ANALYTIC HIERARCHY PROCESS APPLIED TO INDUSTRIAL LOCATION: A BRAZILIAN PERSPECTIVE ON JEANS MANUFACTURING

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ABSTRACT

The textile sector is one of the most important among all industrial branches. It is important in world commerce because it is a highlight both in the economy of developed countries and in emergent countries. The purpose of this study is to help a Brazilian textile company, which specializes in jeans production, to study the conditions for installing a plant in three possible regions where the most important textile companies of the country are located. In the study, the Analytic Hierarchy Process (AHP), a multicriteria methodology for decision support, is used and results show a slight tendency toward the Rio de Janeiro state when compared to the Santa Catarina state, with both presenting a significant advantage over the Rio Grande do Norte state.

Key words: Textile industry; industrial location; multicriteria decision; AHP

1. Introduction

The textile segment is one of the most traditional industrial branches, with significant relevance in the economy of both developed and emergent countries. These countries owe in large part the key role they play today in global manufacturing commerce to this sector.

The textile production chain, including spinning, weaving, knitting, finishing/processing and manufacturing, has gone through several recent transformations. Some of those are worth highlighting, especially those related to technological changes, which allowed for an expansive increase in productivity, and the growing importance of free trading groups, such as: NAFTA; European Union; North Africa and South Asia, as India and Pakistan; Southeast Asia and Far East; Mercosur and Latin America (Gorini, 2000).

The Brazilian textile industry first appeared at the end of the nineteenth century and made great advances with the increase of local consumption starting after World War I (Stein, 1979). It has become very important in the development of the national industrial policy. Currently, the sector includes large, small and micro companies, which can be characterized by their technological and managerial heterogeneity (Melo et al., 2007). On the other hand, it is noted that due to technological innovations in the textile industrial park, there has been a significant impact on the workforce profile, requiring a higher level of qualification, which is an important aspect of competitiveness (Melo et al., 2007).

After more than forty years of import quotas, the textile and clothing sector will become subject to the general rules of the General Agreement on Tariffs and Trade from 2005. Liberalization has been controversial because both textiles and clothing contribute to employment in developed countries, particularly in regions where alternative jobs may be difficult to find (NORDÅS, 2004).

The goal of this study is to help a Brazilian textile company, in the jeans segment, to evaluate the conditions for a plant installation using the Analytic Hierarchy Process (AHP). Three regions, where the most relevant textile companies in the country are concentrated, were considered in this analysis. There are several criteria that are fundamental in the analysis of possible locations to install a manufacturing plant, such as the availability of workforce and feedstock to be processed into final or intermediate products. The local infrastructure must also be studied in order to determine the possibility of economy of scale and demand availability to assure that the production reaches the determined end destination (Sousa, 2004). Finally, financing options should be evaluated to guarantee that the activities will be viable through a pre-determined timeline.

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A review of recent literature (after the year 2000) discovered some articles that apply the Analytic Hierarchy Process to the textile/apparel industry, which emphasizes the current importance and the applicability of this model (Table 1).

Table 1
Recent literature relating AHP to the textile industry

Title	Author(s)
Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard	Cebeci (2008).
Multicriteria decision making approach to evaluate optimum maintenance strategy in textile industry	Shyjith, Ilangkumaran & Kumanan, (2008).
Manufacturing performance criteria: an AHP application in a textile company	Kaya, Caliskan, FGozlu, (2007).
Determination of quality value of cotton fibre using hybrid AHP-TOPSIS method of multi-criteria decision-making	Majumdar, Sarkar & Majumdar (2005).
Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection	Ertuğrul, & Karakaşoğlu, (2008).
AHP approach in the credit evaluation of the manufacturing firms in Turkey	Yurdakul, & Tansel Ic (2004).
Supply chain management in the textile industry: a supplier selection model with the Analytical Hierarchy Process	Koprulu & Albayrakoglu (2007).
Study on the selection and evaluation system of the textile machine manufacturer's supply enterprises based on AHP theory	Zhi Yu-ping (2008).
The application of AHP approach to fabric selections	Liu Zhenzhen, Chen Chao (2008).
Optimization of production combination in a textile factory using AHPtechnique	Madhoushi & Amirfazli (2002).
Selection of maintenance policy for textile industry using hybrid multicriteria decision making approach	Ilangkumaran, & Kumanan, (2009).

