EVALUATING BIODIESEL SUPPLIERS BASED IN SUSTAINABILITY AND CERTIFICATION VARIABLES: A REFERENCE MODEL

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Biodiesel process sustainability are been discussed in world. Some norms are being created in Europe involving many environmental and social aspects. This paper has the objective to evaluate biodiesel plants suppliers according to competitiiveness and sustainability dimensions. Will be presented a model composed by many variables to evaluate these suppliers. To identified these variables, was done an international research. Suppliers are observed in six dimensions. These dimensions involve necessary characteristics to chain competitiveness and sustainable directions observed in world. To evaluate the suppliers the SMART model was used to propose the importance to each criteria, because it's easy to be implanted and used, being easier to biodiesel industry use. A big advantage of this model consists in the innovative proposal to choose suppliers observing their development in dimensions considered important to consumers' chain.

Palavras-chaves: Sustainability, Competitiveness, Suppliers selection, Biodiesel

1. Introduction

It is observed in world a moving around cleaner energy production. According to this concern, biodiesel can be a product very competitive and produce a big advantage to Brazil in international economy. Brazil has a big potential to produce the oils necessary in biodiesel industry.

On the other hand, biodiesel process sustainability are been discussed in world. Some norms are being created in Europe involving many environmental and social aspects. Some of them are: environmental impact, labour used in oil production, impact in food production, etc. It is necessary observe all links of biodiesel supply chain and they need be appropriate to consumers necessity. Just observe these aspects don't ensure the chain successful. It is necessary observe competitiveness variables.

This paper has the objective to evaluate biodiesel plants suppliers according to competitiveness and sustainability dimensions. Will be presented a model composed by many variables to evaluate these suppliers. To identified these variables, was done an international research. The structure of this paper follow some steps:

- Concepts of Multicriteria Decision Aid (MCDA)
- Biodiesel Supply Chain;
- Model developed;
- Results observed.

2. Multiple Criteria Decision Aid (MCDA) Process

Chen et al. (2009) understand that MCDA methods can be considered decision aid technics, ranking best alternatives. There are some steps to be followed to structure this model (HAMMOND et al, 1999, CHEN et al., 2009):

- Define decision objectives;
- Define variables to be evaluated observing objective proposed;
- Rank variables importance;
- Propose variables weights;
- Establish the equation to aggregate all variables;
- Evaluate and rank options.

Most MCDA methodologies follow these steps. The difference consists in defining weight method used. Figure 1 shows MCDA process. We can observe that decision process evaluates options observing variables established in model.

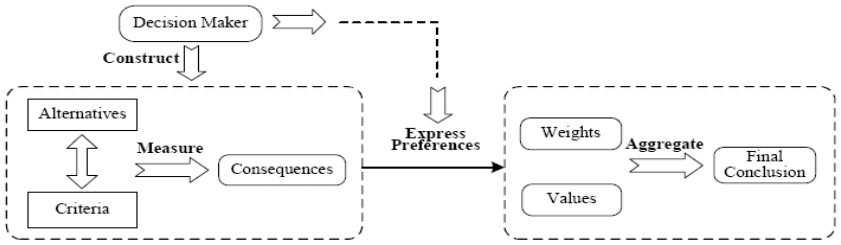

Figure 1 – MCDA process structure. Chen et al. (2009).

Kujawski (2009) identified that there are many MCDA methods and any one can be considered the best. Each situation requires a different method. Parreiras (2006) see that decision problems can be math modeled through function maximization. This function assigns an evaluation to each alternative. There are some methods using this configuration.

These methods are used to define importance by weights to each variable evaluated. In second step, according to Chen et al. (2009), is necessary establish the aggregate equation.

The method used in this paper is SMARTER, proposed by Edwards & Barron (1994), defining utilities multiatribute. Lopes e Almeida (2008) see thisn kind of model like MAUT (Multi-atribute Utility Theory) simplification, described by Keeney & Raiffa (1976). The biggest benefit using this method consists (CAVALCANTI, 2007):

- The method choose consider trade-off between modeling errors and elicitation;
- Method implantation facility.

This model define that after rank variables importance, weights are defined by ROC (Rank Order Centroid Weights). To define weights, Equation 1 is used.

$$w_k = \frac{1}{m}\sum_{1=k}^{m}\frac{1}{i} \qquad \text{(eq. 1)}$$

3. Biodiesel supply chain

Biodiesel can be defined like fuel produced by renewable energy source. It can be considered an excellent green additive to diesel because it replaces sulfur, ensuring diesel lubricity and reducing ambient impacts (HOLANDA, 2006).

