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Seeing the broader picture: Stakeholder contributions to understanding infrastructure impacts of the Interoceanic Highway in the southwestern Amazon

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ABSTRACT

There is a large research literature on the impacts of roads and other infrastructure, which highlights the economic benefits, environmental harms and social problems. Most previous research on infrastructure impacts adopts a top-down approach, such as via the use of governmental or remotely-sensed data. This paper argues that a bottom-up approach that features stakeholder perspectives offers complementary advantages to understanding infrastructure impacts that can support improved planning and governance. We conducted stakeholder workshops about impacts of the Interoceanic Highway in the tri-national "MAP" frontier of the southwestern Amazon. The findings confirm previous research in several respects, but also indicate several contrasts. The range of impacts is much broader than topics featured in previous research, and some of the most commonly reported problems, such as diverse forms of crime, have been rarely studied as infrastructure impacts. We conclude by discussing the implications, in terms of criminological research on infrastructure impacts, synergies among diverse impacts of infrastructure, and improved planning of infrastructure for better governance of impacts.

1. Introduction

Previous studies of infrastructure impacts in developing regions such as the Amazon often adopt a top-down perspective from the view of researchers with remotely sensed data (cf. Laurance et al., 2001; Soares Filho et al., 2004). Such work offers the advantages of relying on large data sets with consistent methodologies that permit analysis at a high spatial resolution and broad geographic extent. The result is a detailed picture of spatial and temporal patterns of infrastructure impacts. However, such work tends to focus on selected impacts of scholarly interest. This can lead to narrowly-focused work that may miss unexpected or less-studied impacts (cf. Ritter et al., 2017).

We argue that a bottom-up approach to understanding infrastructure impacts, grounded in stakeholder perspectives, offers complementary advantages to top-down research (cf. Zamojska and Prochniak, 2017). Because stakeholders draw on their lived experiences, they are well-positioned to point out multiple change processes and their consequences. While scholarship already recognizes that infrastructure impacts are diverse (e.g., Perz et al., 2012), stakeholders can identify additional impacts beyond those featured in scholarship. A bottom-up approach to understanding infrastructure impacts based on stakeholder perspectives can thus broaden scholarly consideration of the benefits and problems.

Stakeholder perspectives can also inform policy debates about the wisdom of new infrastructure proposals. Like top-down studies, stakeholder-based research on infrastructure impacts can support improved governance of infrastructure (e.g., Alencar et al., 2004; Morales et al., 2021). In particular, stakeholder participation in evaluations of infrastructure impacts improves participation in infrastructure governance (Mendoza et al., 2007).

In this paper, we take up the case of the Interoceanic Highway in the tri-national "MAP" frontier in the southwestern Amazon, named for Madre de Dios (Peru), Acre (Brazil) and Pando (Bolivia). The Interoceanic Highway was an emblematic project of the Initiative for the Integration of Regional Infrastructure in South America (IIRSA) (e.g., CAF 2013; Van Dijck, 2013). It was a strategic priority of Brazil and Peru, but it was inadequately planned, and the contracting process had several irregularities (e.g., Dourojeanni,

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2006; Guerra Garcia, 2005). The highway became the focus of controversies due to contrasting conclusions from studies of potential economic benefits (e.g., Bonifaz et al., 2008; Guerra Garcia, 2008) and negative social and ecological impacts (e.g., Balvín Diaz and Patrón Alvarez, 2008; Dourojeanni, 2006). When built, the Interoceanic Highway generated various impacts that revealed inadequate governance along the road corridor (e.g., Dourojeanni et al., 2010; Prado Filho, 2018; Southworth et al., 2011; Swenson et al., 2011). The highway also featured in the *Lava Jato* corruption scandal involving the construction company Odebrecht, which engaged in bribery to secure construction contracts for key sections of the road (e.g., Pari 2017; Durand, 2018).

We held stakeholder workshops in multiple locations along the Interoceanic Highway in the MAP frontier in 2019, roughly a decade after the road was built. The findings reveal a broad range of specific impacts, which indicates that the consequences of infrastructure for stakeholders are diverse. The findings also indicate differences in impacts among locations. Overall, the results include many road impacts go beyond those emphasized in previous research. This includes particularly salient impacts such as various forms of crime, including types that go beyond previous treatments of illegal activity in the Amazon. We conclude by discussing the implications for research priorities and initiatives to improve governance of infrastructure impacts as a means of capturing the development benefits.

2. Background

There are many studies of the economic, ecological and social impacts of roads. The literature on the economic impacts of roads is large and of long standing. Early macroeconomic studies suggested large impacts of infrastructure investments on productivity (e.g., Aschauer, 1989; Munnell, 1992). Such studies confirmed infrastructure as a key hallmark of development policy for economic growth and poverty reduction (e.g., Gramlich, 1994; World Bank, 1994). Subsequent reviews confirmed large positive impacts of infrastructure investments on economic growth documented in many developing countries (e.g., Straub, 2008), including in Latin America (e.g., Calderón and Serven, 2004). This reinforced the policy consensus that roads generate economic growth (e.g., Bourguignon and Pleskovic, 2008).

As a complement to the macroeconomic literature, microeconomic studies based on field surveys also confirmed significant effects of infrastructure investments on poverty reduction. This is true not only of regional studies with local jurisdictions as the units of analysis (e.g., Demurger, 2001; Fan et al., 2004), but also rural communities (e.g., Gunasekera et al., 2008; Pender et al., 2004) and family households (e.g., Gibson and Rozelle, 2003; Jacoby, 2000).

More recent economic research has focused on high-profile infrastructure programs and arrived at the same conclusions. China's Belt and Road Initiative, the world's largest infrastructure program, has been evaluated in numerous studies (e.g., Chen and Li, 2021; Islamjanova et al., 2017; Wang et al., 2020; Yu et al., 2020). Whether they employ econometric methods or computable general equilibrium models, such studies conclude that infrastructure investments generate economic growth, stimulate trade, and reduce poverty.

In the Amazon, there is a large literature that focuses on environmental impacts of roads. That work has frequently drawn on spatially-explicit analyses of land cover change using satellite imagery and GIS approaches (e.g., Baynard et al., 2013; Botazzi and Dao, 2013; Laurance et al., 2001; Nascimento, 2021; Southworth et al., 2011). High-resolution raster data permit computation of deforestation rates on a pixel-by-pixel basis. Such studies consistently show that lands closer to roads have higher probabilities of deforestation. Such cellular automata approaches in turn permitted modeling of forest loss based on distance from roads and other factors. This supported development of simulation models for different scenarios of change (e.g., Soares Fllho et al., 2004).

Spatially-explicit modeling has found frequent application to evaluating the effectiveness of protected areas in mitigating road-induced deforestation. Such research indicates that various types of protected areas indeed reduce the effects of roads on forest loss (e.g., Barber et al., 2014; Jusys, 2018; Milien et al., 2021; Nolte et al., 2013; Pfaff et al., 2015).

As a complement to the roads-and-deforestation literature, the road ecology literature has focused on road impacts on wildlife. Proximity to roads tends to coincide with lower incidence of various native species (e.g., Carpio et al., 2009; Espinosa et al., 2018; Gallice et al., 2019), roadkill of native species with larger ranges (e.g., Caires et al., 2019; Filius et al., 2020), and changes in faunal community structure (e.g., Whitworth et al., 2015).

Recent modeling work has sought to integrate economic and ecological on road impacts in the Amazon. Multi-criterion analyses have sought to confront the tradeoffs between the economic benefits and the ecological harms of roads (e.g., Laurance et al., 2015; Vilela et al., 2020). This involves integration of numerous governmental data sources (e.g., Klarenberg et al., 2019). Such studies highlight that while some roads may generate large economic benefits and relatively small ecological impacts, many proposed infrastructure projects in the Amazon are of dubious economic value and would have large negative environmental impacts (Vilela et al., 2020).

There has also been epidemiological research on roads in the Amazon. Roads constitute corridors for transmission of diseases. That has driven quantitative studies of disease contagion along roads in the Amazon (Bauch et al., 2015; Cortez et al., 2018; Hahn et al., 2014; Tallman et al., 2020). Such work has highlighted the epidemiological risks roads pose to indigenous peoples (Opas et al., 2018; Reyes-García et al., 2020).

