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Air transport and sustainability: Lessons from Amazonas

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Abstract

Some states of Amazonia (or the Legal Brazilian Amazon) chose to develop from the exploitation of the rainforests to implement further agriculture and cattle ranching. To sustain this economic development model, an extensive road network was implemented in the region. Since local authorities are inefficient in monitoring and enforcing environmental laws in such a large region, those roads have been providing unrestricted mobility of people and cargo. This is leading to ever spreading deforestation.

In contrast, Amazonas the largest state in Brazil chose a high-tech industrial development model, based on the production of high-added value products. By having an operational air transport network, but virtually no more than one major interstate highway, deforestation has been avoided, with 98% of its area still covered with virgin forests. The reason behind this phenomenon is that air transport provides only restricted mobility to passengers and freight, and the possibility exists to provide unrestricted accessibility to any remote site. Accessibility was particularly important in 2005, when the atypical dry season left many communities in Amazonas all but isolated if it were not for air transport, paramount to disaster relief. Drawing on this example, the paper examines whether air transport should be considered seriously as a major transport option for the sustainable development of Amazonas.

Keywords: Amazonas; Air transport; Road/river transport; Deforestation; Environment; Sustainable development

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Introduction

Any sustainable development strategy should aim at achieving social justice, economic growth, and environmental sustainability (Greene & Wegener, 1997). An important variable for its success is ''sustainable transportation'', or the capacity of satisfying current transport needs without compromising the ability of future generations to meet the same needs. In other words, transportation should satisfy three basic conditions: the rate of use of renewable resources should not exceed their natural rate of regeneration; the rate of use of non-renewable resources should not exceed the rate at which sustainable renewable substitutes are developed; and the rate of pollution emission should not exceed the rate of assimilation of the environment (Upham et al., 2003). Whilst this definition covers the major transport concerns for developed countries, in developing countries there have been more basic and urgent concerns, since their ecological and social priorities almost always are subordinate to economic ones (Ayala-Carcedo & Gonzalez-Barros, 2005).

Induced impacts on the environment as a result of transportation[1] is defined as those impacts intrinsically related to transportation strategies, policies and programs put into practice, such as deforestation[2] induced by transportation. Induced impacts happen over a period of time and their consequences are usually irreversible (i.e. biodiversity loss) but can also generate immediate direct environmental impacts like air pollution from slash-and-burn deforestation practices.

Within Amazonia, transportation has been one of the many components of development strategies. In some states of Amazonia (particularly Rondônia, Mato Grosso, Pará, Maranhão) an agricultural/cattle ranching model of development has been implemented, supported by an extensive road network. As this has generally occurred without the respective forest control/monitoring/law enforcement, consequent deforestation is present and spreading.

Within Amazonas state, however, a different option has been implemented. Here what can be termed a high-tech development model, mostly supported by air (and even river) transport. In contrast to the agricultural model, deforestation has not occurred to the same extent as in other Amazonian states. Even though air transport may not be the most socially inclusive transport option, it is paramount to the high-tech industry production output flow from Manaus, the state capital, thus playing a major role in the sustainable development of Amazonas. Indeed, air transport is an essential public service, often the only means of transportation available. The atypical dry season of 2005 proved this, when the water levels of several rivers were so low that many communities and towns, including some along the upper Amazon River in the western Amazonas, would have been isolated if it were not for air transport. One important characteristic regarding air transport in

[1]Induced impacts refer to the environment; developmental impacts (Simon, 1996) imply a much broader meaning.

[2]Deforestation is the partial or total elimination/modification of the native forest cover resulting from both its conversion to non-forest uses and cutting practices that exceed self-re-growth rates (Ledec, 1985). It is a non-spatially homogeneous process; most deforestation in Amazonia occurs in a small number of high-intensity slash-and-burn deforestation fronts in a series of quasi-parallel lines along access roads (fishbone shape). By the time 50% of the forest cover has been cleared, the remaining fragmented forest has also lost critical resources for its conservation (Sierra, 2000). Deforestation presents many environmental impacts (i.e. local soil erosion and runoff into rivers, endemic species loss, loss of environmental services and greenhouse gases emissions), besides the socioeconomic ones (land conflicts, persistent poverty and poor health; Perz, Arambur, & Bremner, 2005).

Amazonas is that it has the potential of providing unrestricted accessibility[3] to virtually any remote location in Amazonas while allowing only restricted mobility[4] of people and cargo, thus contributing to the preservation of the environment without hindering the sustainable development of the state.

In drawing on the example of transportation developments in Amazonia, this paper explores the extent to which air transport, despite its current positionality as a contributor to global pollution, offers a sustainable transport option in some locations, and especially within developing countries. In so doing, the core argument is that in some circumstances air transport can work effectively to offer not only economic but also environmental benefits.

