TRANSPORT NETWORK DEVELOPMENT AT AMAZON REGION: UNDER ECONOMIC GROWTH APPROACH

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1 – Introduction

Considering countries with large territorial extensions, such as Russia, U.S.A., Brazil, have a physical and geographic characteristics necessary to reach the economic development. Therefore the use of available natural resources (rivers) in these countries, become essential elements to displacement of people and products. However, the use of such resources as necessary elements to the economic development, can be explored of rational way, in order to keep the sustainability of economic growth.

In the special case of Brazil, Sant'Anna[1)] relates that, the use of the large waterway network located at Amazon region, are considered basic elements to development of a transport network for the region. However the structure of transport network toward the Amazon region requires the identification of some criteria that have be analyzed. Such criteria, must consider the regional integration, continental integration with others countries that constitute the "Legal Amazon", regional economic development (cost of transport and land use), and finally the minimization of the environmental impact.

In this way, this paper aims to develop a transport network at Amazon region, whose proposal is to support decision to develop the local region. The information about the physic network has been collected in between years of 1998 and 2000. It has been considered the problem of trade and products carry of interest of the region and countries that are inserted at "Legal Amazon", toward finally to propose actions and hierarchies of the transport infrastructure network.

This way, in the next items will be describe briefly the principal factors considered regarding to the development of the research, including the theoretical assumptions about the theory of transport network and demand generator poles, besides of the methodology used for definition of the transport network proposed.

2 – Theoretical Assumptions

Two main theoretical assumptions have been established in order to develop the methodology for this study. The first one, consider the transport network theory and the second, is the demand generator poles. In the following item, few considerations are presented about the theory of transport network, cost and capacities; and finally demand generator poles.

2.1 – Theory of Transport Network

According to Teodorovic[2)], a transport network can be defined as a set of nodes and a set of links which transport activities are carried out. The other concept about transport network is proposed by Steebrink[3)] and Setti & Widmer[4)] that consider a mathematics representation about flow of vehicles, persons and goods among points into the transport system, i. e., basic network is constituted by branches and nodes, where the nodes are important points in the space which can be assumed as facilities of transport such as: centers of regions; cities; center of neighborhoods; terminals and others; and the links are considered as the connections among the nodes, in other words, highways, railways, waterways, streets and so on (Taaffe et al.[5)]). The figure 2.1 defines a simple transport network constituted basically for nodes and links.

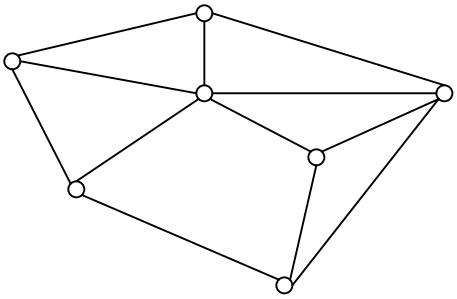

Figure 1 – A simple transport network, constituted for nodes and links.

[*] Keywords: theory of transport network, waterway transport; development and economic growth; demand generator poles.

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It is important that in nowadays the theory of network has been used as a tool to solve some problem found in transport field, for instance, such as: determination of critical path, capacity of ways, cheapest rout, minimum cost of transport associated to the links and others. Besides it can be used to define routes necessary towards occupation and consequently development of some regions.

2.1.1 – Cost and Capacities of Transport Network

Usually, cost in transport network can be identified as travel times, delays, distances, money, or perhaps the combinations among all. Theses characteristics may be associated to the links (l_i) , nodes (n_i) and routes in a determined transport network. This way, will be introduce the notion of the link cost $c_{ij}\left(f_{ij}\right)$ as an average cost or cost per unit flow by defining the total link cost for a link (i, j) with flow f_{ij} as: $f_{ij}c_{ij}\left(f_{ij}\right)$.

The notation indicates that the link cost is usually a function of the link flow f_{ij} and that, this function can differ for several links. With regard to route cost, which is defined as the cost of unit flow on a route, such as a chain or path, from an origin in a node n_i to a destination in a node n_r of a network, it can be represented by:

$$C(n_1, n_r) = \sum_{i=1}^{r-1} c(n_i, n_{i+1}) \tag{2.1}$$

For the urban networks intersections delays are important, a more general definition of route cost is required, thus the route cost of unit chain flow denoted by the link sequence $l_1, l_2, ..., l_r$ is then defined to be:

$$C(l_1, l_r) = \sum_{i=1}^{r-1} [c(l_i) + p(l_i, l_{i+1})] \tag{2.2}$$

Where:

$c(l_i) \Rightarrow$ the flow-independent link cost associated with link l_i;

$p(l_i, l_{i+1}) \Rightarrow$ the penalty associated with a turn from link l_i to link l_{i+1}.

