Forest Roads in the Amazon Basin

James R. Sherar¹, Gordon R. Keller², Johan Zweede³

Abstract

The Amazon Basin is an incredibly diverse region covering South American countries from the mouth of the Amazon River in Eastern Brazil to the uplands of Ecuador/Bolivia/Peru and Columbia. It is generally roadless with the exception of highways to major population centers and rural roads that serve smaller communities and the mining and forest industry. There are significant challenges to planning, designing, locating and maintaining the road system that serves resource management in the remote areas of the Amazon Basin. The newly created Brazilian Forest Service is responsible for managing large areas of roadless Amazon forest through the offering of forest concessions. The National Park Service of Brazil has similar issues and challenges in managing their road system for public access. With the assistance of the USDS Forest Service-International Programs, the Brazilian Forest Service, and the Institute for Tropical Forestry in Brazil, a manual specific to the challenges of developing and maintaining a road system for Amazon Basin rural roads has been written. Those unique challenges along with the Best Roads Practices for roads in the Amazon Basin, based upon the authors’ experiences and backgrounds in engineering and forestry, are presented in this paper.

Keywords: Best Roads Practices (BRPs), Tropical, Drainage, Maintenance, Planning

History:

The history of forest transportation systems is relatively new in the Amazon Basin, beginning in the mid-1960's and based upon river transportation, mostly rafting. Early on, exotic wood products were barged down river to Belem from swamp forests that were harvested along navigable waterways. Forests were manually logged, dragged by a team of men over a corduroy trail to the side of the river for loading on barges.

The first roads served the early and primitive mining industries. The majority of these roads had very little planning and design, and were not supervised or built by engineers and were generally located and constructed by field personnel, using techniques and skills learned through experience. Environmental and safety concerns during this early development of the forest infrastructure was not an important consideration when compared to the need for durability, serviceability, and cost efficiency for hauling needed by the developing industry.

1 James R. Sherar, PE/RF, Treetrans Systems, Arden, NC., jrs4trees@gmail.com.
2 Gordon R. Keller, PE, Genesee Geotechnical, Taylorsville, CA. gordon.r.keller@gmail.com
3 Johan Zweede, Forester, Fortaleza, BR. zweede@gmail.com

With the advent of the Belem-Brasilia highway initiated in the 1960’s and the TransAmazon Highway during the mid 1970’s, incentives for clearing and conversion of the forest to agriculture were given. This new supply of wood products led to the development of the sawmill industry and the advent of the logging industry which used primitive techniques. The wood was free, there were no good logging practices and no oversight from environmental or safety agencies.

Landowners continued selling their timber and logging their own lands with the same land conversion practices developed by the logging and road building contractors. There were no Best Management Practices, no good construction practices, and no research or educational institutions with expertise to teach and guide the logging and road building. The forestry schools taught forestry, but nothing on logging and road building for good forest management. The Food and Agricultural Organization (FAO) provided guidance in forestry practices but did not emphasize roads and infrastructure development.

The first forest industry which was established north of the Amazon River was the Jari Project. The project was initiated in 1968 and the pulp mill started in the mid 1970’s. The native forests were harvested and large ares were converted to plantations for a pulp mill. This was the first project with road and infrastructure engineering which eventually included over 5,000 km of roads and 68 km of railroad. Jari employed 5 professional engineers for construction and maintenance of the transportation system. The Jari project became a model for many Amazonian people to visit and employed the only rock crusher in the Amazon at the time which also supplied rock to the corps of engineers.

In the mid-1980s, Non-government Organizations (NGOs) began to fill the gap to promote good forest development practices in the Amazon Basin. World Wildlife Fund financed an NGO called IMAZON which began providing technical guidance for best forest practices including infrastructure and began conducting research in Reduced Impact Logging (RIL) techniques under the guidance of Johan Zweede, forest engineer. This project was succeeded in 1986 by the Instituto do Foresta Tropical (IFT) at Cauaxi, Para, BR, headed by Johan Zweede.

In the late 1980's new laws were established and incentives for land clearing were discontinued. Clearing became more controlled by IBAMA, a government agency formed to oversee the environmental activities, particularly for the mining and forest industry. The logging and road building practices which were used in the land conversions brought about a concern for environment regulation in the 2000's. It also brought about the need to designate government lands for management and as a result, the National Forest Service (SFB) was directed to oversee the management activities on the designated lands through the use of concessions. This Best Roads Practices guide presents proper planning, location, design, construction and maintenance techniques which will help to assure that environmental concerns are addressed for the national road system in the Amazon Basin as well as the rural road systems found in national parks, other government ownerships and private lands within the Amazon Basin.

**Current Road Issues and Solutions Addressed in the Manual:**

The issues encountered on forest roads in the Amazon Basin are basically the same as road related issues encountered on any logging operation or development of any transportation system. Due to the remote locations, very flat, wet terrain, and high rainfall, many unique issues are found in this region, and implementation of many basic design needs is often difficult. Outlined below are some of the road building and management issues unique to the Amazon Basin.

**Strategic and Tactical Planning**

The “Engineering” of a road or transportation system is a process that begins with good planning, first at the strategic level and then at the tactical level. At the strategic level, planning of the road and harvesting systems occurs over a large area, considering many aspects of the proposed road system, such as colonization, illegal activities, and land use changes. At the tactical level, planning considers the more detailed aspects of project implementation.

**Topographic Maps**

*Moderate resolution topographic maps do not exist or are difficult to find in most of the Amazon Basin.* Whereas many areas of Central and South America have 1:50,000 scale topographic maps, these maps are not available for the Amazon. 1:100,000 scale maps have been produced but are limited in distribution and not useful for road planning. Specific maps have to be generated either from LIDAR flights, ground survey or topographic data available from the USGS/NASA SRTM (Satellite Recovery Topographic Mission). Planned road locations or landings can be added to a project by creating layers or shape files that will display the features on the map. These features can then be queried and used to get important analysis information such as road lengths, skidding or yarding distances, stream crossings, etc. Due to the flat terrain, road spacing equations are valid for use and are presented in an appendix.