2. Theoretical foundation

2.1 Textile industry in Brazil

According to the Brazilian Association of Textile and Clothing Industry, Brazil has one of the world’s largest industrial parks and is one of the top ten global markets in the segment (ABIT, 2014). It is the third main jersey manufacturer, one of the top five clothing producers (Table 2), the sixth largest textile and clothing industry of the world, and is listed among the top eight most relevant markets for threads, fibers and fabrics (ABIT, 2014).

Table 2
Textile industry ranking

Country	**Production (mil ton)**	**World %**
China	38,561	50.7
India	5,793	7.6
USA	4,021	5.3
Pakistan	2,820	3.7
Brazil	2,249	3.0
Indonesia	1,899	2.5
Taiwan	1,815	2.4
Turkey	1,447	1.9
South Korea	1,401	1.8
Thailand	902	1.2

Source: ABIT, 2014

The textile sector in Brazil includes more than 32,000 companies, 80% of which are small- and medium-sized manufacturers, all over the country. They employ around 1.7 million Brazilian workers, and 75% are manufacturing sector employees, mostly women (ABIT, 2014).

During the first period of the industrialization, manufacturing activity in Brazil was concentrated mainly in the Southeast region (Cury, 1999). Now this activity is broader, distributed in various regions of the country, following the world tendency for decentralization. These regions offer, besides fiscal incentives, lower labor costs, and better sources of workforce and feedstock (Saboia & Kubrusly, 2008).

The first region for the segment of clothing and other textile articles is located in the Northeast region (states of Pernambuco, Ceará, Bahia and Rio Grande do Norte). In this region, some of the main companies are Vicunha Têxtil S.A. and Coteminas S.A. (Leão, 1999). The second region is the South, which has significant relevance due to the geographic proximity of the main consumer's center and MERCOSUL countries (Argentina, Brazil, Paraguay and Uruguay). A highlight in this region is Itajaí Valley, an important textile sector located in state of Santa Catarina. Some of the main companies, among others, situated in this area are: Companhia Têxtil Karsten, Marisol S.A., Renaux Blue Label, Malwee (Cury, 1999). The third region is the Southeast (the states of São Paulo, Minas Gerais and Rio de Janeiro), where small, medium and large size companies are concentrated: Companhia Têxtil Ferreira Guimarães, Werner Fabrica de Tecidos S.A. and Companhia Industrial Cataguases (Saboia & Kubrusly, 2008).

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2.2 Cotton and denim (or jeans)

Cotton is a natural vegetal fiber, presented as a thin, 24 to 38mm long, thread. It can be produced in almost every continent considering the little requirements regarding soil and climate. The most relevant advantages of cotton, when compared to other artificial and synthetic fibers, include the comfort of the manufactured items, especially favorable to hot weather countries, and the ecological aspects since it is biodegradable (Oliveira, 1977).

Currently, this fiber is responsible for 70% of the textile world market, with 20 million tons of production per year. The highly distinctive countries in cotton production are: the US, Brazil, Argentina, Spain, China, Russia, India, Pakistan, Egypt and Australia. Cotton is native in Brazil and has continuously played a major role in the country's textile industry development, as a main input to the threads and cloths production (Kon & Coan, 2005). Presently, Brazil is the world's fifth cotton producer, and the largest production comes from the Midwest and Northeast regions (Aubert & Goldminc, 2001).

In the fashion industry cotton is the most important feedstock for the manufacture of denim, which is composed of crude or indigo stained warps interlaced with white woof threads, to create the fabric. The denim market reaches all kinds of social-economic layers as well as all age groups (Panucci-Filho & Garcias, 2010). Fighting with China and Turkey, year-by-year, for the first position in the world's denim production rank, Brazil produces 25 million meters a month (ABIT, 2014).