The focus on risks to local peoples calls attention to the broader social impacts of infrastructure in the Amazon, notably with regard to illegal activities. The literature on crime in the Amazon does not typically focus on illicit activities as a road impact, but rather as a result of the broader process of frontier expansion. Such work tends to focus on very specific forms of crime, usually involving natural resource exploitation. For example, there is extensive work on illegal logging (e.g., Brancalion et al., 2018; Perazzoni et al., 2020; Santos de Lima et al., 2018; Vasco et al., 2017). This is complemented by research on the estimation of illegal deforestation (e.g., Azevedo-Ramos et al., 2020; Klingler and Mack, 2020; Perazzoni, 2018; Perazzoni et al., 2020; Pinheiro Ribeiro Paiva et al., 2020). Other research has focused on indicators of illegal gold mining (Asner and Tupayachi, 2017; Caballero Espejo et al., 2018; Cortés-McPherson, 2019; Siqueira-Gay and Sanchez, 2021; Swenson et al., 2011). There are also studies of drug trafficking (Dávalos et al., 2016; Salisbury and Fagan, 2013; Schönenberg, 2002). Finally, there is an established literature on "unofficial" roads, some of which are themselves illegal (Brandão and Souza, 2006; Perz et al., 2007; Barber et al., 2014).

However, there remains limited crossover between research on roads and crime in the Amazon, despite the fact that illegal activities can be seen as facilitated by infrastructure. The criminological literature encompasses the tradition of environmental criminology, which includes theory and research findings that have established the importance of infrastructure and other determinants of accessibility to explain the incidence of crime (e.g., Bernasco and Luykx, 2003; Bruinsma and Johnson, 2018; Frith et al., 2017). This includes the illegal exploitation of natural resources (e.g., Ceccato and Uittenbogaard, 2013; Cowan et al., 2020; Kurland et al.,

2018). In the Amazon, there is some recognition that roads serve as corridors for illicit economic activity, as via organized criminal networks (Perazzoni, 2018; Schönenberg, 2014). This complements work on the Amazon that related frontier expansion via road building to agrarian violence (e.g., Alston et al., 1999; Hoefle, 2006; Schmink and Wood, 1992; Simmons et al., 2007), and recent work on violence in urban areas after infrastructure investments (e.g., Souza et al., 2015).

If there has been limited focus on roads and crime in the Amazon, that is perhaps due to the conceptual approach of roads and environmental governance. Previous work has noted that the focus of governments on building infrastructure often corresponds to inadequate planning for regional governance (e.g., Baletti, 2012; Damonte, 2018; Piketty et al., 2015). There is a longstanding problem of building roads without adequate planning or governance of impacts in the Amazon (e.g., Dourojeanni et al., 2010; Ferrante et al., 2021; Perz et al., 2008).

Previous work on road impacts in the Amazon permits certain conclusions. Roads impel some modicum of economic growth, in part by facilitating deforestation for various forms of resource exploitation, some of which is illegal. There are also negative impacts in terms of wildlife mortality and disease transmission. Planning for governance of road impacts is generally inadequate.

Those conclusions rest on specific methodological approaches with advantages and limitations. The reliance on top-down approaches with spatially-explicit data has permitted a detailed geographic accounting of impacts. While such work is eminently valuable for calling attention to the extent and spatial distribution of particular impacts, it has often paid less attention to the range of impacts and the processes behind them. In particular, such approaches carry the liabilities of making a priori decisions about the impacts to be studied.

Bottom-up approaches based on stakeholder perspectives offer the complementary advantages of more mixed qualitative and quantitative assessments that are not a priori bounded in terms of the range of impacts identified. Stakeholder-driven approaches thus permit broader assessments of road impacts. Stakeholder processes are an established approach in initiatives for environmental conservation and sustainable development in the Amazon (e.g., Castro and Albernaz, 2016; Folhes et al., 2015; Krause et al., 2013; Perz et al., 2010; Sarmiento Barletti et al., 2021). In the case of infrastructure projects, stakeholder consultations are a key element of the planning process, but are often inadequate. This is a key reason for inadequate governance of roads in the basin (Laurance et al., 2015; Morales-Giner et al., 2021; Perz et al., 2008). There are a few experiences of stakeholder consultations about road impacts in the Amazon (Mendoza et al., 2007; Perz et al., 2019; Rodriguez and Sarmiento Barletti, 2021). We draw on those experiences for our stakeholder-based study of the impacts of the Interoceanic Highway.

3. Methods

While the Interoceanic Highway has been the subject of various impact studies, most employ remotely sensed data (e.g., Milien et al., 2021; Southworth et al., 2011), governmental data (e.g., Klarenberg et al., 2019; Swenson et al., 2011; Tucker Lima et al., 2016), or information from standardized surveys (e.g., Perz et al., 2013, 2015). They also draw on information from the late 2000s or early 2010s, when many impacts were still unfolding.

We therefore pursued a stakeholder-based approach via workshops conducted in 2019. That year was roughly 10 years after completion of paving of the Interoceanic Highway in the MAP frontier, and roughly 15 years since workshops on stakeholder concerns about prospective impacts (Mendoza et al., 2007). We identified towns in municipalities along the Interoceanic Highway in the MAP frontier (Fig. 1), the sites of previous stakeholder workshops on road impacts (Mendoza et al., 2007). We contacted local governmental representatives and community leaders to consult with them about their interest in sharing their perspectives on the impacts of the road. Local leaders were highly receptive. We therefore planned nine (9) workshops in towns of different municipalities across the MAP frontier. These towns span most of the roughly 800 km of the Interoceanic Highway in the southwestern Amazon. In some workshops, participants came from more than one municipality. Overall, participants came from nine municipalities in Peru, three in Brazil, and one in Bolivia, for a total of 13. This reflects the geography of the highway and municipalities in the MAP frontier. Here we number the workshops and denote where a workshop included participants from more than one municipality: 1) Capixaba (Acre/Brazil), 2) Brasiléia and Epitaciolândia (Acre) with Cobija (Pando/Bolivia), 3) Iñapari (Madre de Dios/Peru), 4) Iberia (Madre de Dios), 5) Mavila and Planchón (Madre de Dios), 6) Puerto Maldonado (Madre de Dios), 7) Laberinto (Madre de Dios), 8) Virgen de Candelaria (Madre de Dios), and 9) Santa Rosa and Mazuko (Madre de Dios). Some workshops included participants from more than one municipality because some towns are located immediately adjacent to each other (Brasiléia, Epitaciolândia, with Cobija), or because participants came from smaller towns in adjacent municipalities to permit sufficient numbers of participants for the workshop activities (Mazuko/Santa Rosa and Mavila/Planchón); see Fig. 1.

We designed each workshop to be a half-day event. That reflected the importance of attracting a diverse array of stakeholders, recognizing that many were busy people in local institutions. We worked with local governmental representatives and other community leaders such as church leaders who served as local coordinators. Together, we compiled lists of key local institutions and their prominent current and former representatives for invitations to participate. We thus sought participants who were representatives of diverse institutions, including governmental agencies, universities, non-governmental organizations (including religious organizations), private sector businesses, and community associations. Local coordinators also identified prominent local citizens of long-term residence, often local landholders, elderly members of longstanding families, prominent church members, informal community leaders, and so on. In both types of cases, we prioritized stakeholders who had resided in their community for many years, ideally since before road paving, to permit stakeholder contributions based on before/after comparisons. In each proposed workshop site, the local coordinators then contacted the identified individuals to seek their participation. Coordinators noted the previous workshops on prospective impacts of the highway and introduced the new workshops as a means to revisit that question in terms of actual impacts. Because many invitees had participated in previous workshops (Mendoza et al., 2007), the goals and commitments involved in the proposed workshops were clear to them. In all cases, local coordinators presented the workshops as an opportunity for diverse stakeholders to discuss the various impacts of the highway in their community.

Across the nine workshops, 218 individuals participated, ranging from 15 to 37 recorded registrants per workshop. There was diversity by age (33 of ages 18–30, 67 of ages 31–45, 78 of ages 46–65, and 32 of ages 65+) and organizational type (84 from governments and universities, 54 with no affiliation, 49 from community associations, 16 from NGOs, and 14 from the private sector). Table 1 provides a breakdown of participants by age groups and type of organizational affiliation by workshop location. Most workshops had an age distribution similar to the overall pattern, with mostly middle-aged participants, though there were more younger participants in Mazuko/ Santa Rosa and more older participants in