Economic development versus the environment

Amazonia (Fig. 1), or the Legal Amazon in Brazil, encompasses the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Roraima, Rondônia, Tocantins, and a part of Maranhão (west of W 044° meridian) and Goiás (north of S 13° parallel). It has a population of more than 18 million inhabitants (IBGE, 2001) and a total area in excess of 5 million km^2, of which more than 80% is covered with rainforests. As such, it has both national and international importance in the global debates on sustainability.

The region has been subjected to different phases of development, each having consequences for the sustainability of the area. In the late 1950s, the Brazilian government implemented an agrarian colonization strategy aiming at the socioeconomic integration of Amazonia with the rest of the country (Silva, 2001). In the 1960–1970s, further improvements included tax breaks, low interest rate loans for agriculture/cattle ranching, land titling processes (Becker, 2001), and the implementation of road networks (i.e. the BR-153/010, BR-364 and BR-230). The region was 'opened up' to settlement by landless people from other regions, and also to commercial logging on a vast scale and iron ore mining (Simon, 1996). As a result, land possession conflicts, intense population spatial mobility, and uncontrolled deforestation characterized that period.

In the 1980–1990s, the federal government adopted a 'green' discourse by creating new environmental agencies, a new forestry code that required 80% of private properties to remain forest, and a new National Integrated Policy which included the Pilot Program to Preserve the Brazilian Rainforest (PPG-7, in 1993), the Rainforest Corridors Project (in 1999), and the demarcation of indigenous/extractive reserves and conservation units. At the same time, and into early 2000s, the development policy evolved into an agro-industrial model in some Amazonia states, with programs like the Brazil in Action (in 1996); the National Integration and Development Axes (in 1999); and the Forward Brazil (in 2000, which emphasized the renewal of top-down infrastructure development projects). All of these programs led to increased deforestation (Haddad & Rezende, 2002)—approximately 400,000 km^2 were deforested between 1978 and 1998 (INPE, 2001).

Those regions in developing countries without technological development have failed in transferring the economic benefits of their development model to their people;

[3]Accessibility is defined as the ability to make a journey from one location to another, which is located beyond walking distance; transport is needed to overcome the distance barrier that separates them.

[4]Mobility is simply the ability of moving people and goods to and from any accessible location (Hoyle & Knowles, 2000).

