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AHP method for supplier selection: application in reverse port logistics

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Abstract: **Contextualization**: With the increase in the use of production resources in great seaports, the importance of reverse logistics in the production system becomes evident. **Research Problem**: However, lack of knowledge, procedural capacity or non-accomplishment for strategic reasons sets precedents for selecting and hiring the most appropriate third-party companies. **Justification**: The article allows institutions, even if not by their own means, to find a way to be more sustainable. **Objectives**: With this, it was sought to use a supplier selection tool to effectively perform the disposal and reuse of materials. **Methodology**: Through a case study, the Analytic Hierarchy Process method was applied, where the criteria for choosing suppliers were selected and compared in pairs. **Results**: the study ranked in order of importance those most significant for the institution, presenting statistical relevance (consistency ratio 0.06). **Conclusion**: with the use of the techniques, it opened up so that other ports and organizations can better choose their suppliers, thus contributing to the reduction of exposure of contaminants, especially in Brazil, the stage of diseases such as dengue, malaria and yellow fever, caused by partially due to the incorrect disposal of products.

Keywords: Analytic Hierarchy Process; Green; Logistic; Performance Evaluation; Sustainability.

Método AHP para Seleção de Fornecedores: Aplicação na Logística Reversa Portuária

Resumo: Contextualização: Com o aumento da utilização dos recursos produtivos nos grandes portos marítimos, fica evidente a importância da logística reversa no sistema produtivo. **Problema de pesquisa**: No entanto, a falta de conhecimento, capacidade processual ou não cumprimento por motivos estratégicos abre precedentes para a seleção e contratação das empresas terceirizadas mais adequadas. **Justificativa**: O artigo permite que as instituições, ainda que não pelos seus próprios meios, encontrem uma forma de ser mais sustentável. **Objetivos**: Com isso, buscou-se utilizar uma ferramenta de seleção de fornecedores para realizar com eficácia o descarte e o reaproveitamento de materiais. **Metodologia**: Por meio de um estudo de caso, foi aplicado o método Analytic Hierarchy Process, onde foram selecionados os critérios de escolha dos fornecedores e

comparados em pares. **Resultados**: o estudo classificou por ordem de importância os mais significativos para a instituição, apresentando relevância estatística (razão de consistência 0,06). **Conclusão**: com o uso das técnicas, abriu-se para que outros portos e organizações possam escolher melhor seus fornecedores, contribuindo assim para a redução da exposição de contaminantes, principalmente no Brasil, ao estágio de doenças como dengue, malária e febre amarela, causado parcialmente devido ao descarte incorreto de produtos.

Palavras-chave: Análise Hierárquica de Processos; Verde; Logística; Avaliação de Desempenho; Sustentabilidade.

1. INTRODUCTION

1.1 Contextualization

With the increase in world production capacity and the consequent increase in the use of production resources, there has also been a growing awareness about the environment and sustainability, where institutions through products their processes can no longer afford to neglect them (LUTHRA; GOVINDAN; KANNAN; MANGLA; GARG, 2017).

Thus, reverse logistics takes a relevant position in the modern scenario, allowing the return of materials, sustainable development and ecological responsibility. Companies image improvement, in turn, generates appreciation of its assets and reuse brings cost savings.

1.2 Research Problem

Although it is a trend and reverse logistics is already an integral part of the logistics system of great seaports, the big challenge lies in those where there is no knowledge or sufficient capacity to develop such a process. In addition, the company may also choose not to do so as it is not part of its strategy, making use of third parties to fill this demand.

1.3 Justification

The relevance of the work is not only because of the possibility of providing feedback to the logistics of harbours that do not have the competence today to do it alone, but by introducing an easily applied large-scale tool that disposes of a product consumed worldwide that It has a long deterioration time, generates soil contamination and sun exposure eliminates waste and gases that contaminate the ecosystem and the atmosphere. In the special case of Brazil, it has been shown to be the focus of several diseases such as malaria, dengue and yellow fever, due to its incorrect disposal.

1.4 Objectives

The purpose of this paper is to use a practical and easily accessible tool to select suppliers capable of effectively pursuing the reuse or disposal phase of the seaport. Given the importance and difficulty of selecting suitable suppliers, it is intended to apply by a case stuy the Analytic Hierarchy Process (AHP) model to select suppliers that will manage the reverse logistics of a after their consumption.

More specifically, it is expected to define which are the main criteria to choose the suppliers of inputs and to hierarchize them. In this way, it is hoped to contribute to the scientific community with more efficient processes, eradicating or mitigating wastes.