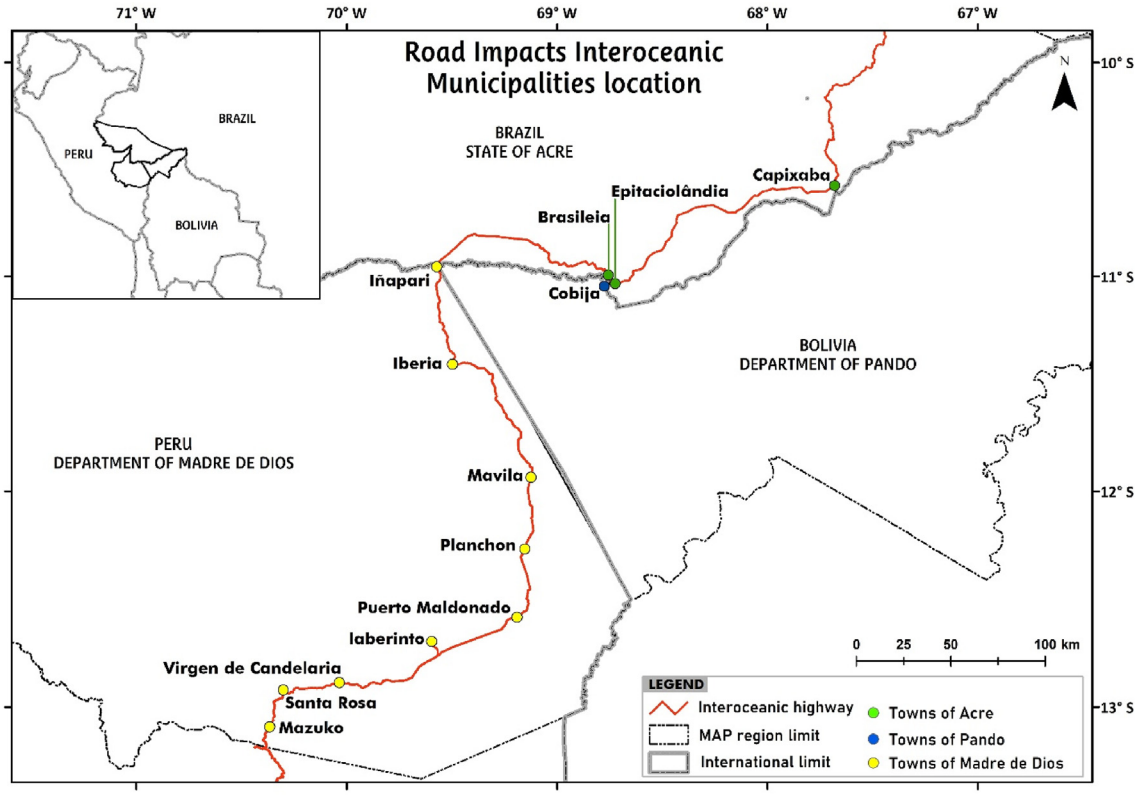

Fig. 1. Locations of towns along the Interoceanic Highway for stakeholder workshops on road impacts, 2019.

Table 1
Participant Composition by Age Group and Organizational Affiliation by Workshop Location, Stakeholders in the MAP Frontier, 2019.

Panel A: Age Groups	18–30	31–45	46–65	65+	No data	Total
Mazuko/ Santa Rosa	10	16	7	0	0	33
Virgen de Candelaria	1	6	8	2	1	18
Laberinto	3	5	8	2	0	18
Puerto Maldonado	2	7	5	1	0	15
Planchón/ Mavila	1	2	10	17	1	31
Iberia	3	3	12	5	1	24
Iñapari	4	4	9	3	1	21
Brasiléia/ Epitaciolândia/ Cobija	5	14	14	2	2	37
Capixaba	4	10	5	0	2	21
Total	33	67	78	32	8	218

Panel B: Organizational Afifliation	Government/ University	Non-governmental Organization	Community Association	Private Sector	None	No data	Total
Mazuko/ Santa Rosa	5	2	4	2	20	0	33
Virgen de Candelaria	3	0	15	0	0	0	18
Laberinto	6	0	12	0	0	0	18
Puerto Maldonado	7	5	1	1	1	1	15
Planchón/ Mavila	2	0	5	1	22	1	31
Iberia	14	3	2	0	5	0	24
Iñapari	8	1	4	5	3	0	21
Brasiléia/ Epitaciolândia/ Cobija	27	3	0	4	3	0	37
Capixaba	12	2	6	1	0	0	21
Total	84	16	49	14	54	1	218

Planchón/ Mavila. In terms of organizational affiliation, most communities exhibited a composition similar to the overall pattern. The exact composition varied among communities, such that in larger towns (e.g., Puerto Maldonado, Brasiléia/Epitaciolândia/Cobija) and smaller towns that are government seats (e.g., Iñapari, Capixaba), there were more organizational representatives, and in smaller communities, there were more citizens who were prominent community members. In both cases, participants were diverse, and they had resided in their community for many years.

We organized each workshop around two main exercises. The first was a cards exercise. We distributed green cards and pens to participants and asked them to indicate any positive impacts of the Interoceanic Highway. Our query was in an open format, and did not prompt participants to identify any particular type of impact. Further, participants decided what they considered to be a positive impact. Participants thus identified impacts in their own words. Stakeholder responses indicated any change in their lives that they attributed to the highway. We distributed multiple

cards to participants. Participants could complete as many cards as they liked. We collected the green cards, and then distributed yellow cards to the participants, and asked them to indicate negative impacts of the Interoceanic Highway. As before, participants decided what they considered a negative impact, and wrote their responses in their own words, and used as many cards as they desired. We then provided participants with a break for coffee and food.

During the break, we organized the green and yellow cards separately into five broad types of impacts: environmental, economic, infrastructural, political, and social. This required some interpretation, and team members consulted internally for consistency of interpretation. Within each type of impact, we engaged in open coding by organizing the cards around specific topics. We coded "environmental" impacts in terms of changes concerning natural resources, pollution, climate, wildlife and related issues. "Economic" impacts concerned changes in commerce, trade, employment, income, products, technology, and specific economic sectors (e.g. agriculture, mining, tourism). "Infrastructural" impacts concerned specific infrastructure (roads, bridges, communications, internet) or its direct consequences (improved access, communication). "Political" impacts referred to state policies, political representation, and political corruption. "Social" impacts included social services (health, education), migration and population, cultural change, various forms of crime, and inequality. We then placed the cards on the walls, organized by positive and negative impacts, and by type of impact.

The participants returned from their break, and we engaged them in discussion of the comments on the cards. This was important for two purposes. First, we sought participant confirmation of our interpretations of their responses, and whether our grouping of their responses made sense to them. Second, we engaged the participants in a discussion of the meanings and processes of the more commonly indicated impacts. Participants offered additional comments about specific road impacts, their underlying processes, why prominent impacts were of particular importance to them, and why they considered impacts to be positive or negative. In the process, participants sometimes disagreed. While infrastructure projects can sometimes cause contention among stakeholders, for participants in our workshops, the Interoceanic Highway was a fact of life. Participants engaged in animated discussion of the comments on the cards, and sometimes had different perspectives on particular impacts, but their reflections indicated engagement rather than contention. Participants also sometimes related one impact to another, including impacts of different types.

The second exercise was a participatory mapping exercise. Prior to the workshops, we printed out maps of the municipalities of the workshops, showing the municipal boundaries, the Interoceanic Highway, prominent towns, and rivers. We also developed legends with items for mapping specific environmental, economic and social impacts. We focused legend keys on those three topics because they had been most often reported in previous stakeholder workshops on impacts of the Interoceanic Highway in the MAP frontier (Mendoza et al., 2007). The legends had lists of specific types of environmental, economic and social impacts, in terms of whether those items had increased or decreased since paving of the Interoceanic Highway. Each item on the legend had a different symbol and/or color. The environmental changes included new protected areas, invasions of protected areas, land degradation, timber extraction, castaña harvesting, family agriculture, cattle ranching, use of fire to burn pastures, forest fires, desiccated creeks, soil contamination, trash accumulation, water contamination, and floods. We identified those indicators to cover topics with established literatures like deforestation and protected areas, as well as other topics like water availability, pollution and flooding. The economic items were changes in telecom businesses, industrial operations, shops, banks, hotels, restaurants, gas stations, taxis/bus lines, fish farming, monocultures, legal mining, illegal mining, legal logging, and illegal logging. We selected those indicators to span economic sectors from resource extraction to intensification of agriculture to transportation and various urban services. The social changes included employment, educational institutions, health care institutions, settlements, population, violence, other forms of crime (e.g. prostitution), police check points, new roads, closed roads, and churches. We picked those indicators to cover population change, public services, crime and security, road networks, and social institutions.

For the mapping exercise, stakeholders chose the group in which they wished to participate, with one group for each type of impact. We provided each group with a map, a legend, and colored pencils. A team member moderated each group, providing clarifications of the legends and guidance on how to draw the symbols on maps. Participants then used the colored pencils to delineate the areas or locations of changes on the maps. Where applicable, participants also estimated quantitative increases and decreases in items involving discrete events in the map legends, noting counts where a specific type of organization became more or less common. The team then coded the changes indicated, in both quantitative terms where participants reported counts, and in qualitative terms where participants indicated increases or decreases.

