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Using Decision Theory and Evaluation System of Agricultural Land Suitability to Identify Aptitude of Rail Freight Terminals

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***Abstract*— Rail freight terminals are points of access between a region and rail transportation system. Arrangement of its physical infrastructure is important so that the transport of goods may be done in efficient way, which it will improve the international competitiveness of the products. Railway is considered more efficient in terms of cost than other transport mode. Investments in railways become essential to recognize the importance of transport with low cost with emphasis in points of access to that system. Under such aspect, this study aims to identify the aptitude of rail freight terminal using Decision Theory applied in vocational psychology studies based on choice, as well as Evaluation System of Agricultural Land Suitability. As result, it was possible to define guidelines related to the kind of terminal appropriated for the transport of products in a given region. It was noticed that it is possible to identify the flexible loading capacity of a rail terminal using multidisciplinary approaches in order to attend the productive dynamism of the regions where those terminals can be introduced.**

***Index Terms*— Decision Theory, Evaluation System of Agricultural Land Suitability, Rail freight terminal.**

I. INTRODUCTION

Brazil still presents inefficient transportation infrastructure that does not allow their products to be more competitive in the international market [1]. The imbalance of the Brazilian transport matrix is clear when comparing the percentage of Brazil and a developed country like USA. The representative values of the comparison between Brazil and USA are, respectively: 61.1% and 22.7% for participation of road; 20.7% and 36.3% for rail; 13.6% and 16.4% for the waterway.

In that context, Brazilian Growth Acceleration Plan (PAC in Portuguese) in second edition proposes until end of 2014 financial investment around 1.59 trillion of reais (Brazilian money) for social and urban infrastructure, energy, logistic and transport. In such plan there is a group of actions to improve the quality of roads, waterways, ports, airports and railways [2].

Once those investments put in work it becomes necessary to guarantee the efficient use of financial investments as well as seek alternative of low shipping cost regarding freight to foreign market. Under this point of view, railways are considered as appropriate transportation mode of goods with low added value, which is recommended for large countries, such as Brazil [3]. According to Nassar [4] the growth of Brazilian exports of several products is higher than in world trade.

On the other hand it's possible to identify that dynamics and variety of the goods produced need to focus on easing the transport of cargo from its origin to the exporting ports. Thus, the hard composition of the rail freight terminals needs to be evaluated in order to identify guidelines to be applied in the structure of the rail terminals. It could be possible to handle several kinds of goods in the rail terminals making them dynamic and susceptible to changes in land use.

Scenario outlined favors to the use of new conceptual approaches in the search for transport solutions. Therefore, it is necessary to identify the suitability of rail freight terminal so that they meet the current products as well as the dynamic changes of the area where the terminals would be deployed. Accordingly, principles of Decision Theory and Evaluation System of Agricultural Land Suitability (Sistema de Avaliação da Aptidão Agrícola de Terras - SAAAT in Portuguese) are used in transportation point view.

II. RAIL FREIGHT TERMINALS (RFT)

Rail freight terminals are defined as dynamic system constituted by infrastructure and physic installations, which railway performs the trains traffic and transshipment of goods from their specific wagons to complementary means of dispersion and concentration [5][6].

Delaprane [7] treats terminal as points enable loading and unloading from a transportation system where can be handle three types of cargo: general, bulk and unitized. The mains activities performed in a rail freight terminal are: (i) services related to cargo handling activities and (ii) services related to cargo storage activities [8].

Regarding to the basic operations of a terminal, there are: (i) achievement of a specific technical plan for trains of cargo transportation in terms of reception, expedition, training and classification of the hauled load, (ii) completion of the transshipment of goods from their wagons to the complementary means [9][10].

III. EVALUATION SYSTEM OF AGRICULTURAL LAND SUITABILITY (SAAAT)

According to Pereira [11] the agricultural suitability is defined as land adaptability for a specific type of agricultural use, in such case, it assumes one or more different level of management. Agricultural land suitability

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is revealed as a form of technical rating. In that technique lands are grouped according to the objective of practical interest. Evaluation of the land potential regarding its suitability presents two main methods that are applied in Brazil [11]. Evaluation System of Agricultural Land Suitability is the most important tool commonly used in Brazil.

