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Analysis of the difference between the Euclidean distance and the actual road distance in Brazil

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Abstract

Soybean is a commodity that has an important influence on the Brazilian economy because it accounts for the largest share among the grains in the export market. Its main production centers excel in regions far from major consuming centers, requiring long commutes especially in road transport. The distance is the most influential factor in transport costs and is directly related to the freight. To define actual road distances, particularly in unfamiliar roads, it is necessary to use a correction factor. In addition to estimating a better correction factor, the paper aims to contribute by developing a procedure to identify this factor. This paper will analyze the relationships between existing Euclidean distances in numerous points, the producing centers and Brazilian's ports, performing comparisons between the correction factor obtained by calculation in this article with the factors obtained by other authors, also seeking to relate the road distances calculated based on intervals and freight. The advantage of obtaining a more accurate factor k is to allow the results of different location, such as p- median be more accurate. The result was satisfactory when comparing with the existing literature.

Selection and peer-review under responsibility of the Scientific Committee of EWGT2014

Keywords: Distance; factor K; road distance.

1. Introduction

According to Embrapa (2011), Brazil is the second largest soy producer in the world, preceded only by the USA. The production began in the 50's, when there was government incentive for the production of soy, along with the cultivation of wheat, which helped the country to establish itself as a producer of the grain as of the 1970's (Lavorente, 2011).

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Soybean exports grow every year, and according to the latest annual average yields, the North-Americans are the largest exporters, being responsible for 43% of the total exported. South America is responsible for exporting about 50% of the total, and is represented by Brazil, Argentina and Paraguay (GEPR, 2012).

According to Kussano and Batalha (2012), soy is a *commodity* that is priced in the international market, being the Chicago Stock Exchange its largest price marker, thus, producers and companies have no control over its price; they can only manage its cost.

In Brazil, road transport is responsible for transporting 60% of all of the country's cargo (Gonçalves; Martins, 2009). It is also the prefered means for the transport of most of the produced soy to the main exporting ports.

Some location methods relate the euclidean distance between the points of origin and destination and it might need to be adjusted in order to bring it closer to reality. This correction is known as factor k or circuit factor.

The purpose of this article is to analyse the relations between the existing euclidean distances for several points between producing centers and Brazilian ports, comparing the adjustment factor obtained through calculation in this article, with the factors obtained by other authors, besides seeking to relate road distances that are calculated based on the coeficient ranges obtained and the freight. The paper is organized in five sections, including this introduction. Section two presents the conceptual framework, followed by the used procedure in section three. In section four, the results are analysed, and the final considerations and suggestions for future studies follow in section five.

2. Theorical Basis

The present paper is about the search for a correction factor that sets the euclidean distances closer to the road distances (actual). In this section, the concepts needed for the identification of this factor, as well as their explanation, shall be presented.

2.1. Road Transport

Road transport is the most used means in the country – it is the main means of cargo transport. With a low maintenance cost and larger flexibility if compared to other modes, this mode is, however, deficient when it comes to the amount of cargo it can carry, being indicated for small distances and multimodal connections – road-rail and road-water (Correa, Ramos 2010; Lavorente, 2011).

According to Novaes and Valente (2008), the road freight transportation system in Brazil has a respectable structure, and it is responsible for the distribution of full crop yields down to common goods shipping's. This structure, larger than that of most other countries, is responsible for about 7.5% of the country's GDP, i.e., approximately US$ 30 million per year.

According to Caixeta (1998), the road freight transport market in Brazil, more specifically, the agricultural freight transport, is not controlled by the Government, which means that prices are established according to free negotiation through the demand and supply of the transport services. As such, transport professionals must be up-to-date with all variables incorporated to the cost, so they are able to negotiate with their customers.

2.2. The Influence of distance on Transport Logistics Cost

According to Ballou (2007), for most companies, transportation is the element that stands out most when it comes to logistics cost, and it can absorb from 1 to 2 thirds of all expenses.