The Figure 1 shows biodiesel supply chain (BSC). There are some sub products from this chain, like soy meal and glycerin, that can be used in others supply chains. Each picture box represents a productive activity. In the same figure, BSC was segmented in two parts: principal chain, responsible for raw material processing and secondary chain, including activities to support the principal process.

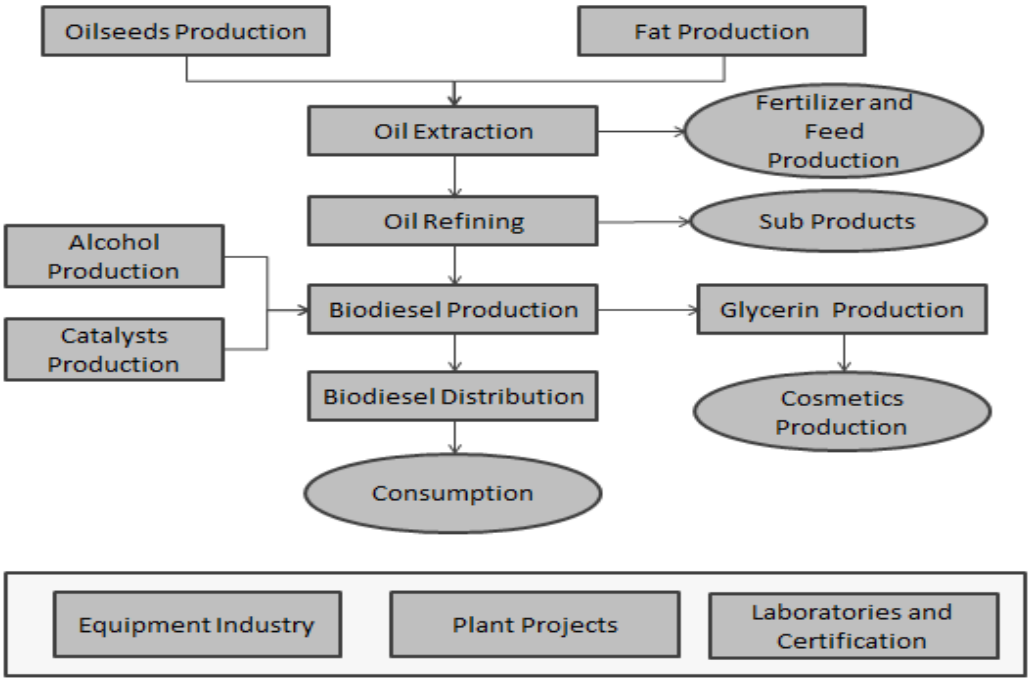

Figure 1 – Biodiesel Supply Chain. Carmo et al. (2009)

The process begins with the raw material production, in this case, the oil production. The first point presented is the oilseeds production potentiality.

3.1 Oil production and biodiesel demand

There are many seeds that can be used to get the oil used in biodiesel production. Ardengy (2008) identified some ones: soy, castor beans, palm, sunflower, canola, palmist, tucumã, cottonseed, pequi, sesame seed, jatropha, buriti, turnip, jojoba and linseed. Some of these possibilities are used in Brazilian Biodiesel Supply Chain.

Carmo (2009) analyzed Brazilian oil production potential, how can be seen in Figure 2. In 2006 Brazil produced 13.102.174 ton of oil, but not all of this production is used in biodiesel industry. Soy oil represents Brazilian oil production potential.