Finally, according to Potts & Oliver[6], the network cost *C* is defined as the sum of the total link costs for all links of the network, as shown the equation 2.3:

$$C \sum_{(i,j)} f_{ij} c_{if}\left(f_{ij}\right) \tag{2.3}$$

2.2 – Demand Generator Poles

The demand generator poles by transport are considered as a large scale enterprises that attract or produce large number of trips, causing negative traffic damage localized in the its immediate around and, in some cases, damaging the accessibility of all region (DENATRAN[7] 2001). The demand generator poles when are not properly introduced, cause traffic damage as in urban environment as environment of big proportion with big uninhabited regions (Amazon). Such damage occur when the traffic flow around the way of access to the pole rise significantly for reason of increase of the trip generate by employed, reducing this way, the level of services and road safety extant in the influence area.

3 – Proposed Methodology for Definition of the Transport Network

The methodology adopted to the definition of transport network has been defined by seven stages, described as following:

Stage 1: Diagnosis of Transport System and Identification of the Demand Generator Poles

It has been identified the final situation of the transport infrastructure in the 2000s and the expectants of the principal models of transport in the Amazon towards, in the second stage, to establish a transport network, which could be oriented the investment of transport sector. The transport infrastructure identified is the following: the waterway subsystem of the west and east Amazon; roadway subsystem constituted by federal and municipal; railway subsystem constituted by 4 railway in operation, and finally the airway subsystem.

The main generator transport poles extant in the Amazon region have been identified as being development poles. In order to understand of natural features of poles, theses have been classified into of four distinct groups, whose classification is not set for goes on only in predominant features. The principal generator transport poles identified have been: poles with high level of urban development; mineral poles; agricultural and forestry poles; and the boundary poles which have been identified the natural resources with great economic potential to be explored.

Stage 2: Identification of the Great Development Routes

The identification of the great development routes at Amazon region was possible after having been done the diagnosis of the region, and having been identified the main demand generator poles by transport. The transport link at Amazon region is being structured deliberately, that link is still not complete, because its development depends of the regional economy as well as the evolution of the politic relations between Brazil and another borderline countries, which share the Amazon basin. However, the infrastructure of transport present and the future proposes for its enlargement has been oriented, in general, toward configuration desired.

Stage 3: Determination of the Transport Network Cost

The transport cost has been defined accordingly with load volume of goods transported by integration of the waterway, roadway, airway and railway network and using the equation 2.1 presented in the item 2.1.1, aim to measurement the variables regarding to each transport subsystem and its link. In that case the use of the variables to waterway network has been adopted as: features of the navigation canal, vehicles flow, volume and distance of the displacement great, features of the vehicles. For the roadway network, the variables have been the same or as similar as possible. It has been avoided the variables associated the ton*km, once that theses privilege the roadway mode.

Stage 4: Structural Definition of the Network Links

In this stage has been defined the type and the function of the links to be planned. These definitions are important, since the sensitivity of the measurement of the variables depends of service type that the links will have to offer. In a link such as bridge line, for instance, that aim to canalize the users of the network for trunk line, the generation of trips has been prioritized in relation to others, as the attraction of trips; and the main ways, equally, have been priority in the drawing of the flow of vehicles in relation to the secondary ways. Thus, toward that the planning of the links may be going together with the necessities of the users, a previous planning for the identification of the operational structure have be made, defining the type and the functions of the same ones.

Stage 5: Definition of the Structural Transport Network: Ways with Potential to Introduce the Links

The transport network has been defined using the Geographic Information System – GIS tools, based on operation of overlap thematic map. Hierarchical Analysis could identify the value of each thematic map, and the thematic maps have been created regarding to waterway network, roadway network and ports with their characteristics obtained in the diagnosis stage. The thematic maps of demand generator poles with their characterization by different products (volumes). In that stage some tasks have been done, such as:

- Determination of the hierarchical structure to take decision;
- Spatial analyze of the region;
- Modeling of the potential surface, e finally;
- Judgment among the criteria (regional and continental integration, cost of transport and land use, minimization of environmental impact).

4 – Case Study

In order to validate the methodology proposed on the previous stage have been done a case study at Amazon region.

The geographic features, such as territorial extension, population and territorial occupation, and the ecosystem always have been performance role in the development and economic growth of Amazon region. Covering an area approximately of 4.850.000 km^2, equivalent around of 57% of total Brazilian territory. The Amazon region comprehends the region north totality, the bulk of Center-west region and part of Northwest region (Maranhao State) (Cabral[8)] 1995). The states that Amazon region covers are: Tocantins, Para, Amapa, Amazonas, Acre, Roraima, Mato Grosso and part of Maranhao and Goias. However, due the geographic localization, in that study was adopted the Amazon region is constituted basically by four great areas, also called development routes (Ministry of Planning of Government[9)] 2001). The development routes are the following:

- **The Arc-North:** it is considered the smaller of the development route which is constituted by Roraima and Amapa States and holds as demand generator poles the following cities: Boa Vista e Macapá. The main economic activities in the Arc North are the public sector and the industry of paper and cellulose, beyond agriculture, animal and vegetal extraction, in special fishing maritime, production of dendê, açaí, grains and wood.
- **The Madeira-Amazonas Route:** it is the biggest region of the country, in territorial extension speaking, constituing the Acre, Amazonas and Para States, the main poles were identified as following: Coari, Manaus, Itacoatiara, Santarém, Belém and Rio Branco.
- **The Araguaia-Tocantins Route:** holding 12,9 million inhabitants, the Araguaia-Tocantins route is constituted by Tocantins, Goias and a part of Maranhao State, the demand generator poles identified in this route were: Carajás, Marabá, São Luís e Palmas. The urbanization degree is 72%, one of the smallest of the country. The agricultural activities at Araguaia-Tocantins are responsible for 9% of this sector in the Country. The agriculture activity, prominence for soya, maize, rice and beans, with 93% of the planted area (Ministry of Planning of Brazilian Government[9)] 2001).
- **The West Route:** It s is constituted by Rondonia and Mato Grosso States, the Porto Velho-Cuiabá route is considered as main transport rout, where the economy is strongly linked. The main products found in this area are: grains, soya bean and maize (Ministry of Planning Brazilian Government[9)] 2001).

Using the methodology proposed in this study, it was possible to obtained a transport network for Amazon region, considering the main criteria identified previously (regional and continental integration, cost of transport and land use, minimization of environmental impact). This way, the figure 2 defines the transport network for Amazon region, where the

trunk lines are represented by thick lines (high flow of vehicles), the bridge lines represented by slim lines, and finally the main demand generator poles which may be identified through of the main cities localized into of the region.

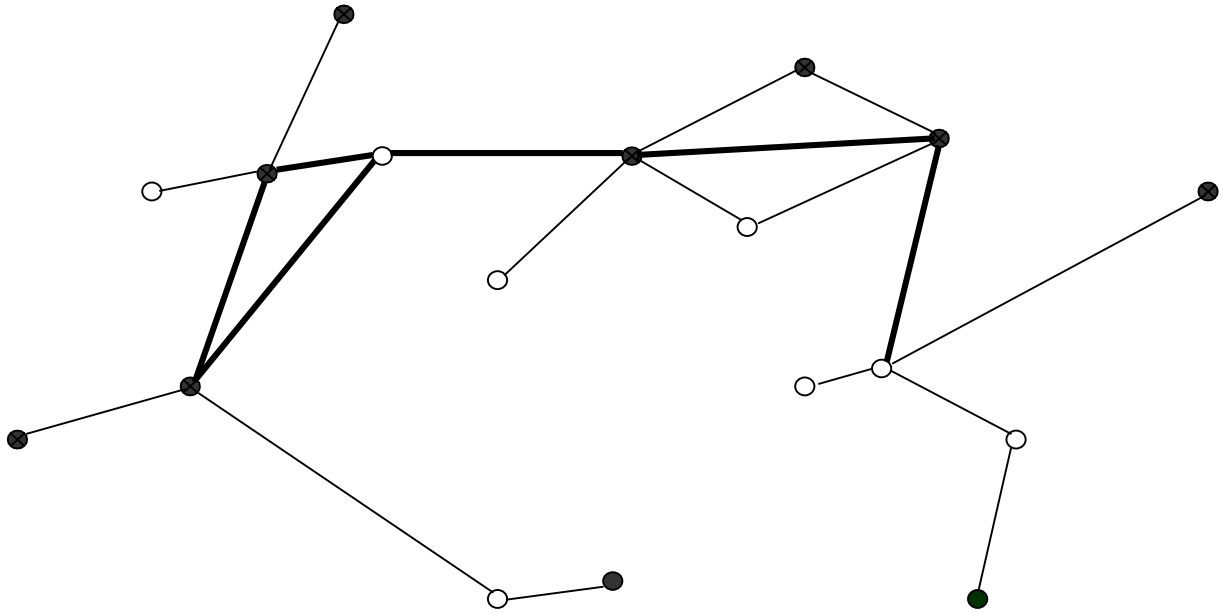

Figure 2 – Transport network for Amazon region with the main development routes.

4 – Conclusions

In view of the infrastructure situation observed at Amazon region in the present day, the criteria estimated previously in the this text, is essential to reach the development sustainable of the Amazon, contributing strongly toward the consolidation of a basic transport network at Amazan, around year 2020. Get on into of a national development route, the Amazon region, by to represent around of 57 % of Brazilian territory IBGE[10)], has an increasingly importance, and will necessitate special attention toward its infrastructure and investment plan, which will attend the reality new in future. This way, we can affirm that the principal result about this work, concern the importance of sustainable development and economic growth of Amazon region, using a transport network and the natural resources available in that region, mainly the navigable rivers.

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Abstract: this paper has as aim to develop a structural network at Amazon, whose proposal is to serve as subsidy toward the politics of development of the region, using a Geographical Information System (GIS) and Hierarchical Analysis as tool to definition of the structural transport network. The methodology used in this work, focus some specific characteristics about the main development poles (demand generator poles), potencies and strengths, extant on the Amazon region, which are considered as the essential elements to develop the regional transport network.