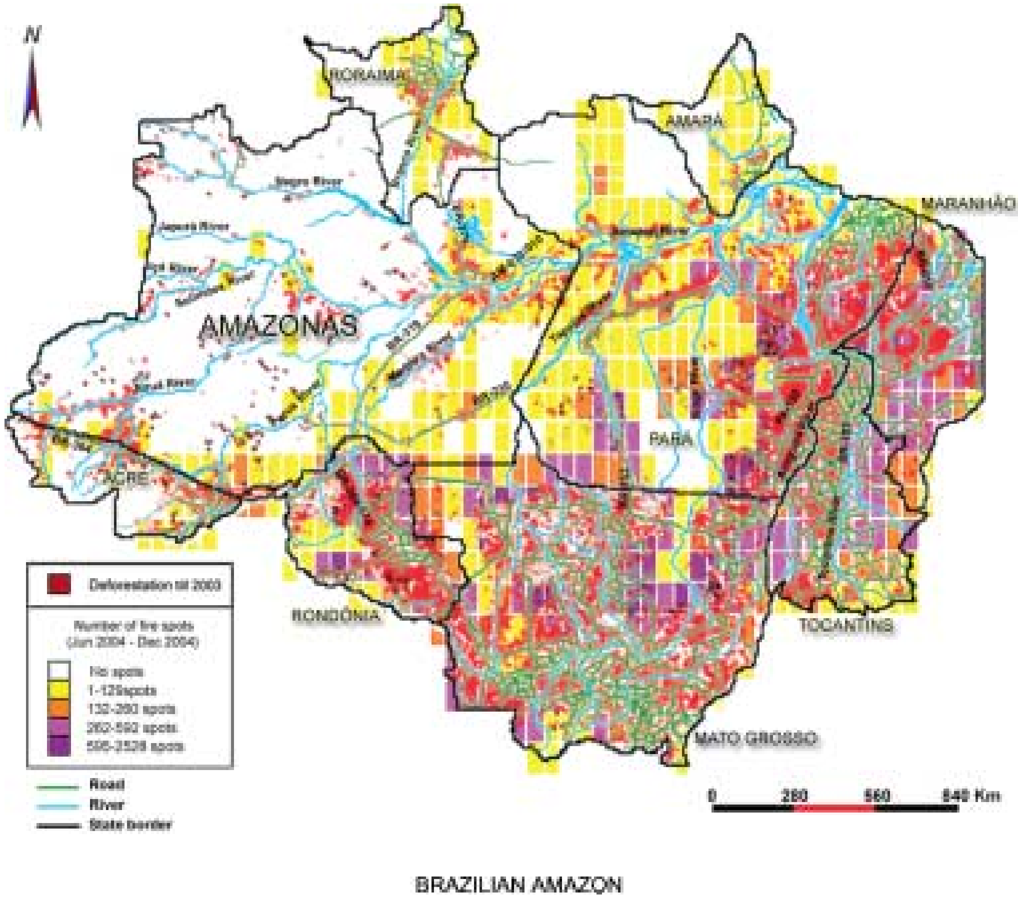

Fig. 1. Deforestation and fire, roads and rivers in the Brazilian Amazon. RMK.: The highlighted spots where deforestation took place (till 2003) do not imply in complete wood clearing; they mean that deforestation happened or is currently under progress; also, some of the highlighted spots have already been reforested. Also, some spots where deforestation took place (i.e. in southern and eastern Mato Grosso or western and central Tocantins states), were originally covered with savanna and contact forest vegetation types. Only main rivers and paved/unpaved roads shown (secondary rivers, fish-bone pattern road systems and vegetation are not shown for clarity). Sources: Deforestation, INPE (2004); fire data: EMBRAPA (2005); transportation (roads and rivers), MT (2006).

additionally, these traditional development models expand their economic frontiers through tremendous environmental costs (Machado & Fernandes, 2000). For instance, the states of Maranhão, Mato Grosso, Pará and Rondônia, in which an extensive road network is operational for the logistics of their low-added value/high weight-volume commodities, have developed their economies through the exploration of minerals, agriculture and cattle ranching. In 2004, these states accounted for 86.17% of the total area deforested in the Amazon (Table 1).

This rainforest exploitation development model was not fully implemented in Amazonas—only 30 agrarian projects covering 1.3 million hectares. Instead, an innovative model took place: a high-tech industrial development model gravitating over its capital,

Table 1
Deforestation in Amazonia, 2004

State	Total area (km^2)[a]	Deforested area (km^2)[b]	Total/deforested (%)	Share of total deforestation (%)
Pará	1,247,689.5	193,606.8	15.52	30.59
Mato Grosso	903,357.9	187,620.3	20.77	29.64
Maranhão	280,210.0	88,234.1	31.49	13.94
Rondônia	237,576.2	75,981.1	31.98	12.00
Amazonas	1,570,745.7	30,538.2	1.94	4.82
Tocantins	277,620.9	29,318.1	10.56	4.63
Acre	152,581.4	17,906.0	11.74	2.83
Roraima	224,299.0	7,552.0	3.37	1.19
Amapá	142,814.6	2,248.6	1.57	0.36
Legal Amazon	5,036,895.1	633,005.2	12.57	100.00

[a]IBGE (2003).
[b]INPE (2006).

Table 2
PIM—commercial trade balance

Year	Total (US$1000.00)
2003	4,453,667.10
2004	6,310,034.70
2005	9,130,986.20

Source: SUFRAMA (2006).

Manaus. This model was based on the intensive use of high-technology (electronics, informatics, micro mechanics, and robotics), the same that characterizes most of its high-added value/low weight-volume ratio products (e.g. electro-electronic appliances, computer hardware, two-wheeled vehicles, chemicals and thermoplastic components, among many others). The transport system to support the model included the construction of few roads (the BR-174 and BR-319), the upgrade of essential riverways (Amazonas and Madeira rivers), and the improvement/expansion of the air transport network already in service.

This industrial development model has not only contributed to preserving the environment, but it also generated economic and social benefits to Amazonas (Table 2). It is the only state in north and northwest Brazil to figure in the 2000s top-10 states ranking of Income Per Capita (SEAD/SEPLAN, 2003), while its capital Manaus ranked in the fourth position of the gross net product (GNP) for all the cities in the country in 2002 (IBGE, 2003). The Industrial Centre of Manaus (Pólo industrial de Manaus) also concentrates 36% of the top-50 ranking main enterprises in the Northern and Northeastern regions of Brazil (Exame, 2005).

The road to deforestation

Which comes first—development or transport? This transport–development relationship is both time and place specific; a function of a range of variants as geography, history, politics, economics and culture (Hilling, 2002). Only when the necessary economic, investment, institutional and political conditions are operating in unison with the spatial relations between economic development, population, markets, resources—and infrastructure—will economic development benefits be achieved (Banister, 2002; Gibbs, 2002). Transport is a necessary but not sufficient element in the sustainable development process, and many transport undertakings have turned out to be extremely wasteful of resources and culminated with wider developmental impacts (Simon, 1996). Even tough a whole set of socio-political-economic driving forces must be dynamically acting for deforestation to take place, the most important intervening factor land use (Perz et al., 2005).