SAAAT addresses identification of the potential use of agricultural land for classification of land suitability. In that case, levels of management are considered in order to diagnose the behavior of land in different technological conditions. After that, classification assists to take decision about kind of land use in geotechnical way, airport construction, sanitary engineering, collection of taxes, railway engineering and so forth [12][11].

SAAAT is an efficient method to evaluate the agricultural suitability and it is constituted basically by: management levels, categorical levels, limiting factors and types of land use. The first two factors are subdivided in groups, subgroups and aptitude classes and thus, land is characterized [13][11].

A. Basic Criteria of SAAAT and Management Levels

Main recommendation detached in Soil Survey Manual of USDA and in the methodology of FAO [14] is regarding to assessment based in systematic surveys and taking into account the several attributes of the land, such as: soil, climate, vegetation, geomorphology. Another concern is cost/benefit ratio. There are three levels related to management levels that are symbolized by A, B, C:

- *Level A:* indicates agricultural activities of low technological level that hardly requires mechanization. There is no application of capital for management, improvement and conservation of land and crops. It is applied in agricultural practices that require only manual technique, use of animal traction and simple agricultural implements.
- *Level B:* use of medium technological efforts in agriculture. The low capital investment is evident in this type of management. However, there is more development than the level "A". It is applied in agricultural practices that require only manual technique, use of animal traction and simple agricultural implements. Agriculture is conditioned to animal traction.
- *Level C:* indicates the use of higher technological investments in agricultural activities resulting in mechanization of various stages of operation.

Ramalho Filho *et. al.* [12] developed a study where authors pointed out limitations and needs improvements considering the management levels, which they were classified by codes that indicate the type of agricultural land suitability. Symbols are shown in Table I where letters represent management levels and they are presented in subgroups by uppercase, lowercase or brackets.

TABLE I Symbols regarding grades of agricultural land suitability [12].

Class of agricultural land suitability	**Type of agricultural using**					
	Tillage			Planted pasture	Sylviculture	Natural pasture
	Management level			Management level		
	A	B	C	B	B	A
Good	A	B	C	P	S	N
Regular	a	b	c	p	s	n
Restricted	(a)	(b)	(c)	(p)	(s)	(n)
Unfit	-	-	-	-	-	-

B. Groups, Subgroups and Classes of Agricultural Land Suitability

The system proposed by Ramalho Filho & Beek [15] presents as main aspect the possibility of the representation of three levels of management in one unique map, this revels advantage in the presentation of results. Basic structure of agricultural land suitability is constituted by levels of management, groups, subgroups, classes [11]:

- *Groups:* simulate the potential of land use. Groups are divided in: 1, 2 e 3 – use for tillage; group 4 – use for planted pasture; group 5 – use for sylviculture and/or natural pasture; group 6 - preservation of flora and fauna (unfit for agricultural use).
- *Subgroups:* comes from the variations of the groups. They represent interaction of the classes with management level. They are described by identification label.
- *Classes:* result from interaction of agricultural conditions and management level as well as requirements of using type. They are separated in good, regular, restrict and unfit class.
- *Limitation Factors:* fertility disabilities (f), water deficiency (h), oxygen deficiency (o), impediment to mechanization (m), and susceptibility to erosion (e).
- *Types of land use:* tillage, planted pasture, sylviculture and/or natural pasture, preservation of flora and fauna.

C. Graphic Representation of the Agricultural Land Suitability

The used symbols are detached by numbers and letters, which define the agricultural land suitability for given types of crops. There are following representation of groups of agricultural land suitability: 1, 2 e 3 – tillage, 4 – planted pasture, 5 – sylviculture and natural pasture. The group 6 requires special consideration as its suitability. The presentation of the agricultural land suitability uses colors that allow visualizing the map in a fast perspective. Groups are indexed as follow: group 1 – green, group 2 – brown,

group 3 – orange, group 4 – yellow, group 5 – pink, group 6 – gray. Table II presents groups and their representation.