4. Findings

4.1. Stakeholder comments on cards

We begin by reporting findings from the cards exercise. Overall, workshop participants submitted 774 cards with positive impacts and 971 cards with negative impacts of the Interoceanic Highway. We compiled comments in terms of the types of impacts (environmental, economic, infrastructural, political, and social). Within those types, we counted distinct impacts as confirmed by workshop participants. We also compiled comments on impacts by location of workshop.

We then conducted a combination of qualitative and quantitative analysis, considering both the counts of comments with specific types of impacts as well as the content of the diverse impacts reported by workshop participants. We first summed the number of cards indicating positive and negative impacts by type of impact for comparison, shown in Fig. 2. The findings are strong and clear, and in some ways, they confirm previous research. Environmental impacts were commonly reported and largely negative; economic impacts were also frequent and mostly positive. That said, other findings were more intriguing. Infrastructural changes were also common, but surprisingly mixed. Social impacts were reported most frequently of all, and were mostly negative.

We also evaluated positive and negative comments by the location of the stakeholder workshops. We held workshops along three distinct segments of the Interoceanic Highway in the MAP frontier: 1) southern Madre de Dios, Peru, in the transition from the Amazonian lowlands up to the Andean highlands where a gold mining boom has unfolded; 2) eastern Madre de Dios, a relatively remote part of Peru, up to the border with Brazil; and 3) eastern Acre, Brazil, along the border with Pando, Bolivia. We conducted four workshops in the first segment, three in the second, and two in the third. Fig. 3 organizes the workshop locations in that order, and shows distinct findings among the three segments. In the first four workshops, there were more negative than positive comments, especially from the Mazuko/ Santa Rosa and Virgen de Candelaria workshops, closest to the gold fields. In the other five workshops corresponding to the other two road segments, there were roughly

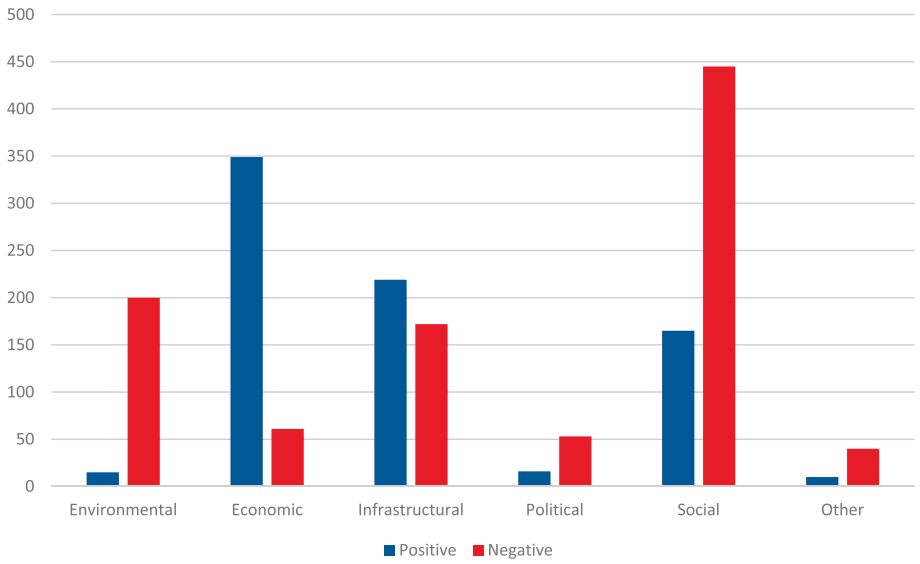

Fig. 2. Positive and Negative Comments on Impacts of the Interoceanic Highway, by Type of Impact, Stakeholders in the MAP Frontier, 2019.

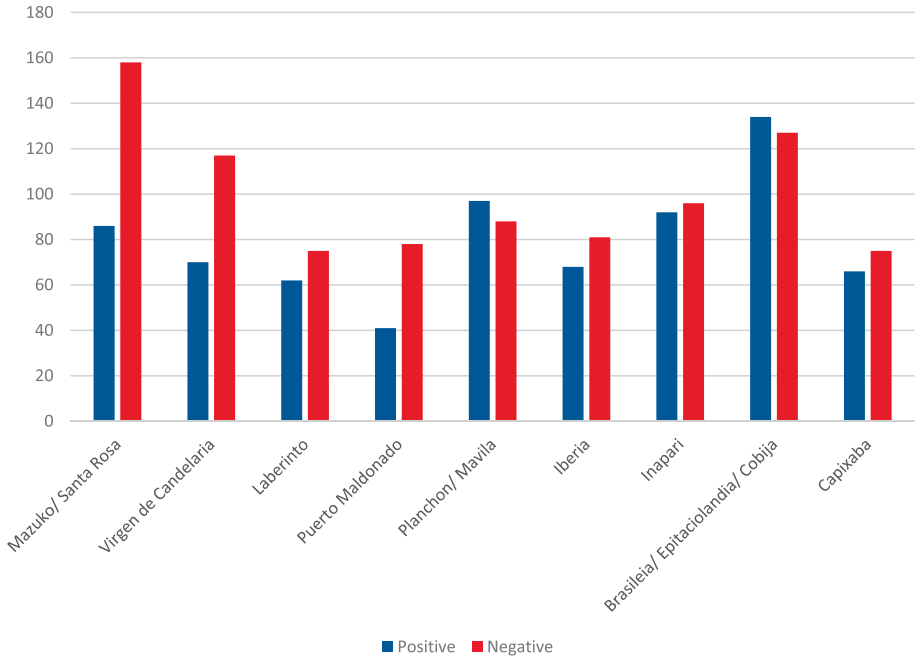

Fig. 3. Positive and Negative Comments on Impacts of the Interoceanic Highway, by Location of Workshop, Stakeholders in the MAP Frontier, 2019.

equal numbers of positive and negative comments. This indicates geographic variation in stakeholder comments on the balance of positive and negative impacts of the Interoceanic Highway.

To illuminate explanations for these differences, Table 2 provides a more detailed breakdown of positive and negative comments, by type of impact and workshop location. For each workshop location and type of impact, we provide two numbers. Each refers to the number of comments, with the first indicating the number of positive comments in that workshop location about that type of impact and the second denoting the number of negative comments for comparison. While economic comments were mostly positive in all workshops, comments on environmental, political and social impacts were mostly negative in all workshops. There was geographic variation in the infrastructural impacts, which were mostly negative in Mazuko/Santa Rosa and Virgen de Candelaria. Many stakeholders in those locations reported significant problems with drainage due to construction of the Interoceanic Highway, which caused flooding and washed out bridges and other infrastructure. This stemmed from the more uneven topography of those locations, which are situated in the Andes-Amazon transition, where numerous creeks cross the highway and heavy rains lead to rapid drainage down hillsides.

These quantitative findings however obscure the qualitative content of the specific types of impacts reported. Overall, workshop participants reported 28 distinct positive impacts and 41 different negative impacts of the Interoceanic Highway (not including "other" impacts and unclear comments). Within each type of impact (environmental, economic, infrastructural, social and political) there were two or more specific impacts noted, both for positive and negative impacts. We therefore present detailed findings

Table 2
Positive / Negative Comments on Highway Impacts by Type of Comment and Workshop Location, Stakeholders in the MAP Frontier, 2019.

	Environ- mental	Economic	Infra- structural	Political	Social	Other/ Unclear	TOTAL
Mazuko/ Santa Rosa	0 / 37	45 / 11	27 / 66	0 / 9	21 / 49	1 / 5	94 / 177
Virgen de Candelaria	0 / 10	36 / 16	32 / 49	1 / 3	13 / 45	0 / 4	82 / 127
Laberinto	0 / 27	22 / 3	29 / 17	1 / 6	12 / 31	2 / 4	66 / 88
Puerto Maldonado	2 / 13	23 / 8	9 / 3	5 / 10	5 / 52	0 / 2	44 / 88
Planchón/ Mavila	0 / 13	41 / 5	29 / 10	2 / 6	28 / 60	2 / 2	102 / 96
Iberia	3 / 21	37 / 4	15 / 3	0 / 4	16 / 56	0 / 2	71 / 90
Iñapari	7 / 19	41 / 5	29 / 4	2 / 2	25 / 59	0 / 8	104 / 97
Brasiléia/ Epitaciolândia/ Cobija	3 / 40	78 / 7	28 / 10	4 / 12	23 / 53	4 / 9	140 / 131
Capixaba	0 / 20	26 / 2	21 / 10	1 / 1	22 / 40	1 / 4	71 / 77
TOTAL	15 / 200	349 / 61	219 / 172	16 / 53	165 / 445	10 / 40	774 / 971

Note. Numbers refer to counts of comments. For each pair of numbers, the first refers to comments indicating positive impacts, and the second refers to comments denoting negative impacts.

on the range of positive (P) and negative impacts (N), for environmental (A), economic (E), infrastructural (I), political (P) and social impacts (S), with unique identifiers for each specific impact. Hence the first of the positive environmental impacts coded would be PA1; the fifth negative social impact would be NS5; and so on.