3. AHP – Analytic Hierarchy Process

The Analytic Hierarchy Process is a multicriteria methodology that aims to select or choose the best alternatives in a process that considers different evaluation criteria (Saaty, 1980). An advantage of the AHP method is that it allows for the comparison of both quantitative and qualitative criteria. It is considered one of the most well-known and widely disseminated decision making tools, having the greatest number of applications reported in the literature (Vaidya & Kumar, 2006).

The method is based on constructing hierarchies and making pairwise judgments. The key elements of a decision problem hierarchy are: the main focus – general purpose, a viable alternatives group – definition of which options will be analyzed in the light of the determined criteria, criteria and sub criteria –attributes or items that will be evaluated in pairs, hierarchy building – after defining the problem, the hierarchy that will represent the problem structure is built (Garuti & Sandoval, 2006).

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When making criteria and alternative judgments, the expert compares pairwise the elements in the level of the hierarchy to each of the elements in the superior level of the hierarchy (Saaty, 2008). If the problem has sub-criteria, those should be submitted to the same evaluation/comparison process. Finally, the importance of the criteria is compared to the main focus. There are several criteria (and sub-criteria) judgment scales and alternatives that have been proposed and used in the literature. In this article, the scale proposed by Saaty (1980) was used. So, in the AHP, the prioritization is done in the following steps: gather the expert's judgments, normalize the judgments to obtain the local weights (or the priorities), and calculate the global weights by weighting them by the weight of their respective elements in the level above.

Several alternatives to conjugate information provided by the experts have been proposed and many of them lead to values that are nearly consistent (Forman & Peniwati, 1998; Escobar et al., 2004; Saaty & Peniwati, 2007; Escobar & Moreno-Jiménez, 2007; Freitas *et al*., 2008; Innes, 2008). In this article, the authors decided to use the Geometric Means to aggregate the individual judgments (Forman & Peniwati, 1998; Escobar & Moreno-Jiménez, 2007).

Even when judgments are obtained from experts, some inconsistency may occur (Serra Costa, 2011). In the case of AHP, according to Saaty (1980), one way of measuring the intensity or degree of inconsistency in a matrix of pairwise judgment is to evaluate how the highest eigenvalue of this matrix deviates from the order of the matrix. So, the Consistency Index (C.I.) can be calculated as shown in Equation 1.

$$C.I. = \frac{|\lambda_{\max} - n|}{n-1} \qquad (1)$$

According to Saaty (1980), the gravity of the inconsistency occurrence can be evaluated by considering its ratio to the average Consistency Index obtained from a large number of matrices of the same order generated by entering random judgments. This is the Consistency Ratio (C.R.), and it is used as a parameter to evaluate the inconsistency obtained from the judgment matrix order (Equation 2).

$$\text{C.R.} = \text{C.I./R.I.} \qquad (2)$$

Where: C.I. = consistency index defined in Equation (1); R.I. = consistency index obtained from a large number of randomly generated reciprocal matrices with non-negative elements. (Brunelli & Fedrizzi, 2011).

According to Vargas (1982), if the calculated C.R. is lower than 0.1, the judgment matrix is considered consistent.

4. Data analysis and results

When selecting the criteria that substantiate the decision model, the research is based on the description of economic conditions that shows how each criterion is subdivided, and that in this subdivision there are other groups, which will be only taken into consideration to guide the expert's judgment. To create the structure, the opinion of the experts was taken into account. The experts are individuals (or a group of individuals) responsible for the performance analysis of the elements of each layer or level of the hierarchy in relation to those to which they are connected in the superior level. The effectiveness of the results is associated with the competency of the experts in providing value judgments, so these experts must acknowledge and even master the topic about which they are making judgments (Malhotra et al., 2007).

Ten experts were selected, including university professors of textile engineering, and industrial and textile manufacturing managers with at least 10 years of industry experience. After some consideration, the model was established by consensus:

- Financial - FI: labor cost (cost per work hours, journey and unions), energy (natural light, acclimatization costs and energy system stability), feedstock (distance from suppliers and transportation), taxes (tax exemption), building (land costs and construction materials cost);
- Infrastructure - IS: consumption market (distance and size), local taxes (land usage taxes and licenses), climate (temperature, humidity, natural light), workforce access (transportation) and products access (transportation);
- Human Resources - HR: technical schools (existence of schools, distance, access to schools), regional culture (holidays and religion), population age group (sex and job stability), indirect benefits (feeding support, health insurance and production bonus) and local consumption philosophy (demand, income, fashion influence).