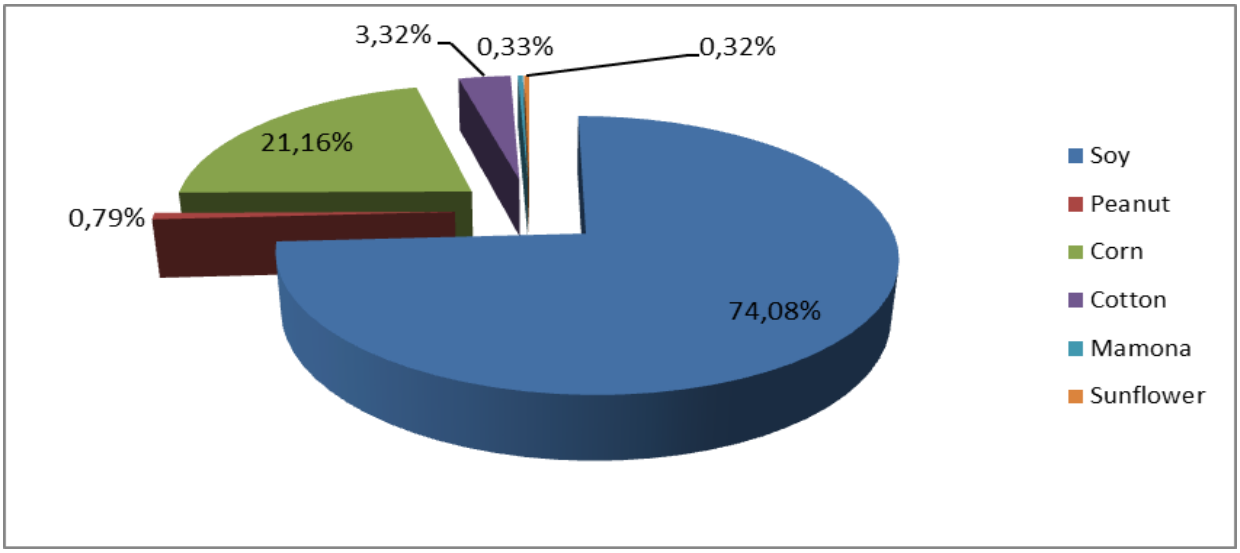

Figure 2 – Brazilian oil potential production. Carmo et al. (2009).

It is important observe some variables to evaluate the oil used. Carmo (2009) proposes some points to evaluate Brazilian oil. He establish nine points of views to evaluate this raw material. Are them: environmental impact, labour exploitation, impact on food supply, carbon credit, production costs, impact on biodiversity and impact in people quality life. Table 1 presents this classification.

Variable	Impact
Environmental impact	Aims to classify the impacts on greenhouse gases, CO2 emissions and use and exhaustion of soil and water.
Labour exploitation	It seeks to identify labor relations, involved in the production of biofuel from the field to the final consumer.
Impact on food supply	Evaluates how the production of biofuel impacts food production, taking into consideration the advancement of culture on food crops.
Carbon credit	Identify how the use of this fuel helps reduce greenhouse gas emissions. It should be taken into account, including carbon emissions during the production phases.
Production costs	Survey of the costs involved in production of biofuels.
Impact on biodiversity	Examines the progress and the pressure of the crops (oilseeds and sugarcane) on the clearing and use of virgin forests.
Impact in people quality life	Assessing the impact of biofuel use in the quality of life.

Table 1 – Variable to evaluate oil used in biodiesel production. Carmo et al. (2009)

According to these variables, Carmo (2009) discusses each oil and prepared a table observing each characteristic. This analysis is presented in Table 2.

Characterist / Seed	Environmental impact	Labour exploitation	Impact on food supply	Carbon credit	Production costs	Impact on biodiversity	Impact in people quality life	Oil yield (Kg/ha)
Soy	Negative	Positive	Negative	Negative	Positive	Negative	Negative	473
Peanut	Positive	Positive	Negative	Negative	Negative	Positive	Positive	837
Corn	Positive	Positive	Negative	Positive	Negative	Positive	Positive	211
Cotton	-	Positive	Positive	Negative	-	-	Positive	69

Mamona	Negative	Positive	Positive	Positive	Negative	Negative	Positive	296
Sunflower	Positive	Positive	Negative	Positive	Negative	-	Positive	644

Table 2 – Oilseed analysis. Carmo et al. (2009)

Observing positives and negatives point views of each oilseed, corn presents many positives aspects but has an important impact in food supply. Mamona and sunflower have big potential because they can be cultivated with another food crops. The big potential, despite the negative aspects is soybean, because Brazilian process allows a big production.

A big problem identified with soybean use is that the use of it represents food security impact. Brazil is known like the one of the biggest soy producer in world. This production is realized by estates with automated process. Brazilian soy production is concentrated in center west region, representing almost 50% from all Brazilian production (CARMO, 2009).

Soy can be used in many industries and Schlesinger (2008) esteem that 40% from all are exported like soybean; 46% is transformed in bran, used in alimentation and just 12% is used for oil extraction, where ¼ from it are exported, remaining only 9,6% from oil production. Carmo (2009) observed that if only 9,6% from soy produced in Brazil is used for oil production, and 18,5% represents oil content in seed, Brazilian oil production potential (national market) reaches 931.772 ton from soybean oil (considering data from 2006).

All these variables must be considered to evaluate suppliers in biodiesel supply chain, being necessary evaluate each one oilseed producer observing these characteristics.

Observing the demand, Carmo (2009) studied biodiesel demand and projected the future Brazilian demand for biodiesel. The decree 11.097, from 2005, established the diesel sell in Brazil must be added of biodiesel in 5% until 2013. The Figure 3 shows biodiesel production evolution.