The logistic activities connect production centers and markets, which are generally separated by distance and time, so that the consumers can have goods and services wherever, whenever, and in whichever conditions they desire (Batalha, 2007).

According to Caixeta and Gameiro (2010), agribusiness products have a low relative value per weight unit or volume. On the other hand, producer and consumer regions are often far from each other. Together, these factors represent significant cost to the distribution of products.

Distance is the greatest influencing factor in transport costs, since it contributes directly to variable expenses such as workforce, fuel and maintenance (Pacheco, Drohomeretski and Cardoso, 2008).

According to Novaes (2001), for long intermunicipal connections, the distance of a straight line measured in a map must be corrected in order to take the Earth's curvature effect into consideration and also to account for the fact that a vehicle does not travel in a straight line, but instead it goes through urban roads or highways. The actual distance is usually larger than a straight line distance (euclidean distance), however, the Geographic Information Systems (GIS) make this correction automatically.

According to Bittencourt (2005 apud Carmo, 2008) and Hörner (2009), two metrics stand out in the use of logistics systems: euclidean and rectangular. The first one comes from basic geometry developed by Euclides, where the shortest distance between two points is a straight line.

The euclidean distance refers to a straight line distance between points, as established in the cartesian method. The euclidean distance is the square root of the sum of the squared differences between the origin (i) and destination (j) values for all variables, as illustrated in Eq. 1 (Albuquerque, 2005).

$$dij=\sqrt{\sum_{v=1}^{p}(X_{iv} - X_{jv})^2} \qquad (1)$$

Where:

Xiv – represents the characteristics of individual i;

Xjv – represents the characteristics of individual j;

p is the number of portions in the sample;

v is the number of individuals in the sample.

Nevertheless, due to geomorphological and even historical characteristics, the distances do not behave as simply as this formula states. It is necessary to adjust the equation using correction factors that are calculated using mathematical methods such as regression analysis. Thus, correction factors for different regions and several distance forms arise in the literature, bringing the euclidean and the actual distances closer, minimizing error. (Carmo, 2008).

2.3. Location Models

Location problems have been studied by humanity since ancient times. In fact, when a nomad tribe decides to settle in a specific region, there are many factors that contribute to that choice. This decision affects all tribe members. Nowadays, the application of location problems helps locating: warehouses, industries, airports, ports, loading and unloading areas in warehouses, among others. (Horner, 2009).

2.3.1. P-median

The p-median problem is a classic facility location problem which consists of locating p –facilities (medians) in a network, so as to minimize the total sum of the distances of each demand node to its closest median (Lorena, Senne, Paiva and Pereira, 2001).

The p-median problem appears in many modeling contexts. Most often, it is seen in location analysis in which, for example, a subset of facilities must be selected to minimize the population's travel time and travel distance in several points, in search for a closer facility (Schilling, Rosing and ReVelle, 2000).

The application of this method can be found in the works of: Avella, Boccia, Salermo and Vasilyev(2012), Jackson, Rouskas and Stallmann (2007), Schilling, Rosing and ReVelle (2000), Gastner (2011), Lorena , Senne, Paiva and Pereira, (2001), Sáez-Aguado e Trandafir (2012), Barcelos, Pizzolato and Lorena (2004), Brondani, França, Netto, Jurkiewicz and Júnior (2012), Rosário, Carnieri and Steiner (2002), Georges (2012), Hörner (2009), Carmo (2008).

3. Research Method

The explanatory study was adopted as a procedure. According to Maffezzolli and Boehs (2008) it is a study that aims to build explanations delimiting a set of causal relations from independent variables, and is considered by Andrade (2009) the first step of scientific research, in which variables are manipulated to identify the relation between cause and effect of a specific phenomenon. This analysis was made through sampling, in which it was considered that the valid results for a set of samples would also be valid for a specific scenario.