TABLE II Symbols used in agricultural land suitability [12]

Subgroup	Features
1ABC	Land with good aptitude for tillage in A, B e C management levels.
1ABc	Land with good aptitude for tillage in "A" and "B" management levels, regular in "C" level.
1bC	Land with good aptitude for tillage in "C" management level, regular in "B" level and unfit in "A" level.
2ab(c)	Land with regular aptitude for tillage in "a" and "b" management levels, restricted in "C" level.
2(b)c	Land with regular aptitude for tillage in "C" management level, restricted in "B" level and unfit in "A" level.
3(ab)	Land with restricted aptitude for tillage in "A" and "B" management levels, unfit for "C" level.
3(bc)	Land with restricted aptitude for tillage in "B" and "C" management levels, unfit for "A" level.
4P	Land with good aptitude for planted pasture.
4(p)	Land with restricted aptitude for planted pasture.
5Sn	Land with good aptitude for sylviculture and regular for natural pasture.
5s(n)	Land with regular aptitude for sylviculture and unfit for natural pasture.
5n	Land with regular aptitude for natural pasture and unfit for sylviculture.
6	Land without agricultural suitability.

IV. DECISION THEORY AND ITS APPLICATION IN TRANSPORTATION FIELD

Decision theory derives from a psychology approach and composes Theories of Career Guidance, which is divided in three groups: Psychological Theories, Non-Psychological Theories and General Theories [16]. Decision Theory discusses how decision arises from detailed analysis of elements that intervene in the process; considering following steps: identification of possibilities, analyzes of consequences, evaluation, decision and choice. Steps of this logical sequence are called: predictive, evaluative and decision, respectively [17].

Decision Theory's origin refers to economy based in theories of decision-making. However, its application under psychological approach began in 60s. Thus, models of decision-making have been increasingly used in the career choice process [18]. All decision is centered on commonalities permeating a decision needs to be taken and at least two tendencies of actions in which one must be chosen [19].

Theories of making-decision have many applications in several areas of expertise with different approaches. All areas follow the sequence of activities: identification of possibilities, analyzes of consequences, evaluation, decision and choice [20]. Considering such approach, Decision Theory under psychological point of view and SAAAT are used as methodological tool to identify the aptitude of rail freight terminal.

V. METHODOLOGY TO IDENTIFY APTITUDE OF INFRASTRUCTURE OF RAIL FREIGHT TERMINAL

Methodology developed to identify aptitude of infrastructure of rail freight terminal is presented in this topic (Fig. 1). Such methodology was developed using SAAAT and Decision Theory.

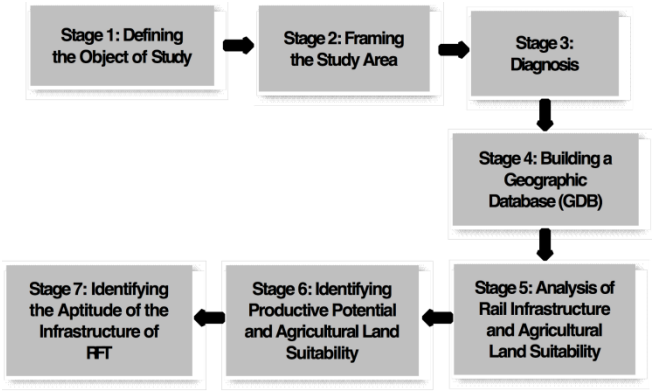


Fig. 1: Methodology to identify aptitude of the infrastructure of rail freight terminals.

VI. CASE STUDY: IDENTIFYING APTITUDE OF THE INFRASTRUCTURE OF RAIL FREIGHT TERMINAL IN NORTH-SOUTH RAILWAY (FNS), BRAZIL

The proposed methodology was applied to the case of Center-North Corridor (CNC) where it is possible to identify the North-South Railway localized in the central region of Brazil.

A. Stage 1: Defining the Object of Study

This definition is important to keep approach in the main object of study, which is the railway. Firstly, all railways in Brazil have been investigated in order to choose the railway that could have available data necessary to check the methodology proposed. Thus, North-South Railway has been chosen, mainly because its strategy location in Brazilian territory.

B. Stage 2: Framing the Study Area

Center-North Corridor (CNC) has been defined as study area because of the North-South Railway (FNS) localized in such area. Transportation corridors are defined as part of transportation system that link areas, which occurs demand for transport to facilitate great flow of goods. Over the years, other terminology used with similar goals have emerged, such as "Logistic Vectors", which was defined by Ministry of Transport of Brazil in order to define guidelines aimed at transportation planning in Brazil. In that case, logistic vectors are: Amazônico, Centro-Norte, Nordeste Setentrional, Nordeste Meridional, Leste, Centro-Sudeste

and Sul (Fig. 2).