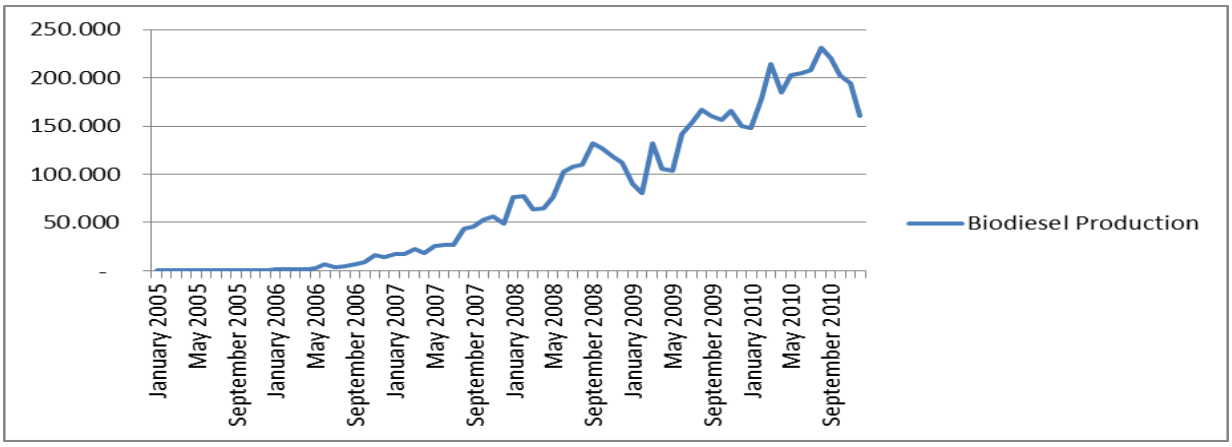

Figure 3 – Brazilian biodiesel production. Carmo et al. (2009).

Observing Figure 3, we can conclude that until 2005, the biodiesel didn't exist and with the decree the production are being increased during the time. Is important highlight that all biodiesel production is tied to diesel sold in Brazil. According to this, Carmo (2009) prepared a forecast model with diesel sell series.

According to this model, the Figure 4 presents the results simulating four options: Using a mixture from 5% from biodiesel to diesel, 10%, 15% and 20%.

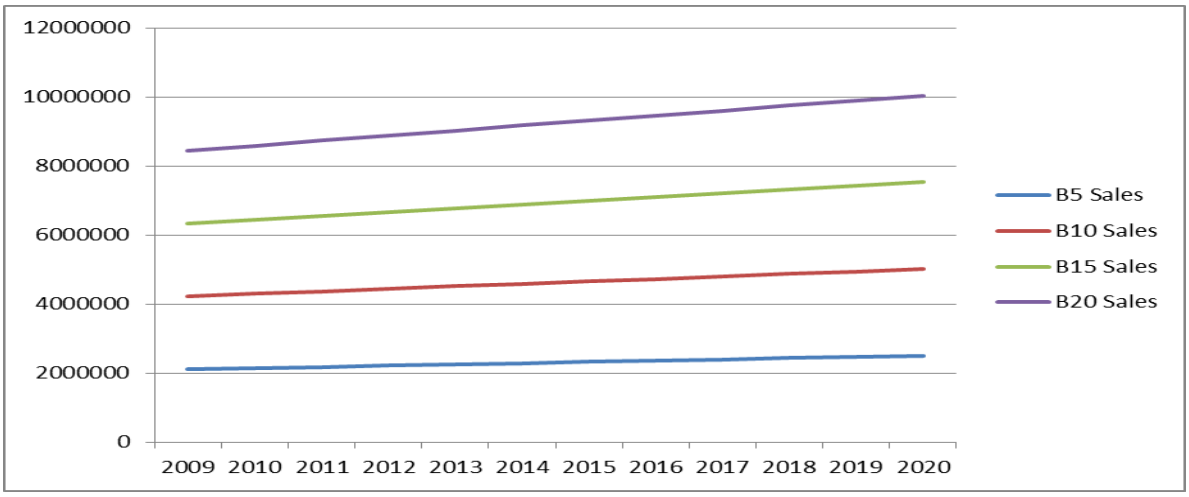

Figure 4 – Brazilian biodiesel forecast results. Carmo et al. (2009).

Observing the Figure 4, we can conclude that biodiesel demand changes aligned the mixture defined. Using the mixture of 20%, means the 10 billion liters until 2020. The big question to be discussed in this case is: Brazil is prepared to supply this demand?

Looking for this answered, Carmo (2009) identified the biodiesel producing plants constructed, being constructed and planed. According to this, he could observe that actually the Brazilian production potentiality is 5.7 billion liters. So, we can attempt to B10 demand. The Figure 5 presents Biodiesel producing plants in Brazil. The concentration is in Brazilian southeast region. There are a little bit plants in northeast and north regions. This is really worrying because this concentration is located in areas with potential to produce food. And the semi-arid region, the northeast, that has a big potential to produce oilseeds with small impact in food supply don't have many plants. This shows that biodiesel produced in Brazil is supported by soybean.