As geographical scope, we chose the soy producing regions grouped in mesoregions– being these the origins – and the Brazilian ports being the destinations, making a total of 254pairs of points, because, according to Novaes and Valente. (2008),an expressive mapping of pairs of points with extremely varied distances between each other must be considered in order to find α (correlation factor that adjusts the euclidean distance to actual distance). Novaes (1989) used 110 highway connections in São Paulo as samples. The choice of soy transport was due to the economic relevance this product has in Brazil. The data related to freight prices were taken from the Information System for Freights (Sifreca). The values were taken during the period from 09/21to 10/25/2013, and with these values, through regression, a mathematical equation which describes the relation between the distance and price of freight was achieved, without considering cargo weight.

In order to analyse the Euclidean and Road distances of each pair of origin and destination points, a Geographic Information System (GIS) was used. According to Câmara (1996 apud Kaiser, Prata and Ribeiro 2007), these systems include efficient integrated optimization methods, besides graphic output such as maps. In order to obtain the actual road distance, equation Eq. 2 was adopted (Novaes and Valente, 2008; Rosário, Carnieri and Steiner, 2002):

$$\mathrm{dr} = \mathrm{de} \times \alpha \qquad (2)$$

Where:
dr – actual distance
de – euclidean distance
α – alpha factor (correlation factor)

We used the software TransCAD, academic version, since among many existing GIS's, it has been standing out, being recognized in literature as a GIS specially directed to transport (Kaiser, Prata and Ribeiro, 2007). According to Silva and Waerden (1997 apud Kaiser, Prata and Ribeiro, 2007), it is classified as a Geographic Information System for Transportation (GIS-T).

Based on points obtained in TransCAD and their respective euclidean and actual distances, calculated from this software's algorithms, we calculate here what would be the best adjustment factor, comparing them with the ones that have already been mentioned by other authors.

In order to make the calculations and generate charts, we used Excel, part of the Microsoft Office Suite, due to the fact that most of the administrative applications are based on Microsoft Office resources, making it an accessible and familiar tool.

4. Assessment of road distance for soy

4.1. Data

Fig. 1 (a) shows soy producing municipalities. Since it is a high number, we chose to group the municipalities in mesoregions, making a total of 72 mesoregions (points of origin). In Fig. 1 (b), we can see the ports that are used for soy exports, a total of 11 ports (points of destination).

Based on the previously mentioned origin and destination points, we obtained a total of 254 points, with the origins being the centroids of each mesoregion and the destinations being the ports.

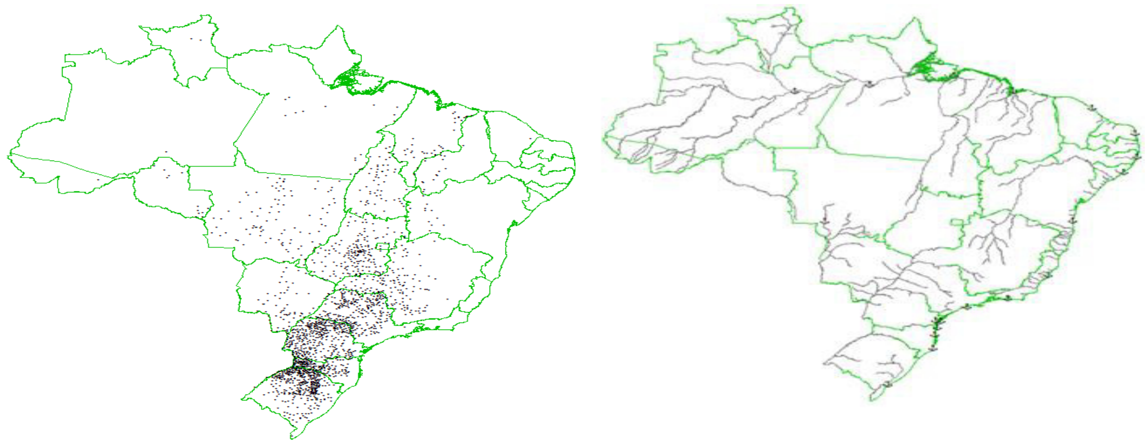

Fig. 1. (a) Soy Producing Municipalities and their Spatial Distribution in Brazil; (b) Ports Used for Soy Exports