The underlying premise is quite simple: Land is allocated between alternate uses to maximize economic returns—that is, deforestation might take place if profitable returns exceed the economic price of deforesting. Factors like vegetation being easier to clear, better soil quality, greater population, more development projects, extra credit incentives and financing, better trade scenarios for agriculture and cattle products, shorter distances to markets, and last but not least, denser river and especially road networks are significant. Each properly coordinated lower costs and increase returns, thus yielding to more clear-cutting deforestation (Pfaff, 1999). Overall, the value of land is a function of the uses to which that land can be put; improved access and lower transport costs can have a profound effect. It is no causality that, in the Amazon, more than 70% of deforestation occurs within 50 km of paved roads (Moutinho et al., 2001).

Deforestation is closely related to road transport in Amazonia. During the 1980–2000 period, the extension of paved roads virtually doubled in the region and unpaved roads increased by approximately 460%. The paving of existing roads and the construction of new paved roads are regarded as some of the main deforestation drivers (Ferraz, 2001), and have the potential of boosting the environmental impoverishment looping cycles of slash-and-burn practices (Nepstad et al., 2000). Deforestation and slash-and-burn practices (fire used as a land management tool) also interrelate with Amazonia rainforests. The use of fire data from remote sensing imaging systems shows a correlation between road networks, fire activity and deforestation (Eva & Fritz, 2003) with 85% of the fires occur in distances less than 25 km from the roads (Margulis, 2001). A closer look at the Arc of Deforestation (Southern and Eastern Amazonia) shows that the denser the road networks, the greater the fire activity (Fig. 1) and hence deforestation. The high-density road network identified in the states of Rondônia, Mato Grosso, Tocantins, Pará and Maranhão delineate the Arc of Deforestation; coincidently, these regions also have the highest fire spotted rates (Becker & Egler, 2001). In Amazonas, the same can be identified along South BR-174 and North BR-319, close to the Manaus epicentre; South BR-319 and far West BR-230, where the agricultural frontier is taking place at Lábrea county, and at the southern border along BR-364. A simple comparison makes this point. Slash-and-burn deforestation practices in Amazonia alone represent 3% of the annual world CO_2 emissions, while those from the burning of fossil fuels due to the whole world aviation activities—to include air transport—represent roughly 2% for the same emissions (Moutinho et al., 2001; IATA, 2004).

The implementation of unpaved/paved road networks (and some riverways) provides unrestricted low-cost mobility to once remote or inaccessible locations deep within rainforests. In so doing, they decrease transportation costs of goods and people in newly created networks, integrate rural labour markets and facilitate migration processes. Unfortunately, it is this new mobility that has contributed to the illegal deforestation in

Amazonia. Invariably, those forest management and agriculture development programs without the appropriate monitoring and control measures have failed. Even though governmental agencies like the Brazilian Environment Agency combat illegal activities, law enforcement in such a large region is nothing but limited. To implement an extensive road network without governmental regulation plus strict-efficient-effective monitoring and law enforcement can only lead to a boost in socioeconomic impoverishment, expansion of the agricultural frontier, and deforestation in Amazonia (MMA, 2001).

Overall, roads providing accessibility to once remote forested areas in synergy with unrestricted mobility of goods and people can be regarded as a major driver pro-deforestation. Thus, further road implementation in Amazonas would be, at least, a questionable transportation option in regard to the environment.

The river network of Amazonia comprises the Amazonas river basin and also part of the Araguaia–Tocantins rivers basin. However, it represents only a marginal role in the country's complete transport matrix (only 0.2% market-share). In the state of Amazonas, the Madeira–Solimões–Negro–Amazonas river network (and their tributaries) is the primary mode of transportation for the low-income population and large volumes of low-added value/high weight bulk goods, to include (many times illegal) timber extraction. Since commercial traffic and economic returns from river transport are not as encouraging to deforestation as those of road transport, this river network has been generating minor deforestation (Bezerra & Ribeiro, 1999).

Air transport in Amazonas: a sustainable approach?

Amazonas is the largest state of Brazil (almost 1.6 million km^2), with 98% of its area still covered with native rainforests. It has a population of about 3.2 million inhabitants (IBGE, 2003), half of which gather in Manaus, the capital; the remainder are scattered among its other 61 counties in small towns, villages and communities along the main rivers.