Table 3 presents the positive impacts in the order in which they were identified during coding. Among the specific impacts, there were three environmental, nine economic, eight infrastructural, two political, and six social. Stakeholders thus reported a much broader array of positive impacts than has been featured in previous research on roads in the Amazon. Positive environmental impacts included improved regulation and reforestation. Positive economic impacts highlighted economic growth, increased sales of agricultural products, increased tourism, the arrival of new products, and increased incomes. Positive infrastructural changes included improved transit and accessibility, and international integration. The two favorable political impacts were increased state presence and better access to elected representatives. Salient social benefits included improved access to health care services and educational institutions, and increased community integration. While some of these positive impacts have been noted in previous research on major roads in the Amazon, stakeholders also pointed out other impacts in contrast to previous scholarship. This includes all of the positive environmental impacts cited (improved regulation and reforestation), economic impacts such as the arrival of new products and increased tourism, both political impacts cited (state presence and better access to elected representatives), as well as many of the social impacts. The stakeholder workshops thus call attention to a diversity of less-studied positive impacts of infrastructure, at least for the case of the Interoceanic Highway.

Table 3
Positive Impacts of the Interoceanic Highway Reported by Stakeholders in the MAP Frontier, 2019.

Impact Type	Code	Impact	Count
Environmental	PA1	More initiatives for conservation and environmental regulation	6
	PA2	Reforestation	6
	PA3	Forest certification and sustainable management	3
Economic	PE1	Increased commerce, economic growth, new businesses	127
	PE2	Increased income, buying power, and/or lower prices	27
	PE3	Increased agriculture, more products, more sales, value-added processing	81
	PE4	Arrival of new, better, fresher, or more diverse products	31
	PE5	Increased value or price of land	17
	PE6	Increased commerce among regions or countries, increased international trade	22
	PE7	Increased tourism	36
	PE8	New financial firms, more credit for investment	4
	PE9	Arrival of high-quality professionals	4
Infrastructure	PI1	Improved or easier access, faster transportation	155
	PI2	International integration, frontier development	23
	PI3	More movement of commercial freight, heavy cargo	14
	PI4	Better bridges	5
	PI5	Improved communication, internet access	9
	PI6	More reliable electricity	7
	PI7	Increased urbanization, urban housing	3
	PI8	More secondary roads	3
Political	PP1	Increased state presence	7
	PP2	Improved communication with representatives, and among levels of government	9
Social	PS1	Population growth	14
	PS2	Improved health care services	49
	PS3	Improved educational institutions	44
	PS4	Improved communication, community integration	36
	PS5	Increased cultural or international exchange	21
	PS6	Improved access to food	1
Other			10
Unclear			0

Table 4 presents the specific negative impacts. Stakeholders reported eight environmental, seven economic, 11 infrastructural, five political, and 10 social impacts. Workshop participants thus reported a broad array of negative outcomes of the Interoceanic Highway. Indeed, the stakeholder lists exceed the long lists of possible negative impacts of the Interoceanic Highway published by prominent critics before paving concluded (Dourojeanni, 2006). Salient negative environmental impacts reported by stakeholders included pollution, deforestation, and logging. Among the negative economic consequences, workshop participants noted lack of economic opportunity, as well as lack of opportunities to sell agricultural produce. Concerning the infrastructural problems, stakeholders called particular attention to drainage issues, traffic accidents, lack of traffic signals and speed bumps, and lack of bridges to homesteads and businesses. The negative political impacts featured the problem of political corruption, which stemmed from the *Lava Jato* investigations. The negative social impacts highlighted violent crime, drug trafficking, in-migration of strangers, inadequate access to health care, prostitution/human trafficking, and land invasions/agrarian conflicts. While the last of these was the focus of earlier work on social impacts of roads in the Amazon, the others have received rather less attention. The same can be said about environmental impacts, which highlighted deforestation, a heavily-studied issue, alongside pollution, which has received much less attention. Stakeholders thus called attention to numerous issues, many beyond those on which scholars have focused.

Table 4
Negative Impacts of the Interoceanic Highway Reported by Stakeholders in the MAP Frontier, 2019.

Impact Type	Code	Impact	Count
Environmental	NA1	Logging, forest degradation	27
	NA2	Deforestation, loss of forests, fires	56
	NA3	Environmental pollution (air, water, solid waste)	77
	NA4	Illegal mining as an environmental threat	14
	NA5	Change in courses of rivers, erosion of riverbanks	5
	NA6	Decrease in size of rivers, reduced access to water	6
	NA7	Wildlife killed while crossing the highway	13
	NA8	Climate change	2
Economic	NE1	Lack of economic activity or opportunity; unemployment	20
	NE2	Lack of support for agriculture, lack of options to sell products or to export produce	14
	NE3	Increases in land prices, land speculation	8
	NE4	Illegal mining as an economic threat	6
	NE5	Change in land use, agricultural overproduction	4
	NE6	Lack of preparation for changing markets, lack of local commercial organization	5
	NE7	Increased taxes, cost of living	4
Infrastructure	NI1	Lack of traffic signals, speed bumps, traffic control	23
	NI2	Problems with drainage and ditches, flooding along the highway	46
	NI3	Lack of bridges over drainage ditches at entrances to properties and schools	17
	NI4	Increased traffic, danger on the highway, traffic congestion, traffic accidents	52
	NI5	Lack of schools	2
	NI6	Lack of health care facilities	2
	NI7	Lack of water infrastructure	5
	NI8	High prices at highway toll booths, illegal tolls	5
	NI9	Lack of road maintenances, poorly-constructed infrastructure	11
	NI10	Lack of electricity	3
	NI11	Lack of adequate secondary roads, informal secondary roads	6
Political	NP1	Political corruption	28
	NP2	Lack of presence of the state, consultations of local peoples	8
	NP3	Lack of policies, planning, land use zoning	8
	NP4	Bureaucracy, lack of governmental coordination, lack of policy implementation	7
	NP5	Policies that restrict development	2
Social	NS1	Lack of educational opportunities	17
	NS2	Lack of health care services, lack of treatments for new diseases	42
	NS3	Lack of water provision, sewage and sanitation services, trash collection	5
	NS4	Violent crime: delinquency, threats, robberies, assaults, murders, arms trafficking	155
	NS5	Prostitution, sexual crimes, human trafficking	41
	NS6	Drug trafficking, drug use, drug addiction	66
	NS7	Land invasions, land conflicts	39
	NS8	In-migration, social disorganization, itinerant population, loss of local culture	69
	NS9	Bars, fights at bars	5
	NS10	Poverty, malnutrition	6
Other			24
Unclear			16

This qualitative analysis featuring the diversity of impacts however obscures the relative importance of specific impacts for stakeholders. In the foregoing paragraph, we admittedly noted the more commonly-reported impacts within each type. That still fails to quantify the differences in salience. We therefore conclude our discussion of the cards exercise by noting the top 10 most commonly reported positive and negative impacts of the Interoceanic Highway. Fig. 4 therefore presents the top 10 most common positive comments (based on Table 3). Not surprisingly, the most commonly cited benefits concerned improved access via faster travel (PI1, 155 comments), followed by economic impacts involving commercial growth (PE1, 127 comments) and agricultural expansion (PE3, 77 comments). Overall, five of the top 10 most frequent comments concerned economic benefits, including increased tourism, better products, and increased income. Stakeholders also frequently noted specific social benefits, including improved health care services (PS2, 49 comments) and improved educational institutions (PS3, 44 comments). While workshop participants indicated a wide range of positive impacts of the Interoceanic Highway, the most common benefits, which were economic, have received ample attention in previous studies.

Fig. 5 presents the 10 most frequent comments involving negative impacts of the Interoceanic Highway (based on Table 4). Here there are many contrasts with regard to previous research on roads in the Amazon. While deforestation was frequently mentioned (NA2, 56 comments), it is fifth on the list, well behind another environmental concern, pollution, which placed second (NA3, 77 comments). Further, it is social impacts that prevail in Fig. 5. Six of the top 10 negative impacts of the Interoceanic Highway are social problems, including violent crime, migration, drug trafficking, lack of health care services, prostitution, and land invasions. Most of the negative social impacts involve various forms of illegal activity, including violent crime (NS4 on threats, assaults, robberies and murders and NS7 on land conflicts) and non-violent crime (NS5 on prostitution and NS6 on drug trafficking). By far the most commonly cited negative impact was NS4 on violent crime (155 comments). While previous work has rightly highlighted problems of roads facilitating the illegal exploitation of natural resources, it has attended much less to violence other than land conflicts. To be sure, land conflicts is 10th on the list among negative impacts. But several other forms of crime were more salient in the MAP stakeholder workshops. The negative social impacts of the Interoceanic Highway are broader than has been recognized in previous research on road impacts.