4.2. Data Analysis and Results Interpretation

Based on the 254 points, we compared their respective euclidean and actual distances, finding the average of the difference of all the distances. Since the focus of this article was the comparison between our results and those of other authors, we found an α of approximately 1.3452, a value that is very close to that used by Novaes and Valente (2008) in his literature concerning urban distribution, considering this value is 1.35. However, for this conclusion, the above-mentioned author considered an expressive mapping of pairs of points and varied distances. Yamaguchi (2004) used 2 as a correction factor,since he found through the confrontation of results with the actual distance measured empirically that circumstances such as terrain and rural roads characteristics would not allow for the suggestion of studiesby other authors. Brondani, França, Netto, Jurkiewicz and Júnior (2012) and Sáez-Aguado (2012) in their respective works used the circuit factor of 1.2. Love, Morris and Wesolowsky (1988) made a study in the urban grids in Ontario (Canada), identifying a correction factor of 1.3. Neto (2010) carried out a thorough analysis in his study in order to determine a factor k in the city of Petrolina/PE and came to the conclusion that more than one factor would be necessary regarding distance: one for distances smaller than 2,937 km and another one for larger distances. Table 1 shows the values of α obtained by the studied authors.

Table 1. Comparison of Correction Factors

Novaes and Valente	Yamaguchi	Neto		Brondani et al and Sáez-Aguado	Love et al	This article	
		x< 2,937km	x≥ 2,937km			x< 819km	x ≥ 819km
y = 1.35x	y = 2x	y = ax 1.269 < a < 1.3	y = ax+b a < 1.152 and 385.00 < b < 492.03	1.2	1.3	y = 1.345x	y = 1.445x - 81.97

For the linear regression analysis, we used the same points as beforeand arrived at Eq. 3, with a R2 of 0.985 which indicates that the model was able to explain 98.5% of the observed values, showing therefore that the model is reliable and indicating that the (actual) road distances are very close to the euclidean distances.

$$y = 1{,}445x - 81{,}87 \tag{3}$$

Where:
y – road distance

x – euclidean distance

Comparing this equation to the others, it can be seen that it is closer to reality, having a smaller difference if compared to the actual distance and its freight. However, it would not be possible to use the value of this equation in order to calculate the actual distance in every scenario, considering that for small euclidean distances, we could find as a result road distances that are negative or smaller than its respective euclidean distance, which would not be feasible. Novaes and Valente (2008) states that, since the vehicle does not travel in a straight line, but travels through urban roads or highways, the actual distance is generally larger than the straight line distance. According to Neto's considerations (2010), there could not be one single satisfactory factor for all distances and thus, he stipulated reliability ranges for the different methods. Based on this assumption, it can be seen that for some smaller distances, calculated with the above-mentioned equation, we would have a value that is far from reality.

In order to solve this problem, we established the intersection of the straight line as O (0,0), removing the negative constant, thus creating Eq. 4.

$$y = 1{,}395x \tag{4}$$

With this new equation, we compared its respective mean error in all points and related this value to the means obtained using the coeficient of other authors. Our value was more representative than those of Yamagushi (2004), Neto (2010), Brondani, França, Netto, Jurkiewicz and Júnior (2012), Sáez-Aguado (2012) and Love Morris and Wesolowsky (1988), but was inferior to that of Novaes and Valente (2008).

Then, a new study was performed comparing what would be the reliability range for Eq. 2. Table 2 presents a comparison between the approximation of distances calculated through proportion and regression equation, in order to identify the point in which both become equal.