International and national, regional and charter airlines, air cargo carriers and air taxi companies meet the air transport demand in Amazonas. In addition, there are the general aviation and military operators, all of which fly both fixed and rotary wing aircraft. There are some routes departing from Manaus to selected destinations in the Americas, but the majority of them are domestic. The main routes (connecting Manaus–Brasília, Manaus–São Paulo and Manaus–Rio de Janeiro) are provided by domestic carriers (IAC, 2002). Regional routes connect 20 counties, even though 30 counties are not equipped with an air facility at this time. The air transport network of Amazonas comprises five Visual Flight Rules (VFR)/Instrument Flight Rules (IFR) operations, one day IFR, two VFR, and 42 day VFR—a total of 50 certified airports, of which Manaus (SBEG) and Tabatinga (SBTT) are international. In addition, there are three VFR and 3-day VFR heliports (SERAC VII, 2006). In order to boost air transport in the state, there are some federal–state–municipal government joint ventures (i.e. five airports implemented by the Federal Programme to Support Airports, PROFAA, in Amazonas) (Table 3).

The land use issue is critical to the preservation of Amazonas' rainforests. The use of land by road transport is overwhelming, and in many parts of Europe there simply seems not to be enough land (Black, 2000). By contrast, air transport uses less than 1% of the land dedicated to road traffic in developed countries (Rochat, 2001). However, that figure is much higher in Amazonas—about 9% (MT, 2006; SERAC VII, 2006)—basically because an extensive road

Table 3
Data from selected counties of Amazonas

County	Founded in[a]	Population in 2000[b]	River access	Road		Airport certified in[d]
				Designation	Trafficable since[c]	
Coari	1874	67,096	Solimões	—	—	1980
Eirunepé	1894	26,074	Juruá	—	—	1979
Humaitá	1890	32,796	Madeira	BR-319	1973	1965
Iranduba	1895	32,303	Solimões	AM-070	1962	—
Lábrea	1881	28,931	Purus	BR-230	1974	1970
Itacoatiara	1874	29,947	Amazonas	AM-010	1966	1959
Manaus	1833	1,405,835	Negro/Amazonas	BR-174/BR-319	1986 1973	1976 (Int'l) 1950 (Mil)
Manacapuru	1894	73,695	Solimões	AM-070	1962	—
Manicoré	1877	38,038	Madeira	AM-364	1978	1963
Maués	1833	40,036	Canumã	—	—	1968
Parintins	1848	90,150	Amazonas	—	—	1982
São Gabriel da Cachoeira	1935	29,947	Negro	—	—	1981
Tefé	1759	64,457	Solimões	—	—	1990

RMK.: Airport dates are those w hen they were first certified for aeronautical operations. Amazonas river is called Solimões from Tabatinga to Manaus in the Amazonas state.

[a] BADAM (2003).
[b] IBGE (2001).
[c] COP/AM (2005).
[d] SERAC VII (2006).

system has not been implemented in the state. Even if there were a substantial increase in air transport demand, the additional infrastructure required would not result in an impressive deforested area in Amazonas. This demand, which is basically concentrated at the international airport of Manaus (SBEG), has not—and is not expected to—increase exponentially. SBEG alone accounts for about 86% of all passenger movements and 61% of all aircraft movements in the state, and the predicted scenario does not prompt for any dramatic changes up to at least 2023 (IAC, 2003; INFRAERO, 2006). Air transport provides fast, high-cost connections between selected cities. Whilst once affordable only by the wealthy elites and middle classes, with the advent of the low-cost/low-fare airlines, which generated unprecedented competition, more and more people are benefiting. In 2003, 148,765 passengers used the Manaus bus terminal (ANTT, 2004), against 1,241,462 passengers used the terminal facilities of the International Airport of Eduardo Gomes (SBEG) in Manaus (Table 4).

Air transport has allowed developing regions like Amazonas to expand their economic activities. Air transport facilities are significant 'growth poles' (Fig. 2), adding value to their locality by attracting economic activities. In so doing, they generate direct (construction of airports, maintenance of aircraft and ground facilities, and airline personnel), indirect (supplier industries and alike), and eventually induced employment (in hotels, restaurants and other tourist facilities). There is a demonstrable positive relationship between air transport and income levels, urbanization, industrialization, education and tourism (yet not a one-way process). Air transport intensively uses and applies high technology, and is actively contributing to the development of the electro-electronic, biotechnology and pharmaceutical clusters in Manaus.

Table 4
Aircraft and passenger movements at the International Airport of Eduardo Gomes, Manaus

Year	Aircraft[a]	Passengers[b]	Cargo & mail (kg)
1995[c]	36,896	1,034,105	127,749,112
2000[c]	35,282	1,154,009	123,097,523
2005[d]	31,470	1,508,022	141,787,346

[a]Total aircraft movements (take offs and landings).
[b]Total passenger movements (embarking and disembarking).
[c]IAC (2003).
[d]INFRAERO (2006).