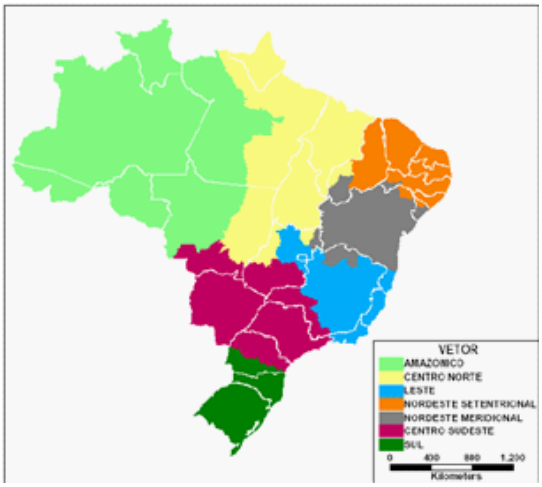


Fig. 2: Logistic vectors according to Ministry of Transport of Brazil [21]

C. Stage 3: Diagnosis

This stage aims to diagnose the study area in order to know rail transportation infrastructure, identify preponderant economic activities and regional productive potential.

Step 3.1: Diagnosis of the Rail Infrastructure

Developing transportation infrastructure present great relationship with economic dynamism of a region. This can be noted by configuration of the Brazilian railway network, which is less than ideal and it's concentrated in south region of the country. However, expansion of new agricultural frontiers since 70s has promoted an economic breakthrough in grain production towards the north of the country. Rail Transportation System of CNC is still poor and answers primarily to the flow of minerals and grains from the product zones to exportation ports. CNC area has two railways: Carajás Railway (EFC in Portuguese) that is operated by Vale Company and North-South Railway (FNS in Portuguese) that is operating partially (Fig. 3a). FNS is considered the central structure of the Brazilian development because it enables the integration between North and South regions. FNS (see EF-151 in Fig. 3b) has 3,100km of length and it passes through the states of Pará, Maranhão, Tocantins, Goiás, Minas Gerais and São Paulo. It has devised in order to answer the demand for transportation infrastructure, especially to transport agricultural production of the central region.

(a)

(b)

Fig: 3: (a) North-South Railway (FNS in Portuguese) and Carajás Railway (EFC in Portuguese), (b) Railways concession from VALEC [22]

Step 3.2: Diagnosis of Regional Economy

Region's economy is supported by mining, forestry and farming. There are twenty main products that sustain this economy, which can be classified in the following groups of activities [23]:

- Mining: these activities are characterized by extraction of several minerals, such as: iron ore, oil, aluminum ore, kaolinite and tin. Iron ore is one of the most important products of the region.
- Forestry: these activities are characterized by the extraction and processing timber and latex.
- Farming (agriculture): a few crops are grown in the region, such as: soybean, rice, cassava, cotton, corn and coffee. Among these, more emphasis is given to soybean and rice.

D. Stage 4: Building a Geographic Database (GDB)

A GIS-based database was built using data gathered in the diagnosis. Three types of layers were manipulated:

- A dot layer representing heads of the towns and their attributes regarding amount produced has been created. Additionally, this layer presents rail terminals. Data of production for the years 2000, 2002, 2004 and 2005 (for some cases) have been attached for each town in the region.
- A line layer representing two main railways in the region has been created, as well as their main features, such as name, gauges, capacity, traction system and main goods transported.
- An area layer representing towns of region was created. A layer was created for each product identified in the diagnosis; it was created a map for the following activities groups: extraction plant, permanent crops, temporary crops, minerals and livestock. Information was attached to each layer regarding production value and amount produced in each town.

E. Stage 5: Analysis of the Rail Infrastructure and Agricultural Land Suitability

This stage is constituted by two activities: analysis of the rail infrastructure and agricultural land suitability are described following.

Step 5.1: Analysis of Rail Infrastructure

Analysis of rail infrastructure was based on the following parameters: operation/construction; connections; types of

railways; gauges, radius of curvature; traction system; main goods transported, and main features of existing terminals. Thus, it was possible to show how the transport could occur along the railway.

Step 5.2: Analysis of the Agricultural Land Suitability

Agricultural Land Suitability is based in the study developed by EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária in Portuguese), which is a company associated to the Brazilian Government concerned to the technological innovation focused on the generation of knowledge and technology for agricultural. Studies developed by EMBRAPA results in classification maps of the agricultural land suitability [13]. These studies are related to maps of potential land use available in IBGE (Instituto Brasileiro de Geografia e Estatística in Portuguese). The basic difference between them is the level of details among of the maps. Maps from EMBRAPA have greater level of detail than from IBGE.