Table 2. Difference between Used Equations

Euclidean Distance	**y = 1.345x**	**y= 1.445x – 81.87**	**Difference**
200	269	207.13	-61.87
400	538	496.13	-41.87
600	807	785.13	-21.87
800	1076	1074.13	-1.87
1000	1345	1363.13	18.13

We observed that with an euclidean distance of 819 km, the difference of the results found by both adjustment factors is null, so with this value there is a higher reliability in relation to the actual distance calculated by Eq. 3, since this value is closer to reality. From the previous conclusions, we established a range in which distances that are shorter than 819 km would adapt better to the use of 1.345, calculated by the average proportion, and for distances equal to or larger than 819 km, we would adopt Eq. 3.

Based on the range mentioned above, we made a new comparison with the other coefficients found in the specialized literature. The comparison was made considering the average soy freight price, obtained by finding the average of the numbers found in SIFRECA (2013). From these comparisons, it is noticeable that, considering a freight value calculated from the distance found using the aforementioned coefficients, our value was closer to the actual value, with a difference of only R$ 1,01 and only 0.55% of variation in relation to the actual freight. The comparison between the actual freight and the calculated one can be seen in Fig. 2 (a). Fig. 2 (b) equalizes the distances: euclidean, road (actual) and the one calculated with the equations obtained by the authors.

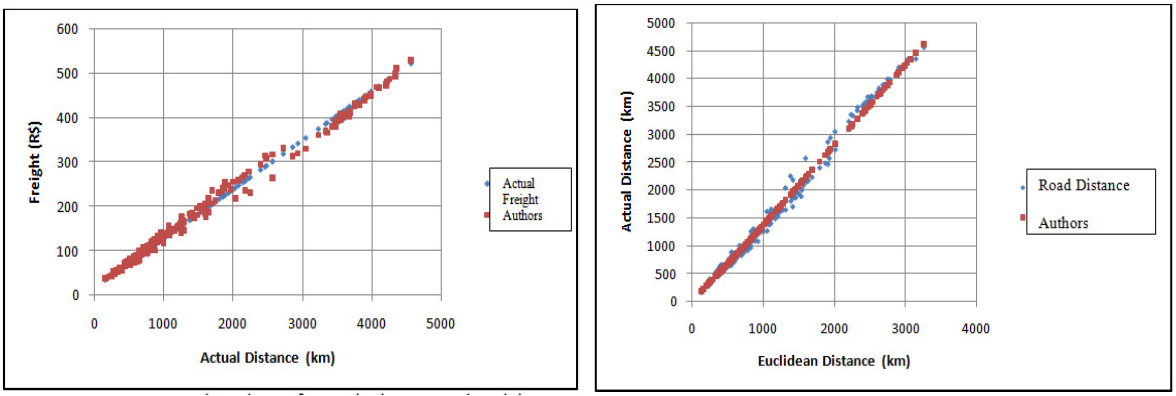

Fig. 2. (a) Comparative Chart of Actual Distance and Freight; (b) Comparative Chart of Distances: Euclidean, Actual and Calculated

With the purpose of demonstrating the relation between obtained data, Table 3 summarizes the differences between the distances and their respective freights, which are calculated using every coefficient mentioned above.

Table 3. Comparison of Differences between Distance and Freight

Means	Novaes et al	Yamaguchi	Neto	Brondani et al and Aguado	Love et al	This Article
Actual Distance–Calculated Distance (km)	94.64	679.75	118.78	194.47	110.69	73.79
Mean Margin of Error (%)	6.45	49.26	6.55	10.67	6.28	6.00
Calculated Freight Price (R$)	179.73	258.33	171.94	179.06	193.97	183.89
Actual Freight Price (R$)	182.87					
Calculated Freight – Actual Freight (R$)	3.24	75.45	10.93	3.82	11.11	1.01
Proportion of Freight Difference (%)	1.81	41.26	6.36	2.00	6.00	0.55

In order to have a more complete analysis and better comprehension about the analysed behaviour, we decided to analyze the data by States using every destination as a parameter due to the fact that a State may present more mesoregions than others. The error in this estimation by States can be seen in Table 4.