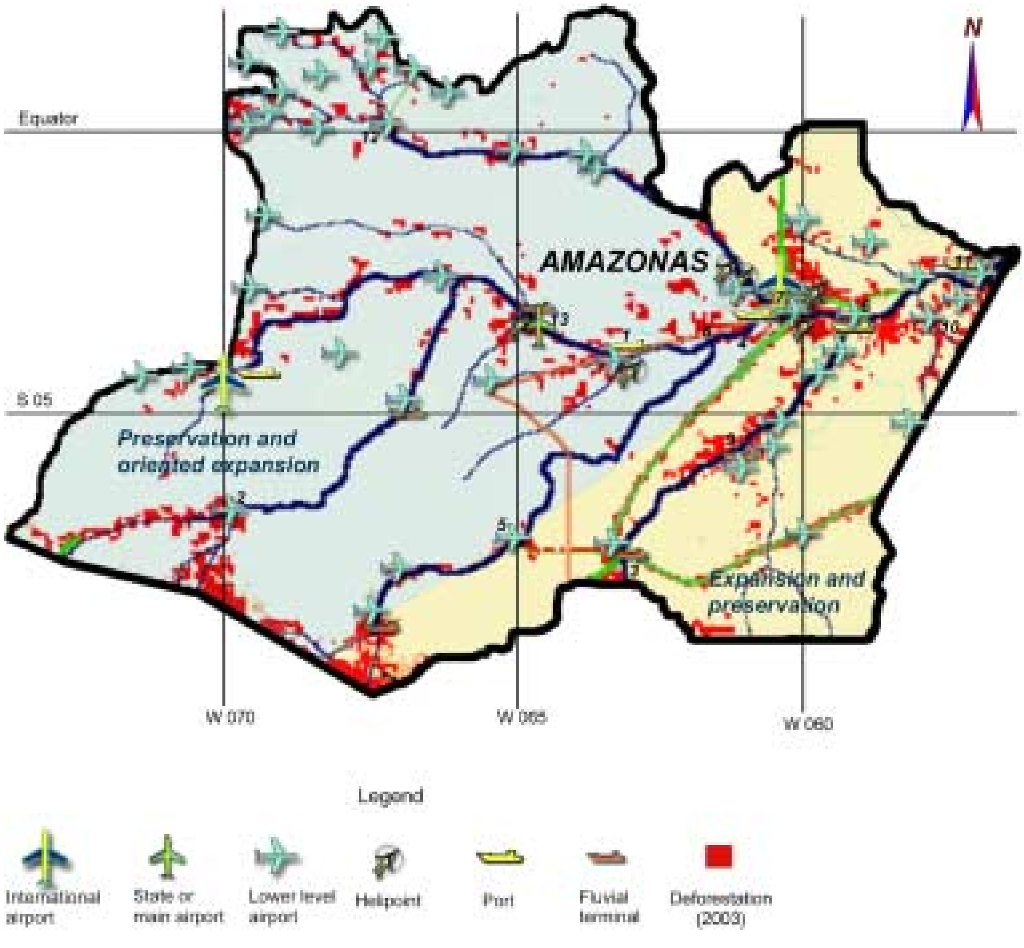

Fig. 2. Air system in Amazonas and the environment. Selected locations shown: Coari (1), Eirunepé (2), Humaitá (3), Iranduba (4), Lábrea (5), Itacoatiara (6), Manaus (7), Manacapuru (8), Manicoré (9), Maués (10), Parintins (11), São Gabriel da Cachoeira (12), and Tefé (13). RMK.: See remark on Fig. 1. Sources: Deforestation, INPE (2004); roads and river transport, MT (2006); air transport, SERAC VII (2006).

Table 5
Economic trade flow comparison between the International Airport and The Port of Manaus

Year	Total (imports and exports)		
	US$ FOB	Net weight (kg)	FOB/net weight
International Airport of Manaus—SBEG			
2003	2,830,360,769	42,182,922	67.10
2004	2,692,262,952	44,301,735	60.77
2005	4,493,028,334	49,735,642	90.34
Port of Manaus, Amazon River			
2003	2,303,678,307	2,176,437,969	1.06
2004	2,923,703,278	2,610,485,380	1.12
2005	3,601,841,500	3,214,526,852	1.12

Source: MDIC (2006).

Much of the high-tech, high value/low volume-weight production from the Pólo industrial de Manaus has a short shelf life, or restricted market windows, thus requiring fast, frequent, safe, timely, and reliable transport which, over the distances involved, can only be provided by air transport. Since 2003, the total value FOB of products imported/exported by air transport has exceeded that of river transport (Table 5), illustrating how strongly the economic model implemented in Amazonas is supported by air transport.