As mentioned in section 2, the three regions most favorable and already prepared for the textile industry in Brazil are: Northeast, South and Southeast (Saboia & Kubrusly, 2008; Leão, 1999). From these regions, three candidate states were selected: Rio de Janeiro (RJ), Santa Catarina (SC) and Rio Grande do Norte (RN). Figure 1 depicts the decision problem structure.

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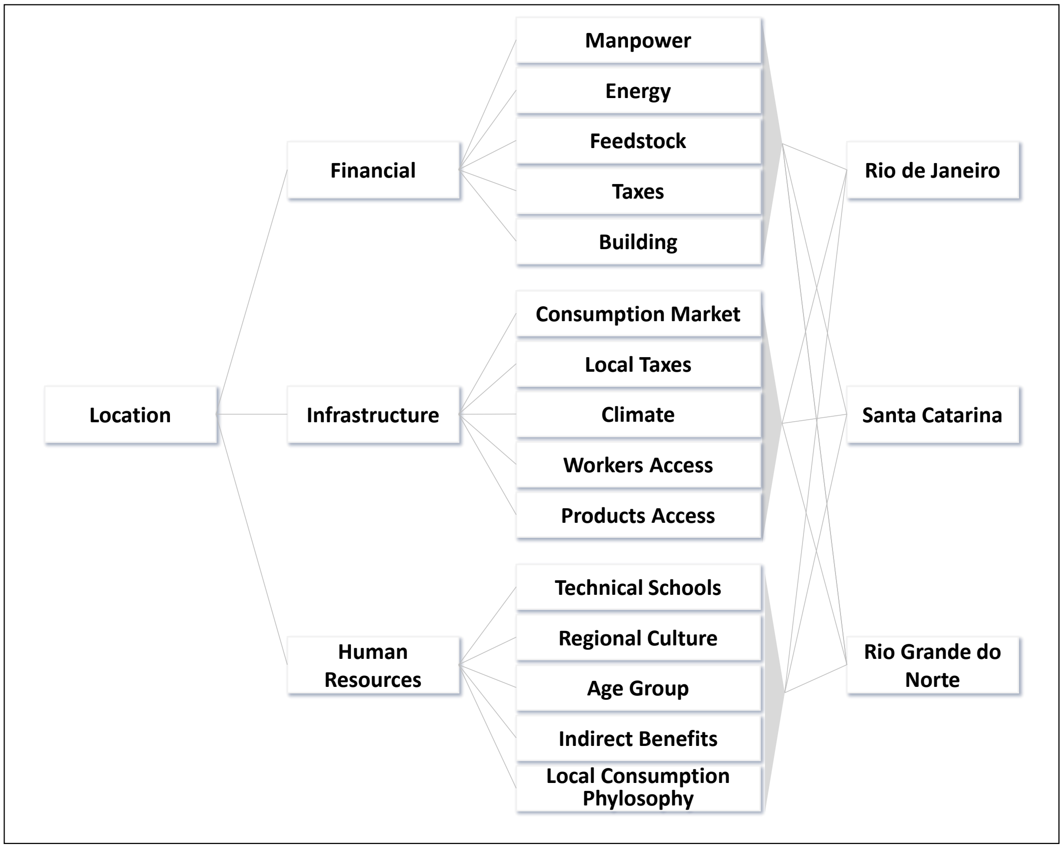

Figure 1. Structure of decision problem

Data was gathered for the model using questionnaires sent by e-mail to the experts selected to participate in the research. When experts could not access the questionnaire, an interview was arranged to collect the information. All the experts confirmed they are deeply involved in or have specific knowledge of textile manufacture, either applied or academic.

4.1 Analysis of the sub-criteria in the light of the criteria

The information gathered from the experts was processed according to the methodology. The local weight of each sub-criteria, in the light of the superior criteria, was determined, as shown in Table 3.