Figure 5 – Brazilian biodiesel plants. Carmo et al. (2009).

Observing the plant's capacity, we can conclude that center west region has the biggest plants. It can be observed in Figure 6. We can observe that the production is concentrated in Center West and South region, despite a bigger number of plants in southeast region.

According to this information presented, we can conclude that Brazil can attempt to production of B10 and has the possibility to export 2.5 billion liters of biodiesel. Biodiesel production needs observe some variables: economics, politics, and environmental ones. This is not easy and evaluates suppliers using these variables is complex (OECD, 2008). The next step presents the characteristics to evaluate biodiesel production sustainability.

3.2 Sustainability and competition characteristics in biodiesel production

Produce biodiesel is important because it can promote sustainability, represented by the development supplying present nations' demand without destroy abilities of future generations (ABNT NBR 16001, 2004). This means produce biodiesel with an environmental reduced impact.

Two themes are been discussed in Europe: in one side, the weather modifications; in the other one, the energy supply in transportation system (BRÄUNINGER et al., 2007). Energy produced by petroleum improves security in energy reserves. The fuel demand increase created spaces to discuss biodiversity, labour exploitation, food security, etc. (DOORNBOSCH et al., 2007; BRÄUNINGER et al., 2007).

The increase in mixture of biodiesel with diesel created an interest from European enterprises in biodiesel importation. So, Brazilian production potential can be an opportunity to national enterprises working in this supply chain.

Looking competitive perspective, there are some characteristics in Brazilian biodiesel supply chain observed by Carmo (2009). Are them:

- Product resulted in supply chain: Brazilian enterprises produce products with big technological innovation. A problem that can be presented is the raw material available. On the other hand, glycerin and oilseed are been exported, fact that prejudice Brazilian biodiesel supply chain.
- Market knowledge: Brazilian production is certified by social seal that promotes social inclusion familiar agriculture. This seal improve the value to biodiesel because European consumers give importance to this variable.
- Competitive position: There are many enterprises dedicated to research and improve the product innovation.
- Integration to value aggregation: There are incentives to producers supply biodiesel plants with refined oil.
- Cooperation: There are governmental incentives like social technology, which are supported by most important chain enterprises.
- Paternalism: There are incentive from government to biodiesel production inside

Brazilian biodiesel program.

All these characteristics must be evaluated in biodiesel plants suppliers and this paper presents a model to evaluate suppliers looking these variable presented in this topic. The next one presents de model developed.

4. Suppliers evaluation model proposed

To develop the model were done a research to identify competitive and certification characteristics. This research produced the areas to evaluate biodiesel suppliers:

- Supply Chain competitiveness;
- Producers' environmental sustainability;
- Producers' social sustainability;
- Productivity and production costs;
- Transportation costs.

Looking these areas, a structure was proposed to evaluate biodiesel plants' suppliers. The Figure 6 presents the variables evaluated in biodiesel plants' suppliers.