**Road Classifications:**

Three classes of roads are recommended and used to designate the transportation system in the Amazon. **Primary** roads are designed as collector roads which connect the **Access** and **Secondary** roads from the harvest deck locations to the point of exit from the **Forest Management Unit (UMF)**. The **figure** below shows the relationship of Primary, Access and Secondary road designations in a UMF.

![Diagram of Primary, Access, and Secondary Roads in a UMF](image)
In level terrain, the roadway must be shaped to carry water from the surface to the sides of the road and into ditches or surrounding terrain and must be elevated above the surrounding terrain in order to keep the subgrade from becoming saturated. A main aspect is to insure the traffic-ability of the road subgrade and surface. The manual also addresses drainage issues that occur in upland areas of the Amazon. **Primary** roads are all weather roads, 1 1/2 - 2 lanes, gravel surfaced, with permanent drainage structures. **Access** roads may remain open and be gravel surfaced or closed after use and be native surfaced. **Secondary** roads are the lowest class of road and are designed for very slow, single lane traffic from log decks to the access or primary road. They are not surfaced and used only during the dry season. **Figure 2** shows a Primary, Access and Secondary Road.

![Figure 2](image)

**Figure 2**-Primary, Access and Secondary Road

**Roads - Location Issues:**

Critical aspects of field road location include checking grades, alignments and control points. In the level terrain of the Amazon Basin, the primary field location issue is the grade of the road. As a **Best Roads Practice**, road grades should be limited to avoid potential problems with surface erosion and hauling. The manual gives specific recommendations based on the class of road to be constructed. **Figure 3** shows a re-location of a steep section of road in the forest.

![Figure 3](image)

**Figure 3**- Steep road at right, re-location to flatter grade at left
Roads - Design Issues

Road surface drainage measures can be challenging in Amazon forest conditions with level terrain, but also the design of structures in poorly defined terrain. Culverts and fords are commonly needed on small drainage crossings and may be constructed with round pipes or simple log culverts. Major stream and river crossings are typically constructed with log bridge structures which must be designed to accommodate the anticipated flows and the weight of hauling vehicles.

![Figure 4](image1.png)

**Figure 4** - Poor drainage.

Another issue for road surfacing materials commonly used in the Amazon region is the lack of suitable rock. Materials available include local laterite deposits, pit run or processed gravels, or occasionally crushed aggregate in some regions. Laterite, which is a weakly cemented, variably hard, reddish deposit rich in iron and aluminum, is commonly available in many tropical regions.

![Figure 5](image2.png)

**Figure 5** - Load of laterite surfacing material being applied to an access road.

Other environmental protection considerations such as the use of Streamside Management Zones (SMZs) along water courses are discussed as a Best Roads Practice to help protect water quality and minimize disturbance along streams.

![Figure 6](image3.png)

**Figure 6** - Surface drainage ponding on a bridge location.
Road Construction Issues - Timing and Equipment

One safety issue in Amazon Basin road construction is the use of appropriate equipment such as crawler-tractors, loaders, and motor graders that incorporate safety design features such as falling object and roll-over protection (FOPS and ROPS). The use of proper personal protective equipment is also an important safety consideration to ensure worker safety. The use of proper road signs for traffic and operational safety is critical for road user safety.

Figure 7 - typical construction and safety equipment.

A second issue is the timing of construction and use of roads. Due to the wet and dry cycles typical to the Amazon region, it is important that once the roadbed has been opened up and rough graded, that it be allowed one season to settle and harden before use. A Best Roads Practice is to properly time harvesting and road use activities to ideally work only during the dry season, and to allow newly constructed roads to set up over a wet season.

Road Construction Issues - Plans and Specifications

An issue in the Amazon Basin is the lack of engineering design of the forest infrastructure components and the accompanying inspection and accountability. Figure 8 shows a bridge and a hollow log culvert installation constructed based solely upon experience. Lack of plans, specifications and inspection lead to problems with road building.

Figure 8 - bridge and hollow log culvert installation at high water flow
Maintenance

An issue seen in the Amazon Basin as well as many other parts of the world on rural road systems is the lack of commitment to maintain the investment in the road. Many times this is due to poor planning and budgeting, other times to lack of funding on an annual basis and lack of proper equipment. Maintenance is a fundamental need on any road, particularly the permanent primary logging access roads. Closing secondary roads when no longer needed or access roads that are not needed for several years is an effective method of reducing maintenance costs and providing environmental protection and is a recommended Best Roads Practice.

SUMMARY

The Best Roads Practices (BRPs) included in this manual provide techniques for good transportation planning that will serve the needs of the user; careful road location to avoid problematic areas; development of methods to create needed topographic base maps; shaping of road surfaces for drainage; appropriate and adequately sized drainage crossing structures; stable cut and fill slopes; use of erosion control measures; appropriate use of locally available roadway materials; and road maintenance practices to minimize negative environmental impacts from roads.

ACKNOWLEDGMENTS

Forest Roads - Amazon Basin, its predecessor, Low-Volume Roads Engineering-Best Management Practices Field Guide, and most of the associated training courses, form the basis of this paper and have been funded by the US Agency for International Development (USAID), and the USDA, Forest Service, Office of International Programs. The authors are grateful for the assistance and support they have received from numerous individuals in these agencies and in the Tropical Forestry Foundation in the development of these and related documents, as well as the support for needed training work in many countries over many years.

REFERENCES