Table 4.Difference of Actual Distance by State of Origin

State of Origin	Difference Average
BA	82.40
DF	114.67
GO	80.94
MA	28.00
MG	38.48
MS	91.56
MT	152.92
PA	74.46
PI	44.73
PR	54.62
RO	76.82
RS	41.26

SC	27.56
SP	85.06
TO	132.93

After the estimation, it could be seen that the state of Mato Grosso presented the highest error rate. This fact can be explained by the fact that a great part of the state's road network is not paved yet, which makes the geographic information systems trace longer ways because there are less options of paved roads, on the other hand, we analysed the distances between every port and every point of origin which is presented in Table 5.

Table 5.Difference of Actual Distance by Ports of Destination

Ports of Destination	Average Difference
ILHEUS	47.50
MANAUS - PORTO - AM	111.91
PORTO DE PARANAGUA - PR	52.59
PORTO DE RIO GRANDE	18.60
RIO DE JANEIRO - PORTO - RJ	67.47
SALVADOR - PORTO - BA	135.01
SANTAREM	134.08
SANTOS – SP	64.49
SAO FRANCISCO DO SUL - SC	45.60
SAO LUIS - PORTO - MA	81.45
VITORIA - PORTO - ES	80.31

In this analysis, it can be seen that the predominant error index is that of Salvador port, which can be explained since, according to Biaso Junior (2007), this port has problems of road access due to the precarious conditions of this system in the area and also due to the lack of multimodal structure in the port because there is no connection with the railway system. The Santarém port stands in second place because the construction of BR-163 highway is still ongoing and the technical, economic and environmental feasibility (in Portuguese, EVTEA) studies for the Tapajós-Teles-Pires waterway are still being carried out. The routes that had errors above 15% were removed –with 15% of the total samples been removed.

4. Conclusion

In this article, we were able to define a model of linear regression for euclidean distances that are closer to reality. This model has shown to be more reliable than those found in the specialized literature. The efficiency of the application of two different methods was verified through analysis. The first one is based on determining the mean of the ratios between the actual road distance and the euclidean distance. The second one, which requires higher computational processing, consists of determining an equation that approximates the distances by means of a regression line. The adjustment that uses the regression method has shown results that come closer to reality, however, it is necessary to analyse its constant because, being it negative or not, it can generate a disproportionate result for smaller distances. Therefore, it is necessary to identify a validity range for such an equation.

It is important to emphasize that, when it comes to soy exports, the coefficients found had better adjustment if compared to the other ones, which does not prove its effectiveness in other scenarios. Nevertheless, the numbers found were very close to the ones found using the coefficient found in Novaes and Valente (2008), which is currently the most widely used coefficient in the literature.

Arriving at a more precise adjustment factor may help in the decision making processes concerning the capacity of delivery vehicles, in defining the logistic structure for companies or distribution centers and for facilities location, such as with the p-median model. The use of this factor, together with a map, represents a low cost alternative to the approximation of calculated and actual distances.

The coefficients found, besides serving the proposed topic, may also be used in other study areas, such as humanitarian logistics, or as help in areas where the region is unknown, considering that it is easier to calculate its euclidean distance since it can be determined using latitude and longitude.

For future studies, we can make two suggestions. First, we suggest that the coefficients found in the article are tested in other scenarios to check if their efficiency would remain the same. The second suggestion would be to make an analysis, removing Mato Grosso as origin and also the destinations of Salvador and Santarém ports since both are the largest bottlenecks identified in the system, having a road distance that is superior to what is expected in the literature, which is explained by the precariousness of the roads in these regions, making the Geographic Information Systems trace longer routes. Because they presented bigger road distances than other regions, a bigger error was shown, reducing the precision of the calculated coefficients.

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