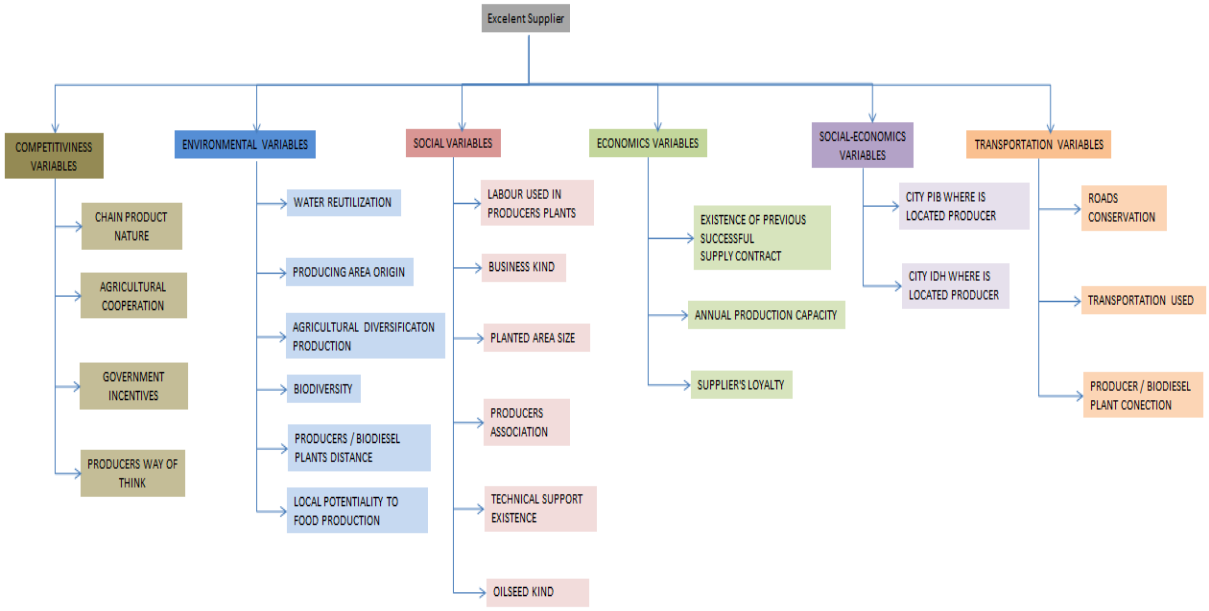

Figure 6 – Criteria to evaluate biodiesel plants' suppliers.

According to Figure 6, suppliers are observed in six dimensions. These ones are constructed by variables were suppliers are evaluated. These dimensions involve necessary characteristics to chain competitiveness and sustainable directions observed in world.

To evaluate the suppliers the SMART model was used to propose the importance to each criteria, because it's easy to be implanted and used, being easier to biodiesel industry use. It is indicated to because it reduces modeling and elicitation errors from administrators, that don't

know, in many cases, certification and competitiveness directions. This was decided because this model brings a suppliers' evaluation innovative vision, being hard to the evaluation because they don't know the variables analyzed in the world.

To each variable, was defined a descriptor with some impacts levels were producers can be located. Qualitative and quantitative variables were used in descriptors.

The first dimension, competitiveness, involves variables that producers must have. To each variable there is a scale, exemplified in Figure 7. The scales were defined using interval average technic.

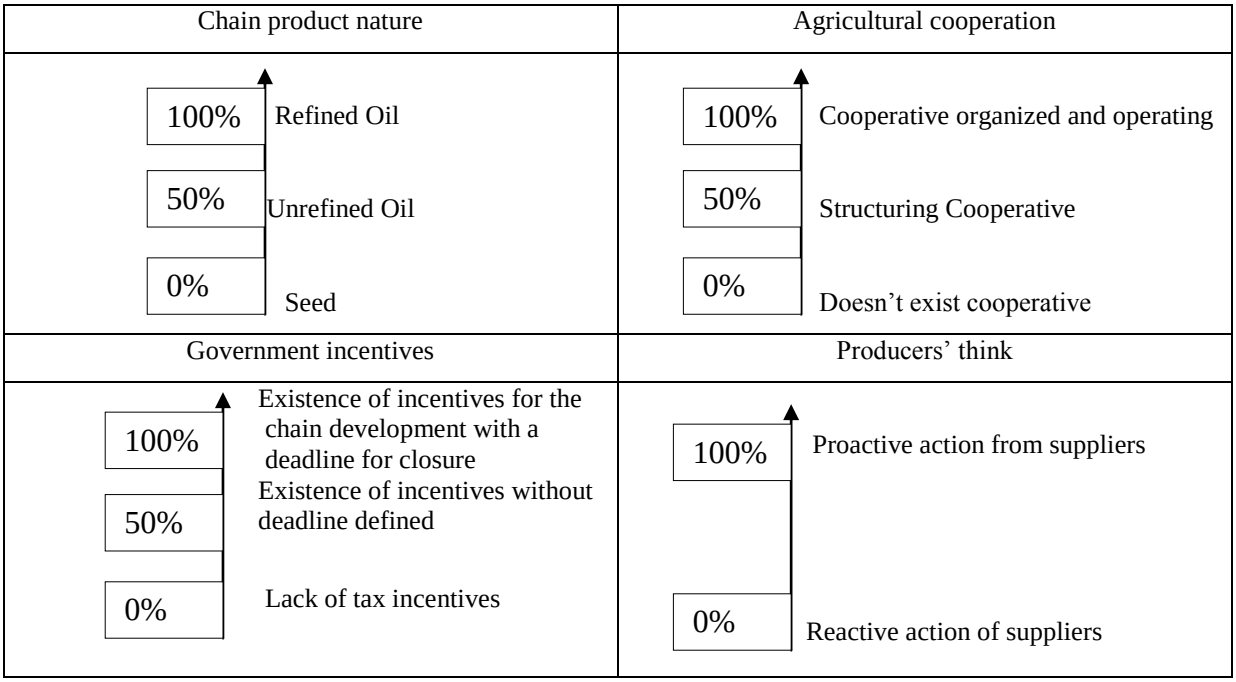

Figure 7 – Competitiveness' variables scale.

