire Ant invasion of Africa. Biotropica *36*, 637–641.

131. Koji, T., and Hoban, C. (1997). Roads and the Environment: a Handbook (Washington, DC: The World Bank), p. 252.

132. Hecht, S.B., and Cockburn, A. (2010). The Fate of the Forest: Developers, Destroyers and Defenders of the Amazon, Updated Edition (Chicago, USA: The University of Chicago Press).

133. Singleton, I., Wich, S., Husson, S., Stephens, S., Atmoko, S.U., Leighton, M., Rosen, N., Traylor-Holzer, K., Lacy, R., and Byers, O. (2004). Orangutan population and habitat viability assessment: final report (Apple Valley, MN, USA: IUCN/SSC Conservation Breeding Specialist Group), p. 65.

134. Wind, J. (1996). Gunung Leuser National Park: history, threats and options. In Leuser a Sumatran Sanctuary, C.P. van Shaik, and J. Supratna, eds. (Jakarta: Perdana Ciptamandiri), pp. 4–27.

135. Porter, G. (1997). Mobility and inequality in rural Nigeria: the case of off-road communities. Tijdschr. Econ. Soc. Geogr. *88*, 65–76.

136. Clements, G.R. (2013). The Environmental and Social Impacts of Roads in Southeast Asia (Cairns, Australia: James Cook University).

137. Fischer, T.B. (2007). Theory and Practice of Strategic Environmental Assessment-Towards a More Systematic Approach (London: Earthscan).

138. Jaeger, J.A.G. (2015). Improving environmental impact assessment and road planning at the landscape scale. In Handbook of Road Ecology, R. van der Ree, D.J. Smith, and C. Grilo, eds. (John Wiley & Sons, Ltd), pp. 32–42.

139. Benítez-López, A., Alkemade, R., and Verweij, P.A. (2010). The impacts of roads and other infrastructure on mammal and bird populations: a meta-analysis. Biol. Conserv. *143*, 1307–1316.

140. Gullett, W. (1998). Environmental impact assessment and the precautionary principle: legislating caution in environmental protection. Australian J. Environmental Management *5*, 146–158.

141. Wood, C. (2003). Environmental impact assessment in developing countries. Int. Dev. Plann. Rev. *25*, 301–321.

142. Climate Bonds Initiative (2016). Bonds and climate change: state of the market 2016 (Climate Bonds Initiative and HSBC Climate Change Centre of Excellence), p. 20.

143. Scholtens, B. (2017). Why finance should care about ecology. Trends Ecol. Evol. *32*, 500–505.

144. Laurance, W.F., and Burgués-Arrea, I. (in press). Roads to riches or ruin? Science.

145. Brealey, R., Myers, S., and Allen, F. (2011). Principles of Corporate Finance, 10th Edition (McGraw-Hill).

146. Kleinschroth, F., Gourlet-Fleury, S., Sist, P., Mortier, F., and Healey, J.R. (2015). Legacy of logging roads in the Congo Basin: how persistent are the scars in forest cover? Ecosphere *6*, 1–17.

147. Laporte, N.T., Stabach, J.A., Grosch, R., Lin, T.S., and Goetz, S.J. (2007). Expansion of industrial logging in Central Africa. Science *316*, 1451–1451.

148. Edwards, D.P., Sloan, S., Weng, L., Dirks, P., Sayer, J., and Laurance, W.F. (2014). Mining and the African environment. Conserv. Lett. *7*, 302–311.

149. African Agricultural Development Company (2013). Developing sustainable agriculture in Africa. http://www.agdevco.com/about_us.php.

150. Killen, T.J. (2007). A perfect storm in the Amazon wilderness: development and conservation in the context of the initiative for the integration of the regional infrastructure of South America (IIRSA) (Arlington, VA: Conservation International).

151. Laurance, W.F., Cochrane, M.A., Bergen, S., Fearnside, P.M., Delamônica, P., Barber, C., D'Angelo, S., and Fernandes, T. (2001). The future of the Brazilian Amazon. Science *291*, 438–439.

152. Ewers, R.M., Andrade, A., Laurance, S.G., Camargo, J.L., Lovejoy, T.E., and Laurance, W.F. (2017). Predicted trajectories of tree community change in Amazonian rainforest fragments. Ecography *40*, 26–35.

153. Tasch, B. (2015). The potential paths for China's $10 billion railway across South America range from crazy to insane. (Australian Business Insider).

154. Asian Development Bank (2017). International Forum on Sustainable Infrastructure: Integrating Climate Resilience and Natural Capital into Transport Infrastructure Planning and Design. (Hanoi, Vietnam).

155. Eleventh Malaysia Plan (2015). Eleventh Malaysia Plan 2016-2020 anchoring growth on people (Putrajaya, Malaysia: Prime Miniter's Department, Federal Government Administrative Centre), p. 372.

156. Economic Planning Unit (2014). Regional corridor development in Malaysia (Putrajaya, Malaysia: Prime Minister's Department), p. 45.

157. Laurance, W.F. (2016). Lessons from research for sustainable development and conservation in Borneo. Forests *7*, 314.