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Selection of Criteria for the Prioritization of Information Technology Services in a Neutrosophic Environment

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Abstract. Nowadays, the provision of quality service should be the main goal of service companies. Those that provide information technology services have a greater challenge since technology is rapidly updating and pleasing customers in an enjoyable way is essential. The selection of certain criteria that allow prioritizing which client an information technology service is provided to, allows optimizing the working time of developers and technicians depending on the type of service demanded. Therefore, the objective of this work is to determine what criteria are necessary to develop software that allows prioritizing information technology services. We applied the Saaty AHP multicriteria method from the neutrosophic perspective by selecting the criteria from a Pareto Diagram.

Keywords: information technology, services, selection criteria, neutrosophic AHP, Pareto.

1 Introduction

As humanity evolves, it can improve the means and services necessary to guarantee a better development of economic, social, technological, and environmental activities, among others. An element that has distinguished this development is information technology, an element that has made a difference regarding others, since it is inserted in the social, economic, medical, and military sectors, in short, it is vital for the progress of each sector.

From the appearance of language in ancient times to the use of electronic devices and its digitization today, the evolution of information has made it possible to optimize the time it takes to provide products or services from large companies to institutions without profit. Technology, in this case, information technology, has favored innovation, the growth of the countries' economies, although more and more work is being done on its sustainability.

In 2015, the Sustainable Development Goals were proposed, key elements to guide the countries towards a transformation for economic, social and environmental sustainability. There are 17 of these goals and are reflected in the United Nations 2030 Agenda for Sustainable Development. Goal 9 "Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation", states that investments in infrastructure (transport, irrigation, energy, and information and communications technology) are essential to achieve sustainable development and empower communities in many countries [1]. In other goals, it is reflected how information technology contributes to reaching the goals for achieving the objectives (objectives 4, 5, and 17).

Therefore, information technology services are gaining strength in the business and institutional world, as they are increasingly demanded by customers who need them to achieve their objectives. The demand for these services tends to increase and a bottleneck may occur, which does not allow pleasing all customers efficiently and effectively. This is a reason to establish strategic criteria to provide quality service to customers and prioritize activities.

Within the consulted bibliography [2-25] it was possible to establish that there are no systematized criteria for prioritizing information technology services. Therefore, some proposals have been gathered that can serve as criteria to prioritize their selection. A service provider needs to know which customer will need attention first. Thus, if software is developed for the selection of clients to whom an information technology service is provided, it must be determined what criteria are necessary for the design and implementation of an application that manages prioritization criteria. That is why the objective of this research is established taking into account the use of the Analytic Hierarchy Process proposed by Tomas Saaty (AHP Saaty from this moment on).

When conducting a bibliography study on the subject [26-29], it was established that some authors have algorithmically sophisticated multi-criteria evaluation models, where hierarchical techniques such as AHP Saaty are used in conjunction with other heterogeneous methods related to decision-making. In addition to the fact that all the methods used are based on the criteria of experts in a majority way. In this research, the environment of uncertainty and possible uncertainties that this social phenomenon brings with it will be taken into account. The abovementioned is given because Neutrosophy is the branch of philosophy that studies the origin, nature, and scope of neutralities. Its incorporation guarantees that the uncertainty of decision-making is considered, including indeterminacies where the experts will issue their criteria evaluating linguistic and not numerical terms [30-47].

According to the previous statements, we have defined as specific objectives of this work:

1. Establish strategic criteria
2. Selection of criteria to prioritize using Pareto Diagram
3. Determine prioritization through AHP Saaty in a neutrosophic environment and then apply it to decision-making regarding the criteria for software development.

2 Materials and methods

The following section describes the theoretical and empirical methods used throughout the current research to meet the specific objectives outlined. The methods used are listed below:

- Inductive, deductive: to verify the factors raised regarding the research topic in addition to structuring the research profile for its application.
- Analytical-synthetic: to compare all the phenomena involved in the research
- Historical-logical and descriptive-systematic: to analyze the problem situation of the research, it is intended to make a current observation of the phenomena for their interpretation.
- Surveys and interviews will be applied to the sample comprised of the target population and selected experts. Questionnaires were prepared aimed at obtaining information about the real problem and issuing possible solutions, to obtain valid conclusions and support the results.

Chain or network samples, known as snowball, are where key participants are identified and added to the sample, they are asked if they know other people who can provide more extensive data, and once their data is obtained, they are included. In other words, it is a non-probability sampling technique in which the experts give information about other known experts. Thus, allows access to difficult-to-sample experts, is an easy and inexpensive process [48].

The Pareto Diagram was presented by JM Jurán in his Quality Control Manual based on what was described in 1909 by V. Pareto under the principle of "the few vital, the many trivial". This diagram is based on problem analysis and is used to present data, drawing attention to the causes of great incidence in the problem in question. Aims to determine 20% of the causes that provoke 80% of the problems [49, 50].