2. THEORETICAL FOUNDATION

2.1 Suppliers Evaluation

The acquisition function, according to Gonçalves (2004), is to plan, execute and monitor bidding processes; analyze proposals and the contracting of suppliers of materials and services requested by the contracting company in the quantity, specification and time determined.

Resende, Mendonça and Araújo (2005) emphasize that the purchasing function has become of strategic relevance, guaranteeing an important role in the success of the corporation. This activity began to connect to the business areas, fostering new opportunities and requiring new suppliers such as: technology transfer, partnerships and leaner production (PEREIRA; TONTINI; SILVEIRA, 2004).

Within the concept of partnerships, SEBRAE (2010) states that the best tactic is not to smother or exploit the suppliers, because in the long term it deteriorates the relationship and the guarantee of supply. In addition, collaboration will enable strategic alignment between the parties.

However, the need to associate with not only one, but several suppliers according to the complexity of the company is already a reality. The choice of quantity is linked to the purchasing strategy, ranging from single sourcing to multiple sourcing. In addition, one can work only with those directly connected (first level) or build a network (second level, third level and so on), where providers provide for providers. Finally, there is also the possibility of acquiring outside the national territory: this is the case of global sourcing (SLACK; CHAMBERS; JOHNSTON, 1999).

Martins (2005) points out that the selection of suppliers has gained new coverage when it comes to the acquisition of resources at a global level. In this broader scenario, there is a great possibility of changing the relation between the cost of acquisitions and the revenue generated by the company. A considerable transfer of technology was experienced, the product lifecycle was reduced and competitiveness was increased.

The lack of connection between supplier selection and the company's strategic objectives results in additional future costs (AMARAL and DEMARI, 2006). These include management of change, behavioral and system training, rework, new equipment, increased risk, new contractual costs and possible loss of customers (FURTADO, 2005).

The right choice of providers outsources risk in the generation of certain resources and ensures partnerships that can ensure breakthroughs in greater steps. For this, it is fundamental to define the criteria used for the selection (MOTWANI et al., 1999).

These are the ones that will be used as a source of comparison among peers and, although they may vary according to each productive process of the applicant company, a pattern must be sought that supports mainly or at least a large part of their needs (LIU, DING and LALL, 2000).

Martins (2005) says that there was an evolution of the parameters for choosing suppliers. Moving from the more pragmatic ones (such as price, quality and time) to the most comprehensive ones: such as the total acquisition cost (direct and indirect) and requirements that go beyond the required minimums, such as the level of service provided, reliability, compliance flexibility.

Faria and Vanelle (2006) complement with factors such as respect for laws and environment, geolocation, level of management and capacity to produce technology. Furtado (2005) also appoints after-sales services, guarantees, supplier restrictions and intangible variables. Kliem and Ludin (2000) report that during this phase, managers must ensure the contemplation of three aspects: definition of specific criteria, maintenance of their objectivity and consent of the team to those chosen.

2.2 Analytic Hierarchy Process

The AHP method, called the Analytic Hierarchy Process, or its translation Hierarchical Process Analysis, is a decision support technique that compares different choices two by two according to predefined criteria in order to obtain a prioritization order (ABREU; CAMPOS, 2007).

It was created in the 1970s by Professor Thomas Lorie Saaty of the University of Pennsylvania in order to reduce the level of complexity in the decision-making process (SAATY, 1980; SAATY,

1990). One of the advantages of this method is to make decisions through a mathematical model, even in the face of subjectivity and the lack of accuracy of the decision-making human being (IAÑES; CUNHA, 2006).

Costa (2002) cites as elements of decision theory the:

a) Decision-maker: person or group incubated to take a decision;
b) Viable alternative: possible action taken by the decision maker;
c) Scenario: hypothesis of how something will behave in the future;
d) Criteria: property on which the alternative will be analyzed;
e) Attribute: performance or result of the alternative against the stipulated criteria and
f) Payroll: set of results (or attributes) for each alternative.

After defining its basic items, the author presents the steps of the AHP model:

a) Creation of a hierarchy structure with criteria and alternatives;
b) Collection of data or expert opinions;
c) Through the opinions of the experts and in the light of the main objective, a prioritization of the alternatives and
d) Verification of the consistency of the method regarding the classification of alternatives.