The first variable, chain product nature, is better to biodiesel plants receive refined oil. Another benefit in this case is the possibility to producers gives a product with bigger aggregate value, promoting a high quality life style; criteria imposed from biodiesel certification directions. The second variable, agricultural cooperation is important because this structure gives a bigger trustily to suppliers' system and increase familiar agriculture model. The third one, government incentives, proposes that exist financial incentives but them must have a period stipulated. Financial incentives without stipulated period can prejudice the chain development. The last one, producers' think, wants evaluate producers' initiative to solve problems. Producers with active attitude are more trustily suppliers.

The second dimension involves environmental variables, criteria used in certification norms being created in Europe. These variables must evaluate environmental impacts from oil producers. The variables were defined observing international directions. The first variable from this dimension, water reutilization, wants observe suppliers' concern about water conscience, direction defined by European nations. The second variable, producing area

origin, observe Embrapa zoning to identify areas that can be used in plantations, without deforestation. The third variable, agricultural diversification production, evaluates if it has crop rotation. The fourth one, biodiversity, evaluates if there is reforestation projects. The last variable in this dimension observe if planted area has potential to be used in food production.

Third dimension involves social variables, evaluating oil production impact in society. Here, we look if there is labour exploitation, if oil comes from agribusiness or agricultural family production, producers' area planted size, observe if there is technical support to producers and the last variable evaluates if the oilseed can be used like food or not.

The fourth dimension involves economics variables, prioritizing oilseeds with a smaller transportation costs. There are other variables to evaluate system reliability to ensure oil supply.

The fifth dimension involves socio-economics variables, prioritizing producers located in undeveloped cities, observing government indices. This dimension is aligned with social inclusion criteria and improves population high quality life.

The last dimension evaluates the connection between producers and biodiesel plants. Is preferred transportation modality with a smaller cost. It evaluates too if there is infrastructure to transportation activity.

Defined all variables evaluated, the second step from MCDA model is order the importance of all variables. To get this importance, were used the ROC method (Rank-order centroid). So, were defined the importance order from variables in each dimension. This order was defined by chain managers. Table 3 shows this importance order.

Chain Product Nature > Agricultural Cooperation > Government Incentives > Producers way of think	
CHARACTERISTIC	**IMPORTANCE WEIGHT**
Chain Production Nature	52,08%
Agricultural Cooperation	27,08%
Government Incentives	14,58%
Producers way of think	6,25%
Local Potentiality to Food Production > Agricultural Diversification Production > Water Reutilization > Biodiversity > Producing Area Origin	
Characteristic	**Importance Weight**
Local Potentiality to Food Production	45,67%
Agricultural Diversification	25,67%
Water Reutilization	15,67%
Biodiversity	9,00%
Producing Area Origin	4,00%
Business Kind > Labour used in plantations > Technical support existence > Planted area size > Oilseed Kind	
Characteristic	**Importance Weight**

Business Kind	45,67%
Labour used in producers plants	25,67%
Technical support existence	15,67%
Planted area size	9,00%
Oilseed kind	4,00%
Suppliers' loyalty > Existence of previous successful supply contract > Annual production capacity > Distance	
Characteristic	**Importance Weight**
Suppliers' Loyalty	52,08%
Existence of previous successful supply contract	27,08%
Annual production capacity	14,58%
Distance	6,25%
City IDH where is located producer > City PIB qhere is located producer	
Characteristic	**Importance Weight**
City IDH	75,00%
City PIB	25,00%
Transportation system used > Producer/Biodiesel plant connection > Roads conservation	
Characteristic	**Importance Weight**
Transportation system used	61,11%
Producer/Biodiesel plant connection	27,78%
Roads conservation	11,11%

Table 3 – Variables Importance Weight

Observed variables weight, the next step was define dimensions weights. ROC method was used again. To define the importance order, some assumptions were defined:

- Many biodiesel plants are working without all capacity installed. The most important dimension is economic because it involves the reliability suppliers evaluation.
- The second dimension is competitiveness, because it involves the future chain viability.
- The third dimension is environmental one, because it considers food security impacts.
- The fourth is social dimension, because it is considered a dimension very important in certification systems.
- The fifth is transportation, looking for a better efficiency in this process.
- The last one is social-economics dimension, analyzing city economics situation.

According to this order, the weights were defined using ROC method, shown in Table 3.

Dimension	Importance Weight
Economics Dimension	40,83%
Competitiveness Dimension	24,17%
Environmental Dimension	15,83%
Social Dimension	10,28%
Transport Dimension	6,11%
Socio-economics Dimension	2,78%

Table 4 – Dimensions Importance Weight

Observing all weights obtained, were developed the equation (1) to aggregate the impacts in each variable and the weight established.

$$Wi = \sum_{j=1}^{n} Fj \,.Wj \,.(\sum_{i=1}^{k}\sum_{j=1}^{k} Cij \,.Wij) \qquad \text{(eq.1)}$$

Each variable is described above:

- C_{ij} = Variable i, in dimension j;
- W_{ij} = Variable weight i in dimension j;
- F_j = Dimension j;
- W_j = Dimension weight;
- W_i = Supplier evaluation;
- n = Number of dimensions;
- k = numbers of variables in each dimension.