4.2. Stakeholder participatory maps

We turn to the findings from the participatory mapping exercise. Fig. 6 presents an example stakeholder map of economic impacts. This example shows that stakeholders often made notes about the details of specific changes occurring in their municipalities. In this and other cases, impacts are concentrated along the highway and around local towns. We found that stakeholders often had limited experience in mapping, and thus estimated the areas impacted in quite different ways, which makes quantitative areal estimation doubtful. We therefore focus on the map legends. For the legends, we focus on items involving discrete events that stakeholders could count, like the number of new gas stations or health centers. For the counts, we summed the appearance as well as loss (disappearance) of each item, to see if more gas stations opened than closed. Participants were able to arrive at consensus about counts, which permitted calculation of increments and decrements in each item. Because some municipalities had larger land areas and populations than others, with very different bases for calculation of rates, we thus focus our analysis on the direction of change instead of rates of change. With information about increases and decreases in the legend items, we found that most items showed strong increments while very few had any decrements. We therefore calculated the percentage of municipalities with increases. Calculation of percentages across municipalities permits an evaluation of how widespread a given item exhibited increments.

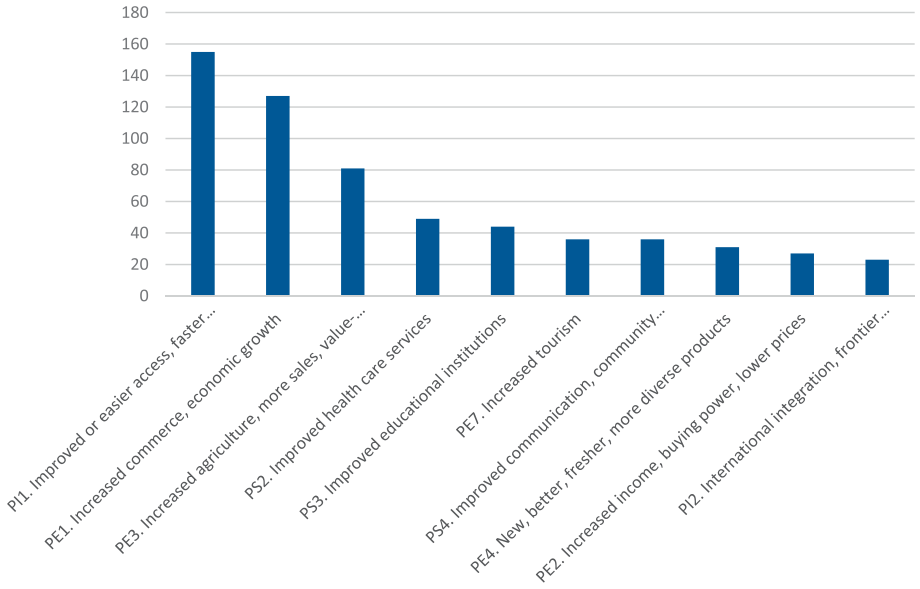

Fig. 4. Top 10 Positive Comments on Impacts of the Interoceanic Highway, Stakeholders in the MAP Frontier, 2019.

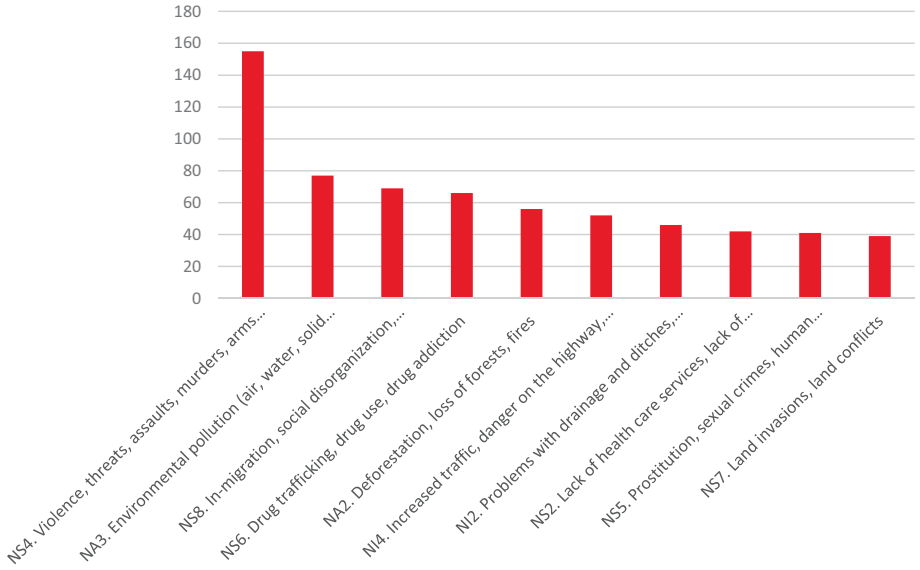

Fig. 5. Top 10 Negative Comments on Impacts of the Interoceanic Highway, Stakeholders in the MAP Frontier, 2019.

This permits a geographic analysis of the extent of specific changes across municipalities in the MAP frontier. We focus on a comparison of Peruvian and Brazilian participants, who constituted the large majority of the stakeholders in the workshops, a reflection of the geography of the Interoceanic Highway in the MAP frontier. Consequently, for the geographic comparisons, we differentiate findings between municipalities represented in Acre/Brazil (n = 3) and Madre de Dios/Peru (n = 9). However, totals reflect responses from participants in all 13 municipalities in the workshops.

Fig. 7 shows the percentage of workshop municipalities where stakeholders reported increases in various indicators of economic activity. Fig. 7 shows that virtually everywhere, the Interoceanic Highway facilitated increases in services, industry, and commerce, as well as financial institutions and various businesses oriented to travelers and tourism (hotels and restaurants, gas stations and taxis/bus lines). Similarly, agricultural intensification increased almost everywhere, whether in terms of monocultures or fish farms. Much less common were mining (including illegal mining), which was limited to the gold fields west of Puerto Maldonado. Logging and especially illegal logging had however increased in many municipalities. The mapping exercise thus indicates widespread economic growth, especially outside the extractive sectors. This contrasts with the focus in previous work on highways and resource extraction in the Amazon.

Fig. 8 shows percentages of municipalities where stakeholders reported increases in the environmental indicators. As with economic indicators, workshop participants largely reported environmental increases, so we focus on those. That said, stakeholders did not report increases in environmental problems as widely as they reported increases in economic activity. In a few workshops, participants reported establishment of new protected areas, though invasions of protected areas (including their buffer zones) were more widespread. Land degradation was noted universally, but