Table 3
Local weights of the sub-criteria in the light of the criteria

Criteria	**Local Weight**	**Sub-criteria**
Financial	0.210	Manpower
	0.180	Energy
	0.296	Feedstock
	0.246	Taxes
	0.068	Building
Infrastructure	0.374	Consumption
	0.190	Local taxes
	0.097	Climate
	0.137	Workforce access
	0.202	Products access
Human Resources	0.358	Technical schools
	0.154	Regional culture
	0.094	Age group
	0.227	Indirect benefits
	0.167	Philosophy

The Consistency Ratio of each matrix of sub-criteria confirmed that the judgments were consistent for the three criteria (Financial = 0.0274, Infrastructure = 0.0077 and Human Resources = 0.0134).

4.2 Analysis of the alternatives in the light of the sub-criteria

Next, the local weights of the alternatives in light of the sub-criteria were calculated, as depicted in Table 4, which also shows the Consistency Ratios (C.R.) of the sub-criteria. The sum of the priorities for the alternatives for each sub-criterion is 1, computed by adding across the rows. By examining the rows it is easy to determine which alternative is best for each of the sub-criteria.

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Table 4
Local weights of the alternatives in the light of the criteria and consistency reasons

Criteria	Sub-criteria	Alternatives			CR
		RJ	SC	RN	
Financial	Manpower	0.186	0.227	0.587	0.0216
	Energy	0.362	0.342	0.296	0.0415
	Feedstock	0.413	0.426	0.161	0.0454
	Taxes	0.17	0.215	0.615	0.0044
	Building	0.187	0.195	0.618	0.0005
Infrastructure	Consumption	0.618	0.277	0.105	0.0659
	Local taxes	0.157	0.233	0.61	0.0378
	Climate	0.316	0.43	0.254	0.0179
	Workforce access	0.306	0.437	0.257	0.0149
	Products access	0.415	0.466	0.119	0.0059
Human Resources	Technical schools	0.53	0.377	0.093	0.0027
	Regional culture	0.237	0.567	0.196	0.0539
	Age group	0.402	0.471	0.127	0.004
	Indirect benefits	0.36	0.36	0.28	0.0625
	Philosophy	0.615	0.273	0.112	0.0314

4.3 Analysis of the alternatives in the light of the sub-criteria

The local weights of the criteria in the light of the main focus were placed in Table 5.

Table 5
Local weights in light of the main focus

Criteria	Local Weight
Financial	0.455
Infrastructure	0.261
Human Resources	0.284

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The Consistency Ratio of the matrix referring to the pairwise comparisons of the main criteria with respect to the main focus is equal to 0.0189. Therefore, the judgments are consistent.

4.4 Global weights

Using the hierarchy previously presented in Figure 1, it is possible to determine the global weights (Table 6). As presented, in order to calculate the global weights (GW), it is necessary to combine the local weights related to the alternatives, criteria and sub-criteria. The elements of the global weights give the performances (priorities) of the alternatives in light of the main focus.

Table 6
Global weights of the alternatives

Alternatives	**Global Weights**
Rio de Janeiro	0.364
Santa Catarina	0.339
Rio Grande do Norte	0.297

5. Conclusions

Questions related to industrial location are generally strongly connected to several characteristics that need to be analyzed. Most of the time, these characteristics are in conflict and difficult to quantify. In the situation analyzed here, fifteen sub-criteria and three criteria were used to characterize the necessary attributes to be considered when installing a textile plant for the denim / jeans segment in Brazil.

The results of the global weights demonstrated a slight tendency for the state of Rio de Janeiro (0.364) with little advantage over the state of Santa Catarina (0.339), and both with significant advantage when compared to Rio Grande do Norte (0.297). The reasons for this could be attributed to the local weights determined by the experts for Rio de Janeiro and Santa Catarina in the Financial criterion (sub-criterion Feedstock) – which had the highest local weights among all the criteria of 0.455, and the Infrastructure criterion (sub-criterion Consumption Market) and the Human Resources criterion (sub-criterion Technical Schools).