According to Saaty (1990), the alternatives are selected through human judgment (Table1):

Table 1 – Saaty's scale

Pounds	**Description**
1- Equal importance	Two activities contribute equally to the objective
3- Weak importance of one over another	Experience and judgement slightly favor one activity over another
5- Essential of strong importance	Experience and judgement strongly favor one activity over another
7- Demonstrated importance	An activity is strongly favored and its dominance demonstrated in practice
9- Absolute importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,3,4,8 – Intermediate values	When compromise is needed

Source: adapted from Saaty (1990)

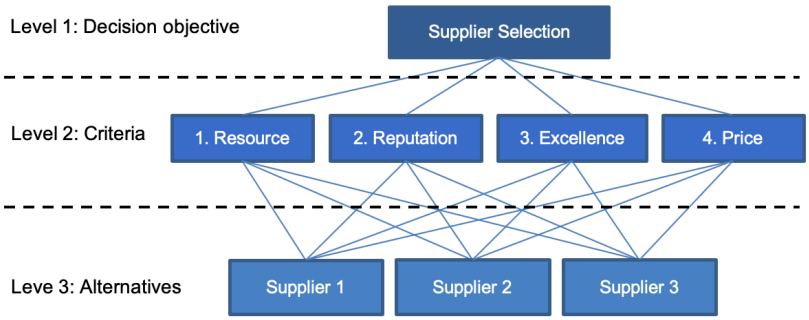
3. SEAPORT SUPPLIERS SELECTION

3.1 Selection Criteria

The seaport study environment highlighted the increased complexity that reverse logistics has been acquiring over time and its importance in the production and after-sales process. Thus, those who do not have the knowledge or ability to perform it neglect or resort to suppliers of this service.

In order to select what would be the selection criteria of these providers to later compare them (LUTHRA; KUMAR; GARG; HALEEM, 2015; RAJESH; RAVI, 2015), the direction of the contracting company, aligned with its strategic planning, defined as the main four themes: resources (interpreted as financial, technological and logistical resources), reputation (which would be a good track record, risk and benefit sharing and experience in the area), excellence (equivalent to its competence, quality and customer satisfaction) and price, as shown in Fig. 1.

Fig. 1 Problem Hierarchical Structure



Based on Fig. 1, it is possible to observe that the supplier selection process comes from a decision process that uses four distinct criteria.

3.2 AHP Application method

A multiple criteria decision-making (MCDM) is a part of the field of operational research that, since 1960, has been using mathematical and computational tools to assist decision makers (MARDANI; JUSOH; NOR; KHALIFAH; ZAKWAN; VALIPOUR, 2015).

Selecting suppliers, in turn, is a strategic decision in the company's supply chain management, being one of the critical success factors involving high decision complexity (DWEIRI; KUMAR; KHAN; JAIN, 2016).

Thus, within the MCDM methods, the Analytical Hierarchy Process (AHP) is the main model, given its higher frequency of applications (MARDANI et al., 2015).

The AHP methodology devised by Saaty is fundamentally based on the construction of three steps (SAATY, 1980):

1) Creation of the hierarchical structure of the problem, as shown in Fig. 1;

2) Elaboration of a criteria comparison matrix in pairs and

3) Calculation of the consistency of values derived from the decision-making process.

Thus, given that step 1 was performed in the previous section, then step 2 will be done comparing the criteria in pairs according to the Saaty scale present in Table 2 and obtaining as a result Table 3 (the sum of each column was also calculated).

Table 2 Saaty Fundamental Scale

Scale	**Definition**	**Comment**	**Reciprocal**
1	Equal importance	The two activities contribute equally to the goal	1
3	Moderate importance	Experience and judgement slightly favor one activity over another	1/3
5	Strong importance	Experience and judgement strongly favor one activity over another	1/5
7	Very strong importance	One activity is strongly favored over another; element is very dominant as shown in practice	1/7
9	Extreme importance	The evidence is in favor of one activity over another, to the greatest extent possible	1/9
2,4,6 e 8	Intermediate values	Used to express preferences that are between the scale values	1/2,1/4,1/6 e 1/8

Table 3 Paired Criteria Comparison Matrix

Criteria x Criteria	C1. Resource	C2. Reputation	C3. Excellence	C4. Price
C1. Resource	1	1/4 = 0.25	1/4 = 0.25	1
C2. Reputation	4	1	3	3
C3. Excellence	4	1/3 = 0.33	1	3
C4. Price	1	1/3 = 0.33	1/3 = 0.33	1
Sum	10	1.92	4.58	8

Finally, each element of the matrix is divided by the sum of its respective column and the weight of the criteria will be the arithmetic mean of each row. The outcome is expressed in Table 4.