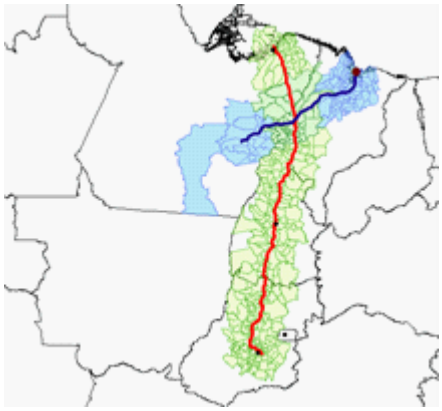
IBGE has digital maps in shapefile, which allow handling them by georeferencing software. In this study was necessary to do some specific adaptation due limited availability of maps of agricultural land suitability from EMBRAPA. Compatibility between maps of agricultural land suitability and potential land use could be done without conceptual loss for the research. Compatibilities among maps have been done for study area in order to identify agricultural land suitability.

F. Stage 6: Identifying Productive Potential and Agricultural Land Suitability

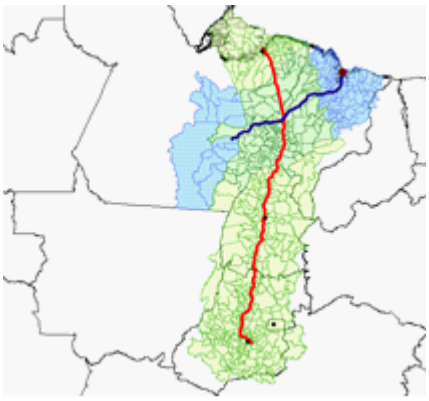
Following activities constitutes this stage: (i) determining area of direct influence of the railway; (ii) identifying productive potential of the region; (iii) determining agricultural land suitability; (iv) identifying rail terminal infrastructure. Such activities were developed based in Decision Theory and SAAAT as well as manipulation tools for digital georeferencing files.

Step 6.1: Determining Area of Direct Influence of the Railway

IIRSA guidelines were used to frame the area of direct influence of the railway. The acronym IIRSA stands for Initiative for the Integration of the Regional Infrastructure of South America (in Spanish: Iniciativa para la Integración de la Infraestructura Regional Suramericana) [23]. Therefore, two limit extensions from each side of the FNS were adopted. The first one has around 100 km from FNS including 348 towns, and the second has around 200 km including 504 towns. It was noted the area of direct influence with 200 km of extension could be more consistent for assessment, because of the prospective of transport of agricultural production with destination to Itaqui Port (MA). The same process was applied to the EFC (see Fig. 4).



(a)



(b)

Fig. 4: Area of direct influence of railway with (a) 100 km of limit extension and (b) 200 km of limit extension, following IIRSA's guidelines.

Step 6.2: Identifying Productive Potential of the Region

Identification of the economic relevance activities and products has been done using data collected in 2000, 2002 and 2004. Once data have been collected it was possible to analysis them, after that, they have been preliminary classified according to economic activities. Finally, ABC Analysis becomes possible to find the most economically important products in terms of production value. ABC Analysis served to identify the most important products in the study area (see Table III). Extraction and production activities of these products were used to determine the agricultural land suitability.

Table III Products of the database according to ABC Analysis

Groups of Activities	Considered Products
Vegetal extraction	Firewood and round wood
Permanent crops	Orange
Temporary crops	Cotton, rice, sugar cane, beans, corn, soybean
Minerals	Minerals in general
Livestock	Sheep, cattle, pork and poultry

Thematic maps were elaborated for each product to do

spatial analysis. Example about soybean is detached in order to show the process used to identify productive potential of the region. Soybean is one of the most important products exported by Brazil (Fig. 5).