Overall, as expected, global weight values for the alternatives were not disparate when compared to each other, especially when considering that these states represent the main productive poles in this segment, all of them situated in the most relevant economic regions in the sector in Brazil.

The AHP method proved to be very effective, efficient, and simple to apply according to the experts who participated. Their opinion is reinforced by the values calculated during the judgments consistency analysis, which were considerably lower than the acceptable limits.

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REFERENCES

ABIT - Associação Brasileira da Indústria Têxtil e de Confecção. Relatório de atividades 2013. Available at: < http://www.abit.org.br/Publicacao.aspx >. Accessed: March 2014.

Aubert, C., Goldminc, M. (2001). *Vétement: la fibre écologique*. [s.l.]: Terre Vivante.

Brunelli, M., Fedrizzi, M. (2011). Characterizing properties for inconsistency indices in the AHP, *Proceedings of The International Symposium on the Analytic Hierarchy Process*, Sorrento, Italy.

Cebeci, U. (2008). Fuzzy AHP-based decision support system for selecting ERP systems in textile industry by using balanced scorecard. *Expert Systems with Applications, 36(5),* 8900–8909. doi:10.1016/j.eswa.2008.11.046

Cury, V.M. (1999). Algodão e proteção: Indústria textil no Brasil, 1890 – 1930. *História Revista, 4 (1/2),* 79-97.

Escobar, M.T., Aguarón, J., Moreno-Jiménez, J.M. (2004). A note on AHP group consistency for the row geometric mean prioritization procedure. *European Journal of Operational Research*, *153(2),* 318 -322.doi:10.1016/S0377-2217(03)00154-1

Escobar, M.T., Moreno-Jiménez, J.M. (2007). Aggregation of individual preference structures in AHP-group decision making. *Group Decision and Negotiation*, *16(4),* 287-301. doi: 10.1007/s10726-006-9050-x

Ertuğrul,I. Karakaşoğlu, N. (2008). Comparison of fuzzy AHP and fuzzy TOPSIS methods for facility location selection. *The International Journal of Advanced Manufacturing Technology*, *39(7-8),* 783-795. doi:10.1007/s00170-007-1249-8

Forman, E., Peniwati, K. (1998). Aggregating individual judgments and priorities with the Analytic Hierarchy Process. *European Journal of Operational Research*, 108(1), 165-169. doi:10.1016/S0377-2217(97)00244-0

Freitas, A.L.P., Trevizano, W. A., Costa, H.G. (2008). Uma abordagem multicritério para problemas decisórios com múltiplos grupos de avaliadores. *Investigação Operacional*, *28*, 133-149.

Garuti, C., Sandoval, M. (2006). The AHP: A multicriteria decision making methodology for shiftwork prioritizing. *Journal of Systems Science and Systems Engineering*, 15(2), 189-200. doi:10.1007/s11518-006-5007-5

Gorini, A.P.F. (2000). Panorama do setor têxtil no Brasil e no mundo: reestruturação e perspectivas. *BNDES Setorial, Rio de Janeiro*, *12*, 17-50.

Innes, J. (2008). Managing impact reduction in fisheries: A multi-criteria assessment of objective priorities. *Proceeding of the 37th Australian Conference of Economist (ACE08),* Queensland, Australia.

ISSN 1936-6744
http://dx.doi.org/10.13033/ijahp.v8i1.210

Kaya, E., Caliskan, F.D., Gozlu, S. (2007). Manufacturing performance criteria: An AHP application in a textile company. *Management of Engineering and Technology*, 1186 – 1194. doi: 10.1109/PICMET.2007.4349442

Kon, A., Coan, D.C. (2005). Transformações da indústria têxtil Brasileira: A transição para a modernização. *Revista de Economia Mackenzie*, São Paulo, 3(3), 11-34.

Koprulu, A., Albayrakoglu, M.M. (2007). Supply chain management in the textile industry: a supplier selection model with the Analytical Hierarchy Process. *Proceeding of the International Symposium on the Analytic Hierarchy Process*. Viña Del Mar, Chile.

Leão, M. D. (1999). Desenvolvimento tecnológico para controle ambiental na indústria têxtil: Malhas no estado de minas gerais. *Relatório final*. Belo Horizonte, 255.