Recent climatologic changes, linked to deforestation in the vast Amazon, had a tremendous impact on river transport in Amazonas. The atypical dry season of 2005 set a six-decade low depth record for its rivers. It was the first time in history that the water level of the Solimões river was less than 7 feet deep between the counties of Santo Antônio de Iç á and Tabatinga. Activities were stalled for about 25,000 fishermen, tourism fell 30%, and the navigation of barges transporting grains for exports along the Madeira river was restricted to daytime only. Wildlife also suffered, with an unknown number of fish dying in the ponds and sandbanks formed in the rivers, initiating an epidemic of cholera and retrovirus. Atalaia do Norte, Anori, Caapiranga, Manaquiri, and many other communities which relied solely on river transport became literally isolated (A Critica, 2005). Unfortunately, the reality is that river transport should not be taken for granted in perennially reaching the many remote communities of Amazonas. Fortunately, air transport did reach those communities in distress by drought, famine and diseases. Air transport, by providing rapid and effective response during crisis, plays an essential role in humanitarian aid-relief, delivery of supplies, flying-doctor services, medical evacuations, law enforcement, and even the protection of the environment (Upham et al., 2003).

Breaking the chain

The agriculture/cattle development model is land use intensive. Its production consists of bulk cargo with low-added value/high weight-volume ratios (i.e., minerals, wood, grains and cattle) that require low-cost transportation to yield economic returns. The transportation system should also be able to provide unrestricted levels of mobility from newly accessible production areas to destination markets—all of which are road transport characteristics. In a perfect world, where governmental institutions had positive control over land use, deforestation would not be such a problem. However, in a continent-size region like Amazonia, governmental action due to its limited resources is limited to efficiently enforce environmental laws. Once the vicious cycle of (illegal) deforestation begins and becomes self-sustained, there is virtually no stopping to it; once trunk roads are implemented and operational, fish-bone vicinal roads give way to deforesting new areas, which is followed by slash-and-burn practices, and eventually agriculture/cattle ranching takes place. This whole process is actively happening in Amazonia (as mentioned above).

Therefore, there must be a weak link in this chain reaction that can be broken. In Amazonia, one feasible link is the mode of transportation. Transportation costs are regarded as the key factor of deforestation, which is not uncommon in a frontier region (Margulis, 2001). If no roads were constructed, economic returns would be lower due to increased logistical costs. This scenario would not stimulate agriculture/cattle ranching initiatives (and even illegal deforestation), since there would be neither mobility nor accessibility for the products from remote and isolated locations to consuming markets. On the other hand, the high-tech industrial development model of Amazonas requires fast, reliable delivery for their high-added value, short lifespan products—and transportation costs are not that important since the economics returns are worth them (Fig. 3). The good news for the environment in Amazonas is that, while delivering all that, air transport is still expensive enough to break that link in the 'deforestation chain'. It also provides an extremely efficient means of monitoring (and detecting) illegal forestry practices.

Road transport, more than any other mode of transportation, has improved the mobility and accessibility of the majority of the world's population. It has also been responsible for some of the greatest contrasts in development during the 20th century (Hoyle & Knowles, 2000). Greater mobility has had positive effects on the economic development and social welfare of countries, including greater efficiency in the movement of goods, employment, education and health services (Pew Center on Global Climate Change, 2002). Unfortunately, mobility as currently practiced in developed countries is itself unsustainable, and infinite mobility is not infinitely desirable. It is accessibility—not mobility 'per se'—which is the critical issue in social needs: "The enhancement of accessibility is a key process in policies aimed at alleviating regional disparities" (Graham & Guyer, 1999). Air transport can provide unrestricted levels of accessibility to any remote location, but only at restricted levels of mobility.

Amazonas still has vast scope for transport projects to influence, even determine the direction and pace of the whole development process. A transportation model based on accessibility rather than mobility should be given thought, one that would outcome in a win-win 'green-gold' coalition, while fostering the sustainable development of the state.

Wider lessons

Transportation is an integral and most important part in any development planning or strategy. Its policy's ultimate challenge should be to develop socially and environmentally sustainable transport systems (Button & Nijkamp, 1997). Transportation generates direct and indirect impacts[5] on the environment, and when interacting with other government

[5]Direct and indirect environmental impacts related to air transport include: noise pollution (probably the most serious one); congestions and delays; water table and surrounding soil pollution (due to solid and liquid wastes;