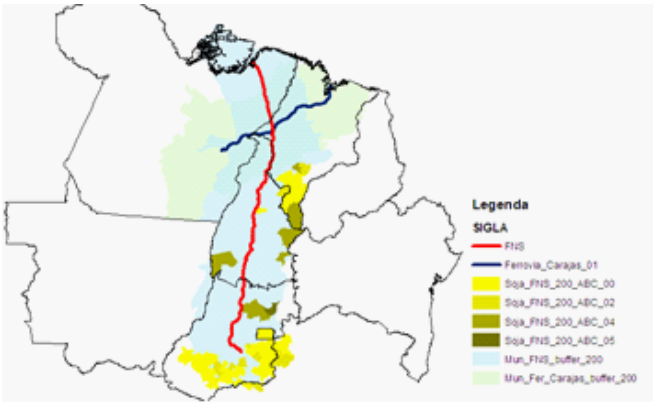


Fig. 5: Soybean producing towns.

Step 6.3: Determining Agricultural Land Suitability

Agricultural land suitability of the study area of the FNS was determined using thematic maps handled by GIS. Spatial analysis identified potential land use, which could be considered as new agricultural frontiers. Fig. 6 illustrates the arrangement of agricultural land suitability coordinated with potential land use and overlapped to the study area of FNS.

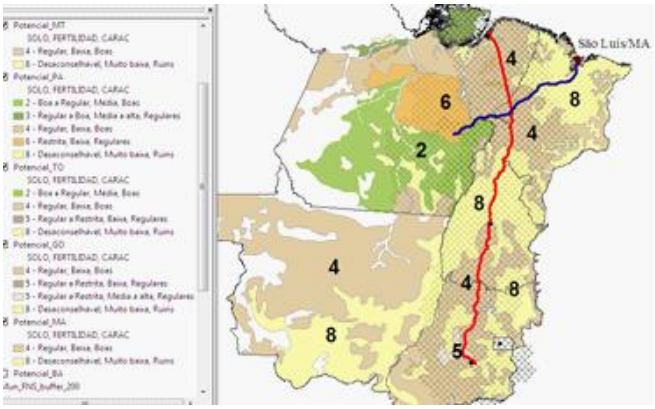


Fig. 6: Agricultural land suitability of the study area of the FNS.

In Fig. 6 is illustrated a hatched area that represent study area of FNS, which in turn allows to note:

- Regular (4) and inadvisable lands are predominant to agricultural production. It is possible to identify limitations such as topography and nutrient deficiency.
- Northeast of Pará State, South of Maranhão State, Center-south of Tocantins State and parts of Goiás State have regular land with low fertility. Topography is regular and/or slightly rolling terrain. Some limitations are: low nutrient availability and high amount of aluminum. Classification adopted is regular (4), but it can be considered also as region for agriculture requiring corrections soils.
- East of Goiás State, Northwest and Northeast of Tocantins State, Center-North of Maranhão State have bad attributes and very low fertility. Such regions are classified as inadvisable for land use (8). There are some limitations, namely: high salinity of soil, reduced depth, and presence of rockiness and sandy texture, mountainous topography. However, some agricultural activities could be developed.
- Southeast of Pará State has good land in terms of fertility and regular topography; such region is classified as "good or regular" (2) and flat topography. Soil has medium to low nutrient availability; however, it should take account sustainable land use.
- Lands in Center of Pará State are regular and they have low fertility with restrict use (6). Regarding limitations there are: steep slopes, restricted drainage, excess of aluminum and mountainous topography.
- A small region of Goiás State has regular and restrict lands (5), soil with medium fertility. There are some limitations: steep lopes, little depth and coarse texture of the soils, and flat topography.

G.Stage 7: Identifying Aptitude of the Infrastructure of RFT

FNS already has rail terminals as shown in Fig. 7. Overlapping maps of the terminal/railways and map of the agricultural land suitability, it is noted crops of cotton, rice, sugar cane, beans, corn and soybean are intensified along of the corridor. Regarding minerals, those are consolidated around Parauapebas city in Southeast of Pará State, which has railway access (Estrada de Ferro de Carajás – EFC). Finally, livestock activities have less representation in the analyzed data; however, they have great potential for growth. It is realized a greater tendency to grain production. Nevertheless, new investments should be made to consolidate the production chain of sugar cane. Concerning livestock, FNS should provide new investment along its route.