Majumdar, A., Sarkar, B., Majumdar, P. K. (2005). Determination of quality value of cotton fibre using hybrid AHP-TOPSIS method of multi-criteria decision-making. *Journal of the Textile Institute,* 96(5), 303-309. doi:10.1533/joti.2005.0013

Malhotra, V. A., Lee M. D., Khurana, (2007). A domain experts influence decision quality: Towards a robust method for their identification. *Journal of Petroleum Science and Engineering, 57*, 181-194. doi:10.1016/j.petrol.2005.09.007

Melo, M.O.B.C., Cavalcanti, G.A., Gonçalves, H.S., Duarte, S.T.V.G. (2007). Inovações tecnológicas na cadeia produtiva têxtil: Análise e estudo de caso em indústria no Nordeste do Brasil. *Revista Produção On Line*, 7(2), 99-117. Available in: <http://www.producaoonline.org.br/index.php/rpo/article/view/75>. Accessed: April 2014.

Nordås, H.K. (2004). The global textile and clothing industry post the agreement on textiles and clothing. *World, 7,* 1-000.

Oliveira, M.H. (1977). Principais matérias-primas utilizadas na indústria têxtil. *BNDES Setorial*, Rio de Janeiro, Brasil.

Panucci-Filho, L., Garcias, P.M. Visão Geral das Alianças no Crescimento das Organizações: Uma Análise sob a Ótica das Indústrias de Confecções de Jeans. (2010). *Revista ADMpg Gestão Estratégica*, PR, 3(1), Available at: <http://www.admpg.com.br/revista2010/artigos/Resumo%20AREA%207%20ARTIGO%207.pdf>. Accessed: March 2013.

Saaty, T.L. (1980). *The Analytic Hierarchy Process*, New York: McGraw Hill. doi: 10.1080/00137918308956077

Saaty, T. L. (2008). Relative measurement and its generalization in decision making, Why pairwise comparisons are central in mathematics for the measurement of intangible factors, the Analytic Hierarchy/Network Process, *RACSAM - Review of the Royal Spanish Academy of Sciences, Series A, Mathematics*, 102 (2), 251-318. doi: 10.1007/BF03191825

Saaty, T. L., Peniwati, K. (2007). *Group decision making: Drawing out and reconciling differences*. Pittsburgh: RWS Publications.

Saboia, J.; Kubrusly, L. (2008). Diferenciais regionais e setoriais na indústria Brasileira. *Revista de Economia Aplicada*, 12(1), 125-149. doi: 10.1590/S1413-80502008000100006

Serra Costa, J.F. (2011). A genetic algorithm to obtain consistency in Analytic Hierarchy Process. *Brazilian Jounal of Operations & Production Management*, 8(1), 55-64. doi: 10.4322/bjopm.2011.003

Shyjith, K., Ilangkumaran, M., Kumanan, S. (2008) Multicriteria decision making approach to evaluate optimum maintenance strategy in textile industry, *Journal of Quality in Maintenance Engineering*, 14 (4), 375 – 386. doi: 10.1108/13552510810909975

Sousa, L. G. (2004). Memórias de economia: A realidade Brasileira. [s.l.]: *Eumed.net*. 226. Available at: <http://www.eumed.net/cursecon/libreria/2004/lgs-mem/index.htm>. Access in: April 2011.

Stein, S. (1979). *Origens e evolução da indústria textil no Brasil – 1850/1950*. Editora Campus, Rio de Janeiro, Brasil.

Vaidya, O. S., Kumar, S. (2006). Analytic Hierarchy Process: An overview of applications. *European Journal of Operational Research*, 169 (1), 1-29. doi:10.1016/j.ejor.2004.04.028

Vargas, L.G. (1982). Reciprocal matrices with random coefficients. *Mathematical Modelling, 3,* 69-81. doi:10.1016/0270-0255(82)90013-6

Yurdakul, M., Tansel Ic, Y. (2004). AHP approach in the credit evaluation of the manufacturing firms in Turkey. *International Journal of Production Economics*, 88(3), 269–289. doi:10.1016/S0925-5273(03)00189-0