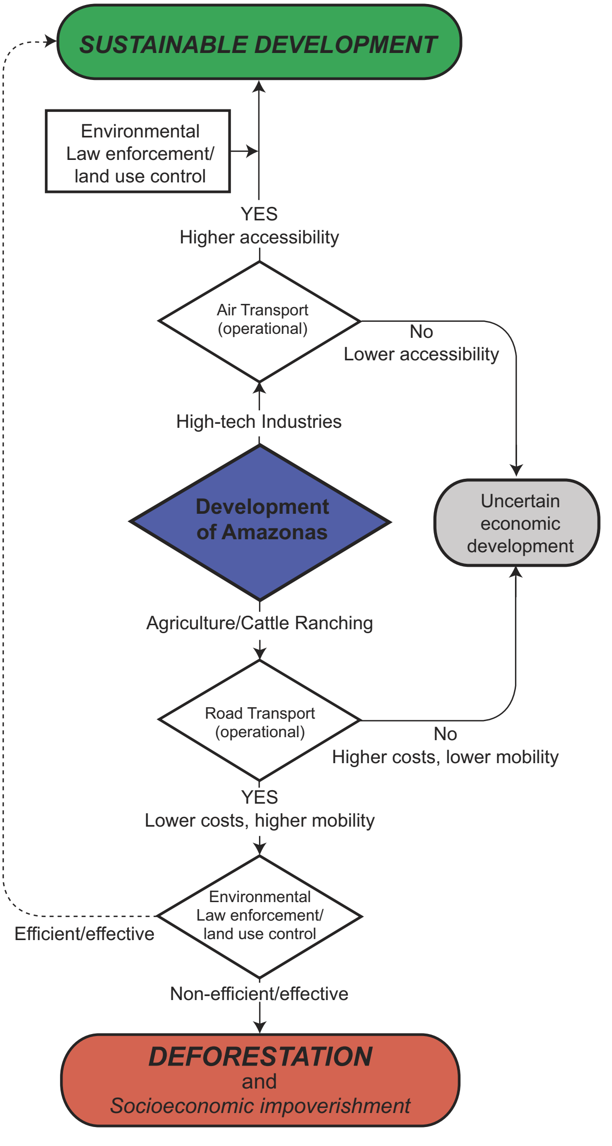

Fig. 3. Development of Amazonas options, as regarded to the environment (simplified flowchart).

(footnote continued)
Patterson, 2001); petroleum consumption (although air transport consumes less than 03% of the world consumption, and expects further 50% fuel saving by 2020; ATAG, 2001, 2005); and air pollution (greenhouse gases emissions and depletion of the stratospheric ozone level, even though all aviation sources produce less than 3% of total CO_2 emissions; Black, 1996; IATA, 2004). To avoid these unwanted impacts, air transport actors put in practice various environment friendly management and operational innovations (Janić, 1999); however, current solutions to these standing issues are not necessarily sustainable yet.

political and economic actions, it can also trigger long lasting induced impacts, in many cases much stronger than the former ones. This is especially true in regions with poor development planning and inexpressive law enforcement.

In developed countries, most of the induced impacts due to transportation are no longer a key factor; and if they were, these countries would probably have the resources and the capability to enforce measures to minimize or even stop them. Certainly, that is not the case for developing or underdeveloped countries. Even though they struggle to identify and implement policies which would balance economic growth with environmental responsibility, usually the economic and social development urges drive the decision process with respect to transportation policies. The environmental concerns become a second priority.

The transport matrix present in many developed countries that prioritize road transport should not be implemented as the primary transportation model in Amazonas. The rapid expansion of the agricultural frontier through road building, without a proportional investment in the government capacity to manage, monitor and control the region, is resulting in disorganized land occupation and boosted deforestation (Nepstad et al., 2000). Air transport is actually the viable transport option to support the high-tech industrial development model of Amazonas. It has low level environmentally induced impacts when compared with other modes of transportation (especially road transport), as much as its infrastructure implementation and maintenance costs are relatively low (Bezerra & Ribeiro, 1999). Even though its main disadvantage is its higher operational costs, it certainly is a viable transportation option for a state of such large dimensions. Air transport provides an unrestricted degree of accessibility to any remote location in the state with a restricted degree of mobility for the transportation of passengers and products (due to economic restraints).

The record dry season of 2005 in the Amazon—atypical as it may be—proved that river transport should not be taken for granted as a perennial mode of transportation even in the main rivers. It was air transport that provided continuous service to those isolated communities along the half-dry rivers, to include the Amazon river. The high-tech development model implemented in Manaus is also the best option for the rest of the state, where there are unlimited possibilities in many research and development areas, like biotechnology for instance. The evolution of both information and transportation technologies can make it possible to overcome logistic issues. In this respect, not only has air transport contributed to the implementation of this environmental and sustainable development model, but it should also be incremented as an innovative transportation approach for the rest of the state. Overall, an environmentally conscious transportation matrix in Amazonas should prioritize air (and river transport), instead of road transport.

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