5. Model Simulation

This model evaluates biodiesel plants suppliers according certification and competitiveness criteria. The biggest problem with it result from weights assumptions based in chain managers.

This model was tested with ten biodiesel plant suppliers. Each one was evaluated in all model variables, observing supplier performance. Using Equation 1, all of them got their global performance, observed in Table 5.

Suppliers	Performance
Supplier 1	14,60
Supplier 2	31,23
Supplier 3	74,65
Supplier 4	75,58

Supplier 5	69,26
Supplier 6	69,81
Supplier 7	65,61
Supplier 8	66,36
Supplier 9	68,24
Supplier 10	71,09

Table 5 – Suppliers' evaluation.

With this model is possible observe performance of each supplier in each dimension. This kind of analyses allows suppliers identify the dimension that need be improved. This can improve suppliers development. This analyses is presented in Figure 8.

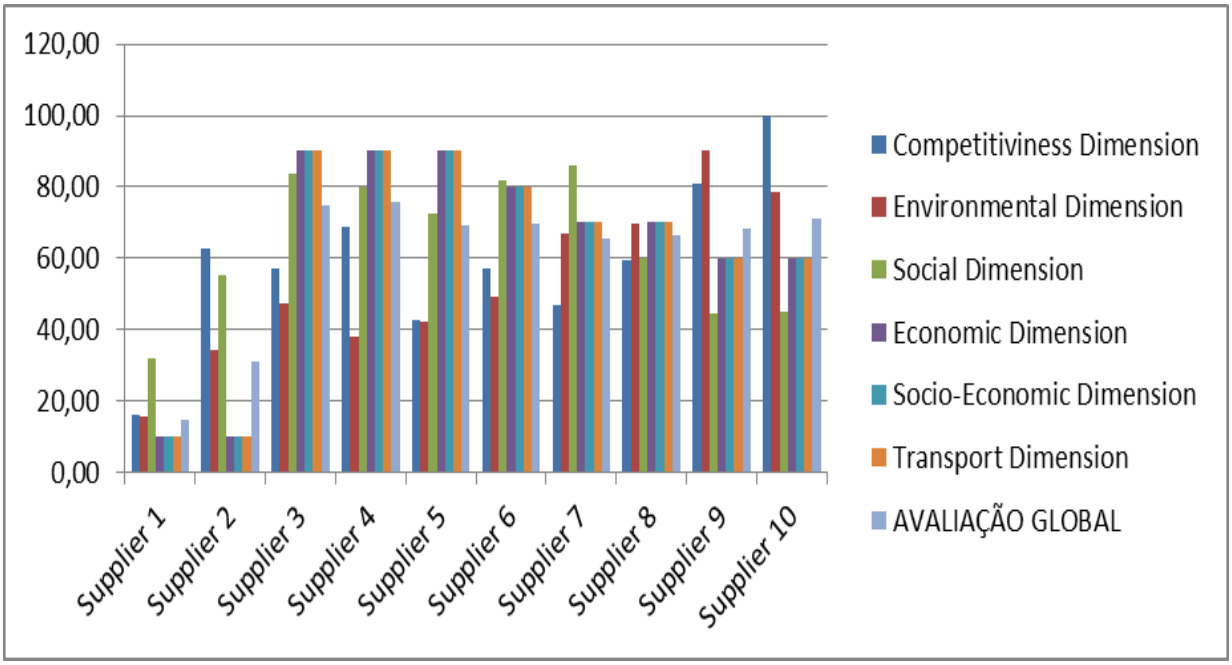

Figure 8 – Suppliers evaluation results.

6. Conclusions

This paper presented a model that evaluates biodiesel plants suppliers according to competitiveness and certification characteristic observed in international review. A big advantage of this model consists in the innovative proposal to choose suppliers observing their development in dimensions considered important to consumers' chain. The innovation consists in way of think supplier's selection, observing not only economics variables, but also sustainability and competitiveness characteristics.

Because of this innovation, SMARTER method was defined to obtain importance weights. The managers don't have a previous knowledge to evaluate the importance of each variable. So, using SMARTER, they could just compare variable without quantify the importance, being SMARTER responsible to give these weights.

On the other hand, is necessary applying this study in a real case to obtain results according to Biodiesel industry. Some other variables must be considered observing a specific enterprise. This model is a general one.

A limitation to Brazilian biodiesel industry consists in evaluate biodiesel international demand and prepare our country to produce and export this product. This model can be used to stimulate government actions to improve biodiesel chain development.

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