Table 4 Normalized Pair Criteria Comparison Matrix

Criteria x Criteria	C1. Resource	C2. Reputation	C3. Excellence	C4. Price	Criteria weight
C1. Resource	1/10= 0.1	0.25/1.92= 0.13	0.25/4.58= 0.05	1/8= 0.13	0.1025
C2. Reputation	4/10= 0.4	1/1.92=0.52	3/4.58= 0.65	3/8= 0.38	0.4878
C3. Excellence	4/10= 0.4	0.33/1.92= 0.17	1/4.58= 0.22	3/8= 0.38	0.2918
C4. Price	1/10= 0.1	0.33/1.92= 0.17	0.33/4.58= 0.07	1/8= 0.13	0.1179

4. RESULTS

After using the AHP method, the following order of criteria and their appropriate weights for supplier selection were reached (Table 5):

Table 5 – Supplier Criteria Selection Order

Criteria	**Global score**	**Hierarchy**
Reputation	0,4878	1
Excellence	0,2919	2
Price	0,1179	3
Resource	0,1025	4
Sum	1,0000	

Following the method's recommendation, as stated in step 3, it is important to interpret the decisions made by the board when comparing and evaluating the criteria in pairs. This is possible through a consistency analysis that multiplies each element of the non-normalized matrix (Table 3) by the weight of the criteria of its respective column.

Then the lines are summed according to the “sum” column and the “sum” column is divided by each value of the “criteria weight” line respectively. Your result is seen in the “sum / weight of criteria” column (Table 6).

Table 6 – Result Validation

Criteria weight	0,10	0,49	0,29	0,12		
Criteria x Criteria	C1. Resource	C2. Reputation	C3. Excellence	C4. Price	Sum	Sum/Criteria weight
C1. Resource	0.10	0.12	0.07	0.12	0.42	0.42/0.10 = 4.05
C2. Reputation	0.41	0.49	0.88	0.35	2.13	2.13/0.49=4.36
C3. Excellence	0.41	0.16	0.29	0.35	1.22	1.22/0.29=4.17
C4. Price	0.10	0.16	0.10	0.12	0.48	0.48/0.12=4.07

$$\lambda max: \frac{4.05+ 4.36+ 4.17+ 4.07}{4} = 4.16$$

$$\text{Consistency Index (C.I):} \frac{\lambda máx - n}{n-1} = 0.05$$

$$\text{Consistency Ratio (C.R.):} \frac{C.I.}{R.I.} = \frac{0.05}{0.9} = 0.06$$

The maximum λ value is calculated as the arithmetic mean of the "sum / criteria weight" column and is 4.16. The Consistency Index (C.I.) is calculated as the diminished λ max of n (number of criteria) and shortly thereafter, divided by "n-1". The result of the C.I. is then 0.05.

Finally, the Consistency Ratio (C.R.) is the division of the C.I. by the Random Index (R.I.), which for 4 criteria (n = 4) has a value of 0.9. Thus, C.R. is worth 0.06 (must be less than 0.10 for consistent matrices).

5. CONCLUSION

This article aims to help companies that do not have their own reverse logistics system, especially for the reuse and disposal of tires, making use of a third-party company.

Due to the difficulty in selecting the most appropriate one for the function, the AHP method was applied and with this, the case study was delimited through a hierarchical structure typical of the method in question. Thus, the supplier selection criteria were crossed in pairs and the board of a relevant national tire manufacturer was part of this decision-making process.

In the light of the results, it can be seen that, in the face of future supplier hiring, the most relevant criterion for the studied company would be the reputation of the contractor (weight of 48.78%), followed by its excellence (29.18%), price in third (11.79%) and resource in forth (10.25%).

The consistency of the results was measured by calculating the consistency ratio (R.I.) of value 0.06. This proved its relevance as it was below the 0.10 limit.

Finally, it can be verified that an interested company, using the method according to its own criteria listed and, aligned with its strategic planning, could make a better choice of its suppliers. These in turn, being more adherent to the company's proposal and performing a reverse logistics more efficiently, would eventually respond to the problem of companies that do not have their own disposal and reuse system, helping competitiveness and improvement in the sector and above all, ensuring an improvement in the conservation of the environment.

Also, with the study that, suppliers more cohesive with the institution and its strategy, should stand out according to the hierarchy obtained. As a suggestion, to select input providers, a weighted individual note can be generated, based on the weights given by each criteria.

Finally, the present work proved to be relevant by providing an easy-to-use tool to select suppliers, as well as other possible criteria that are significant for the research and development area, in order to provide inputs consistent with its processes.

REFERENCES

ABREU, A. O; CAMPOS, R. **O método AHP/ABC aplicado em uma indústria de serviços**. In: XXVII Encontro Nacional de Engenharia de Produção. Foz do Iguaçu, 2007.