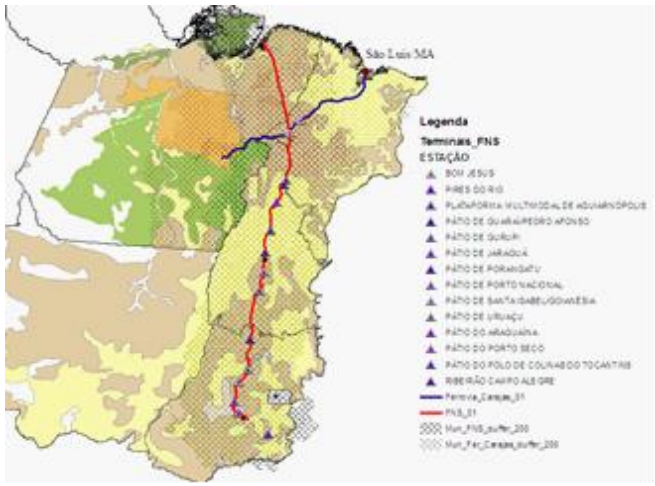


Fig. 7: Terminals of FNS and agricultural land suitability.

It is important to recall the logic sequency of activitives that was necessary to be done in order to identify aptitude of the infrastructure of rail freight terminals: (i) knowledge of the main types of rail terminals; (ii) identifying route of the FNS; (iii) creating thematic maps of the productive potential of the region; (iv) creating thematic maps of agricultural land suitability. Such activities are in accordance with principles established by Decision Theory

Guidelines pointed out regarding infrastructure of terminals in accordance with agricultural land suitability and productive potential of the influence are of the analyzed terminals. That was adopted because of great number of terminals and complexity of their physical structures.

Details about terminals require specific projects. Gathering information for each step performed it was possible to determine types of rail terminals according to the Decision Theory. Table IV summarizes groups of activities, considered products and types of products of the study area as well as types of terminal. Agriculture is the predominant activity around FNS, especially production chain of soybean.

TABLE IV Aptitude of the Rail Freight Terminals

Groups of Activities	**Considered Products**	**Types of Product**	**Types of Terminal**
Temporary Crops	Rice, sugar cane, bean, corn e soybean	Dry bulks, agro-food bulks and liquid bulks	Full wagon terminal for general cargo
Minerals (EFC only)	Ore	Dry mineral bulks	Full wagon terminal for unit load/ private derivations
Livestock	Cattle, pork and poultry	Chilled products	Market terminals

VII. CONCLUSIONS

One of the main contributions of this study was to propose a methodology based in theories and techniques from other sciences (psychology, agronomy), such as Decision Theory and SAAAT, which allow to determine aptitude of rail freight of the FNS, as well as identifying guidelines to develop efficient infrastructure of rail freight terminals.

In this study was possible to verify knowledge bases of Decision Theory allowed making analogy between man and transport, because both influence and are influenced by environment. Aptitude along with skill and dexterity were identified as one of three aspects that define ability. Such aspects from psychological approach were translated into the reality of transport, which aptitude was assimilated as productive potential of lands, ability was defined as infrastructure, which in turn allows dexterity or operation of a rail transport system. This study focuses on aptitude that enables highlight an infrastructure (ability).

Productive potential around FNS was identified, after that it was overlapped to the agricultural land suitability, and then, aptitude of infrastructure of rail freight terminal was identified. Great tendency for food production to supply foreign market has evidenced that most efficient terminals are those with structure capable to perform transshipment of bulk cargo, specially dry bulk. Results allowed validating the proposed methodology. This, in turn, could be used as a planning tool aimed at the rail transport mode. Nevertheless, methodology can be used in other transport mode in order to assist decision-making.

It is necessary to present some limitations of this study: (i) in Brazil there are few scientific studies and techniques focused on the rail transportation. Using international standards should be done carefully to minimize incompatibilities with Brazilian reality; (ii) SAAAT is not available for all Brazilian States, in few cases there are digital databases that allow manipulation in GIS software. However, it requires adjustments between maps of agricultural land suitability and maps of potential land use from IBGE.

The following recommendations can guide future studies on the topic: (i) considering more groups of activities and products in the database for analysis of the most representative products; (ii) identifying size of terminals depending on the current and future production demands; (iii) analysis of efficiency in transshipment of cargo in rail terminals.

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- Redefining Commercial Bus Models in Brazil. Journal of Civil Engineering and Architecture (Print), v. 6, p. 557-573, 2012.
- Rural school transportation in emerging countries: The Brazilian case. Research in Transportation Economics, v. 29, p. 401-409, 2010.
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- Rural School Transportation Waterway in the Amazon: Challenges and Prospects. 1. ed. Palmas-TO: FNDE/UFT, 2011. v. 3000. 272p.