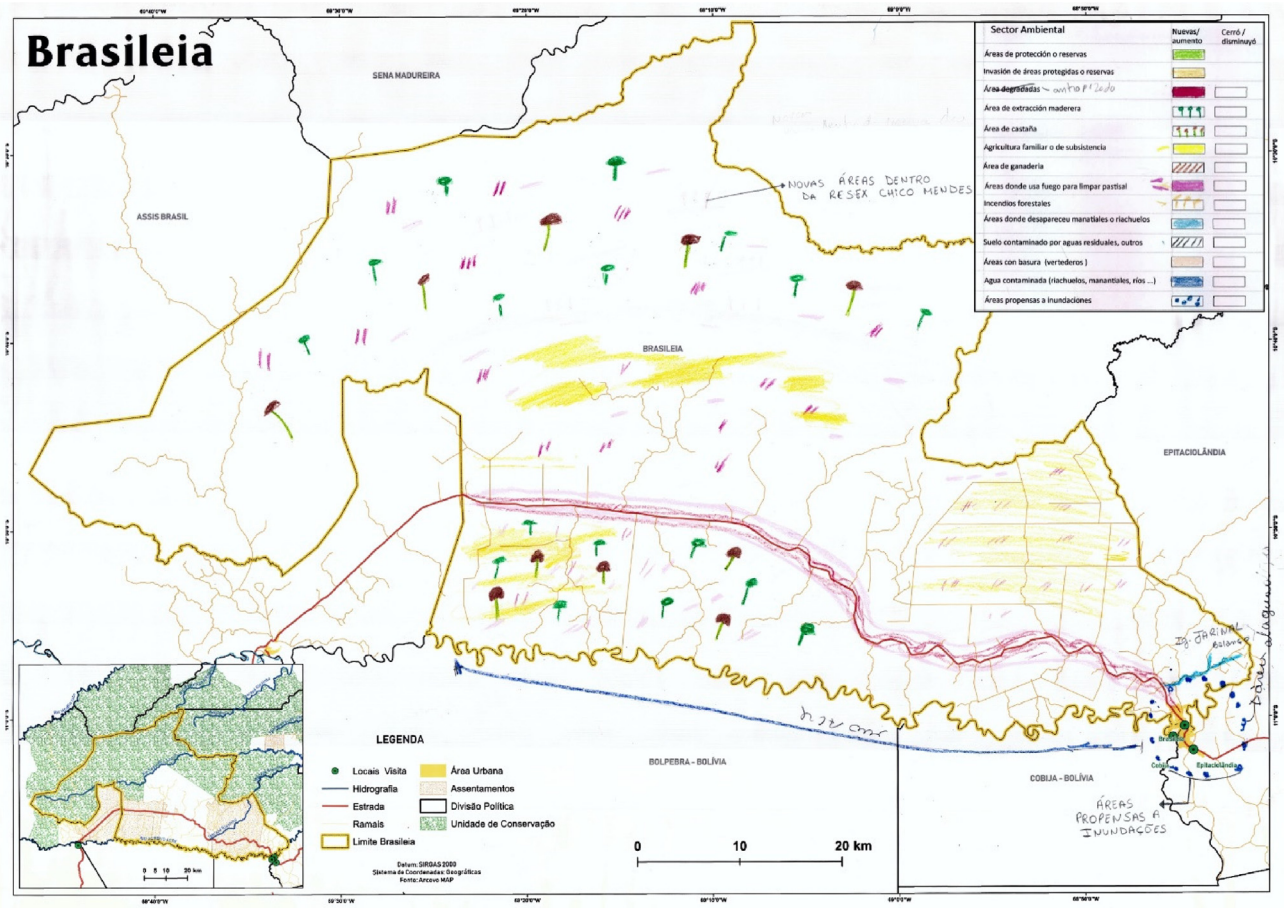

Fig. 6. Stakeholder Map of Environmental Impacts of the Interoceanic Highway, Brasiléia, Acre, Brazil, 2019.

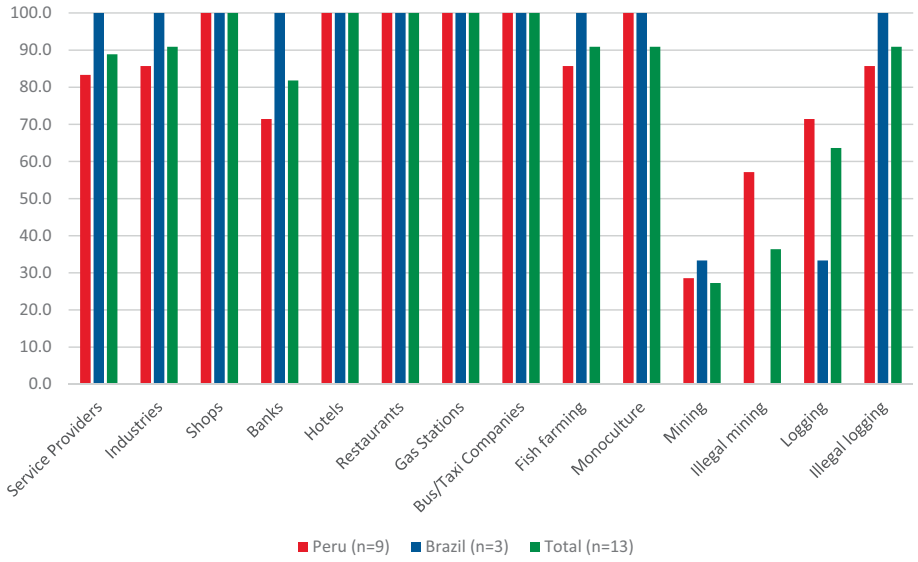

Fig. 7. Percentage of Municipalities with Increased Businesses and Economic Activity, MAP Frontier, 2019.

referred to different processes in different places, from gold mining in southern Madre de Dios to soil erosion and declining soil productivity in eastern Madre de Dios and Acre. Curiously, stakeholders in few workshops remarked on timber extraction or castaña harvesting as environmental issues, though in the economic mapping groups, logging (including illegal logging) was commonly noted. Instead, the environmental mapping groups focused more on the expansion of family farms and cattle ranches, and the closely related issues of the increased use of fire to prepare land for agriculture, the rising risks of fires entering forests, and the desiccation of streams in deforested areas. While the growth of family farms was more widespread in Madre de Dios, the indicators

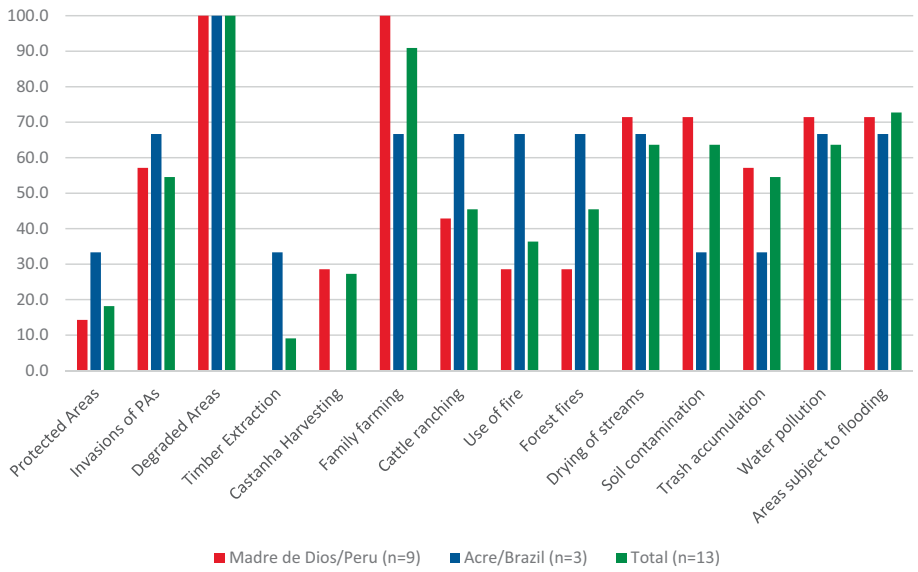

Fig. 8. Percentage of Municipalities along the Interoceanic Highway with Increases in Environmental Indicators, MAP Frontier, 2019.

related to fire were reported more often in Acre. Some stakeholders saw these problems as consequences of the Interoceanic Highway, while others underscored climate change as the driver. Environmental mapping groups also commonly but not universally reported problems of increased pollution, whether soil contamination, inappropriate trash disposal, and water pollution, whether in urban areas or along the roadsides. In most workshops, stakeholders also reported problems of flooding, sometimes with respect to the Interoceanic Highway, and sometimes with regard to climate change. These findings confirm stakeholder concerns with a broad array of environmental problems beyond land cover change as consequences of the Interoceanic Highway.

Social changes among municipalities along the Interoceanic Highway appear in Fig. 9. As elsewhere, we focus on increases because they were most commonly reported. Workshop participants often noted increases in population and settlements as facilitated by the Interoceanic Highway. The question then is whether that demographic growth coincided with more positive or negative social changes. Interestingly, stakeholders commonly reported both positive and negative social changes across workshops. In terms of widespread positive changes, stakeholders indicated rising employment, schools, and churches. Common negative changes focused on violent crime; in stark contrast, virtually none of the workshops indicated an increase in policing, at least in terms of police checkpoints along the Interoceanic Highway. We heard extensive comments on the various forms of violent crime along the highway as well as in towns through which the highway passed, frequently in tandem with complaints about the lack of police presence, which together were understood to permit the free circulation of gangs, bandits, drug traffickers, and other criminal groups. Other changes differed between Madre de Dios and Acre. In terms of positive changes, whereas stakeholders in all workshops in Acre reported an increase in health care organizations, that was rare in Madre de Dios. Among negative changes,