AMARAL, D.S. do; DEMARI, E. C. **Classificação e avaliação do desempenho dos fornecedores dos itens A da curva ABC do programa de medicamentos excepcionais pelo método de análise de gastos do ICHC – FMUSP**. Monografia. Especialização em Farmácia hospitalar da Universidade de Brasília – UnB, 2006.

COSTA, H. G. **Introdução ao método de análise hierárquica: análise multicritério no auxílio à decisão**. XXXVI Simpósio Brasileiro de Pesquisa Operacional: São João Del Rei, 2002.

DWEIRI, F.; KUMAR, S.; KHAN, S.A.; JAIN, V.. **Designing an integrated AHP based decision support system for supplier selection in automotive industry**. Expert Systems with Applications, 62, pp.273-283, 2016.

FARIA, P. O.; VANALLE, R. M. **Critérios para Seleção de Fornecedores: Uma Análise das Práticas de Grandes Empresas Industriais do Estado do Espírito Santo**. XXVI ENEGEP. Fortaleza, 2006.

FURTADO, G. A. P. **Critérios de seleção de fornecedores para relacionamentos de parceria: um estudo em empresas de grande porte**. (Dissertação de Mestrado). São Paulo: Universidade de São Paulo, 2005.

GONÇALVES, P. S. **Administração de Materiais: obtendo vantagens competitivas**. Rio de Janeiro: Elsevier, Campus, 2004.

IAÑES, M. M.; CUNHA, C. B. **Uma metodologia para a seleção de um provedor logístico**. Revista Produção, v. 16, n. 3, p. 394-412, 2006.

KLIEM, R. L; LUDIN, I. S. **The Essentials for Successful IT Outsourcing**. In: Winning the Outsourcing Game, Cap. 5, Auerbach Publications, 2000.

LIU, J; DING, F.Y; LALL, V. **Using Data Envelopment Analysis to Compare Suppliers for Supplier Selection and Performance Improvement**. Supply Chain Management: An International Journal, vol. 5, no. 3, pp. 143-15, 2000.

LUTHRA, S.; GOVINDAN, K.; KANNAN, D.; MANGLA, S.K.; GARG, C.P.. **An integrated framework for sustainable supplier selection and evaluation in supply chains**. Journal of Cleaner Production, 140, pp.1686-1698, 2017.

LUTHRA, S.; KUMAR, S.; GARG, D.; HALEEM, A.. **Barriers to renewable/sustainable energy technologies adoption: Indian perspective**. Renewable and sustainable energy reviews, 41, pp.762-776, 2015.

MARDANI, A.; JUSOH, A.; NOR, K.; KHALIFAH, Z.; ZAKWAN, N.; VALIPOUR, A.. **Multiple criteria decision-making techniques and their applications: a review of the literature from 2000 to 2014**. Economic Research-Ekonomska Istraživanja, 28(1), pp.516-571, 2015.

MARTINS, R. **Estratégia de compras na indústria brasileira de higiene pessoal e cosméticos: um estudo de casos**. 2005: Dissertação (Mestrado); Instituto Coppead, UFRJ, Rio de Janeiro, 2005.

MOTWANI, J; YOUSSEF, M; KATHAWALA, Y; FUTCH, E. **Supplier selection in developing countries: a model development**. Integrated Manufacturing Systems, vol. 10, no. 3, pp. 154- 162, 1999.

PEREIRA, R.; TONTINI, G.; SILVEIRA, A. **Funções, Atividades e Responsabilidades da Administração de Compras: Comparação entre Empresas Catarinenses e Norte Americanas**. XXVIII EnANPAD. Curitiba, 2004.

RAJESH, R.; RAVI, V.. **Supplier selection in resilient supply chains: a grey relational analysis approach**. Journal of Cleaner Production, 86, pp.343-359, 2015.

RESENDE, P. T. V.; MENDONÇA, G. D.; ARAÚJO, B. B. **Estratégias de Formação de Ambientes Colaborativos com Fornecedores no Gerenciamento das Cadeias de Suprimento no Brasil**. XXIX EnANPAD. Brasília, 2005.

SAATY, Thomas Lorie. **The Analytic Hierarchy Process**. New York: McGraw-Hill, 1980.

SAATY, T. **How to make a decision: the analytic hierarchy process**. European Journal of Operational Research. North-Holland, v. 48, p. 9-26, 1990.

SEBRAE. **Pesquisa e escolha de fornecedores**. 2010. Disponível em: http://www.sebrae.com.br/customizado/acesso-a-mercados/conheca-seu mercado/fornecedores. Acesso em: 14 nov. 2018.

SLACK, N.; CHAMBERS, S.; JOHNSON, R. **Administração da produção**. São Paulo: Atlas 1999.