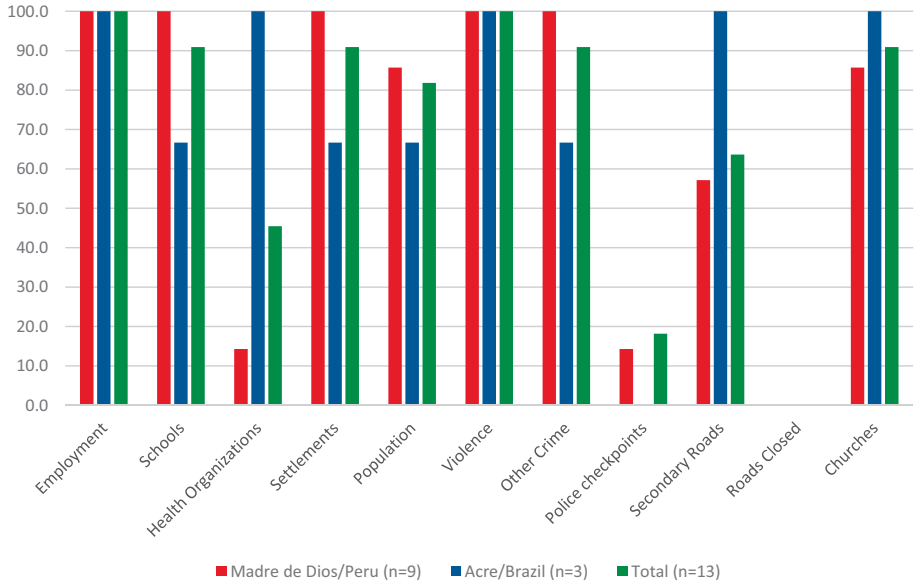

Fig. 9. Percentage of Municipalities along with Interoceanic Highway with Increases in Social Indicators, MAP Frontier, 2019.

non-violent crimes, such as drug trafficking and prostitution, were universally reported in Madre de Dios but not in Acre. That said, stakeholders in most municipalities in both countries reported an increase in non-violent crime. These findings broadly confirm the comments from the cards exercise, and expand on the problem of increased crime by noting inadequate police presence. They also underscore the key finding that the Interoceanic Highway brought a broad mix of positive and negative social changes.

5. Discussion

Overall, stakeholders in the MAP frontier emphasized how the Interoceanic Highway generated economic benefits, environmental harms and social problems. These findings confirm previous research on the impacts of roads in the Amazon. That said, in important ways, the findings go well beyond previous work, notably in the diversity of impacts reported, both positive and negative. Contrary to most previous work, workshop participants noted various economic problems and environmental and social benefits of the highway. Stakeholders also reported a roughly equal mix of infrastructural improvements and complications. More generally, stakeholders identified numerous positive and negative impacts involving topics not very frequently studied in previous research. Among those topics are several of the most commonly reported negative social impacts, especially several forms of crime, including forms of violence beyond land conflicts.

The findings reveal similarities and contrasts in the priorities of regional stakeholders and scholars with regard to infrastructure impacts. Whereas researchers on infrastructure in the Amazon have often focused on environmental issues such as land cover change and protected areas, stakeholders in the MAP frontier recognized those issues but focused more on economic, infrastructural and especially social matters. Stakeholders also exhibited their own subjectivities about the topics they raised, whether between municipalities or at the same workshop. On the issue of gold mining, some stakeholders brought up environmental issues such as water pollution, while others raised the topic in economic terms. More generally, different stakeholders raised the same topic but framed it positively or negatively. In comments about economic growth, many workshop participants had positive comments, but others questioned the benefits of economic growth, noting persistent unemployment and lack of opportunities for local agricultural producers.

The single biggest issue for stakeholders in the MAP frontier regarding impacts of the Interoceanic Highway concerned crime. Workshop participants provided comments on a diversity of criminal activities that went far beyond illegal resource exploitation typically featured in Amazonian scholarship. Stakeholders noted how the highway facilitated the arrival of gangs, cartels, traffickers and other criminal groups. The paving of the Interoceanic Highway was followed by complex dynamics in organized crime in the MAP frontier, as drug traffickers adjusted their routes, gangs became established in local towns, and networks emerged to manage illicit commodity chains. Workshop participants made clear that various forms of crime from petty theft to assaults now occur regularly along the Interoceanic Highway, and that organized criminal groups use the corridor for trafficking of various commodities, including timber as well as drugs and even people. The growth of diverse forms of crime in the MAP frontier matters because it indicates that the Interoceanic Highway has facilitated not just illegal logging but various other types of illicit activities. The diverse range of crime noted by stakeholders suggests that a broader criminological approach to understanding infrastructure impacts would be useful. There remains a need for more systematic attention to how infrastructure fosters criminogenic processes that yield illicit activities in the Amazon. Theory from environmental criminology concerning accessibility would support the argument that infrastructure itself is a cause of various types of crime. Because diverse stakeholders are broadly concerned about public safety, a specifically criminological focus on infrastructure impacts would offer a strategy to motivate improved planning of infrastructure. The prospect of increased crime would require infrastructure advocates to explain how infrastructure planning would provide for governance of impacts, featuring measures to ensure public safety. Arguments for infrastructure as a key to economic development would thus encounter the challenge of ensuring public safety as a key to social well-being.

Another key implication of the findings concerns the large number of different impacts, which in some cases exhibit synergies. One issue that was discussed concerned the infrastructure impact of improved access as related to economic growth, as well as improved access to social services, especially education and health, but also as facilitative of various forms of crime. This example highlights how synergies from infrastructure can simultaneously yield both positive and negative outcomes. Other examples include how improvements in access made it easier to pursue environmental improvements like reforestation despite increasing deforestation, and how increased migration and more business activity also yielded increased urban solid waste production. Beyond simultaneous synergistic effects, participants noted that infrastructure improvements could catalyze synergies via feedbacks to infrastructure. In particular, participants pointed to positive feedbacks among several negative impacts of the Interoceanic Highway, such that negative impacts magnify each other. Infrastructure facilitates deforestation and mining, which modify local precipitation. At the same time, climate change in the Amazon manifests in more extreme weather in terms of droughts as well as floods (e.g., Nagy et al., 2016). The loss of vegetation due to the highway thus worsens the impacts of climate change, resulting in loss of access to water during droughts and rapid runoff and floods during heavy rains. Another concern involving feedbacks was that infrastructure may improve access to education, but the arrival of gangs and the increase of gang activity in schools could result in kids leaving school before finishing. Parents and religious leaders pointed to the rise in profitable illegal activities as an attractive alternative, which detours young people from education to crime, and in the future will undermine labor recruitment for legitimate business enterprises and the formation of new local leaders.

The findings about the broad range of impacts, the importance of crime, and the synergies among impacts confirm that regional societies in the Amazon are not prepared to govern infrastructure impacts (cf. Balvín Diaz and Patrón Alvarez, 2008; Perz et al., 2008). Governmental planning for infrastructure has focused on overcoming the bureaucratic requirements to begin construction, and not on preparation to govern the many impacts (e.g., Dourojeanni et al., 2010; Guerra Garcia, 2008). Macroeconomic policies are inadequate; public audiences with presentations but without stakeholder comments are inadequate; police presence is inadequate; various constituencies have inadequate capacity to compete in changing markets; and so forth. Improved governance of road impacts is crucial to avoid problems highlighted by stakeholders, notably various forms of crime, in order for communities and regional societies to capture the development benefits of infrastructure.

Fortunately, workshop participants made numerous recommendations for improved governance of infrastructure in light of their comments about impacts of the Interoceanic Highway. In light of crime, stakeholders argued for increased police presence, professionalization of the police, and increased efforts to control movement across national borders. They recognized the problem

of urban pollution by calling for improvements in solid waste management, including enforcement of laws against water pollution. They acknowledged the problem of disease contagion by calling for establishment of health posts outside of regional capitals at strategic locations such as border towns. They understood the negative consequences of forest loss by calling for consistent enforcement of environmental laws against illegal deforestation, logging, burning, and invasions of protected areas. They pointed out in detail the traffic problems of the highway itself, calling for more traffic signals and speed bumps in and around urban areas, and for bridges over drainage ditches. They also understood the inadequacies of infrastructure planning by arguing for improvements in local governance plans, recognizing many road impacts and their variation among municipalities. Such recommendations amounted to proposals to mitigate negative outcomes in order to capture benefits, especially in terms of business opportunities, notably in tourism, as well as in improved organization of local producers to reach regional, national and international markets.

Stakeholder-based evaluations of infrastructure impacts thus offer important complements to the valuable scholarly literature. In the case of the Interoceanic Highway in the MAP frontier, stakeholders identified a broad array of both positive and negative impacts. Key findings confirmed results from previous work, but also highlighted important impacts that have heretofore received little attention. Economic problems, environmental benefits, and infrastructural issues all deserve more inquiry. In particular, criminological theory and research are needed to recognize infrastructure as criminogenic. At the same time, stakeholders have numerous valuable proposals to improve governance of infrastructure, which stems from their direct experience of diverse impacts.

CRediT authorship contribution statement

Stephen G. Perz: Conceptualization, Project administration, Formal analysis, Investigation, Methodology, Resources, Writing - original draft, Writing - review & editing. **Elsa R.H. Mendoza:** Conceptualization, Project administration, Funding acquisition, Investigation, Methodology, Resources, Supervision, Writing - review & editing. **Alan dos Santos Pimentel:** Project administration, Investigation, Software, Visualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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