Its main advantages are:

- It allows focusing on the aspects whose improvement will have the most significant impact, thus optimizing efforts.
- Provides a quick and easy view of the relative importance of issues.
- It helps prevent some causes from getting worse by trying to fix other less significant ones.
- His graphical view of the analysis is easy to understand and encourages the team to continue with improvement.

The following algorithm is used to execute the method:

1. Collect the data and tabulate it.
2. Calculate absolute and cumulative frequency, unit, and cumulative relative frequency.
3. Graph by locating all the causes along the coordinate axis ordered from highest to lowest incidence and correspond with their percentages along the ordinate axis. Finally, the cumulative polygonal line is built, and the causes that are up to 80% will be the ones with the highest incidence.

Neutrosophic AHP Saaty: The hierarchical analytical process was proposed by Thomas Saaty in 1980 [30]. This technique models the problem that leads to the formation of a hierarchy representative of the associated decision-making scheme [31, 32]. The formulation of the decision-making problem in a hierarchical structure is the first and main stage. This stage is where the decision-maker must break down the problem into its relevant components [33], [34, 35]. The hierarchy is constructed so that the elements are of the same order of magnitude and can be related to some of the next levels. In a typical hierarchy, the highest level locates the problem of decision-making. The elements that affect decision-making are represented at the intermediate level, the criteria occupying the intermediate levels [36]. Finally, the levels of importance or weighting of the criteria are estimated using pair-wise comparisons between them.

For the description of the method, the following definitions must be presented:

Definition 1: ([51, 52]) The Neutrosophic set N is characterized by three membership functions, which are the truth-membership function TA, indeterminacy-membership function IA, and falsehood-membership function FA, where U is the Universe of Discourse and ∀x∈U, TA (x), IA (x), FA (x)⊆] -0, 1+ [, and -0≤inf TA (x) + inf IA (x) + inf FA (x)≤sup TA (x) + sup IA (x) + sup FA (x)≤3+. Notice that, according to the definition, TA (x), IA (x) and FA (x) are real standard or non-standard subsets of] -0, 1+ [and hence, TA (x), IA (x) and FA (x) can be subintervals of [0, 1].

Definition 2: ([51, 52]) The Single-Valued Neutrosophic Set (SVNS) N over U is A = [48], where TA: U→[0, 1], IA: U→[0, 1], and FA: U→[0, 1], 0 ≤TA (x) + IA (x) + FA (x)≤ 3. The Single-Valued Neutrosophic Number (SVNN) is represented by N = (t, I, f), such that 0 ≤t, I, f ≤ 1 and 0 ≤t + I + f≤ 3.

Definition 3: ([51-54]) the single-valued trapezoidal neutrosophic number, $\tilde{a} = \langle (a_1, a_2 . a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$, is a neutrosophic set on ℝ, whose truth, indeterminacy and falsehood membership functions are defined as follows, respectively:

$$T_{\tilde{a}}(x) = \begin{cases} \alpha_{\tilde{a}}\left(\frac{x-a_1}{a_2-a_1}\right), & a_1 \le x \le a_2 \\ \alpha_{\tilde{a}}, & a_2 \le x \le a_3 \\ \alpha_{\tilde{a}}\left(\frac{a_3-x}{a_3-a_2}\right), & a_3 \le x \le a_4 \\ 0, \text{ otherwise} & \end{cases} \quad (1)$$

$$I_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\beta_{\tilde{a}}(x-a_1))}{a_2-a_1}, & a_1 \le x \le a_2 \\ \beta_{\tilde{a}}, & a_2 \le x \le a_3 \\ \frac{(x-a_2+\beta_{\tilde{a}}(a_3-x))}{a_3-a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases} \quad (2)$$

$$F_{\tilde{a}}(x) = \begin{cases} \frac{(a_2-x+\gamma_{\tilde{a}}(x-a_1))}{a_2-a_1}, & a_1 \le x \le a_2 \\ \gamma_{\tilde{a}}, & a_2 \le x \le a_3 \\ \frac{(x-a_2+\gamma_{\tilde{a}}(a_3-x))}{a_3-a_2}, & a_3 \le x \le a_4 \\ 1, & \text{otherwise} \end{cases} \quad (3)$$

Where, and. $\alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \in [0,1]$ $a_1, a_2, a_3, a_4 \in \mathbb{R} a_1 \le a_2 \le a_3 \le a_4$

Definition 4: ([55]) given $\tilde{a} = \langle (a_1, a_2, a_3, a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle$ and $\tilde{b} = \langle (b_1, b_2, b_3, b_4); \alpha_{\tilde{b}}, \beta_{\tilde{b}}, \gamma_{\tilde{b}} \rangle$ two single-valued trapezoidal neutrosophic numbers and λ any non-null number in the real line. Then, the following operations are defined:

Addition: $\tilde{a} + \tilde{b} = \langle (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$

Subtraction: (4)$\tilde{a} - \tilde{b} = \langle (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1); \alpha_{\tilde{a}} \wedge \alpha_{\tilde{b}}, \beta_{\tilde{a}} \vee \beta_{\tilde{b}}, \gamma_{\tilde{a}} \vee \gamma_{\tilde{b}} \rangle$

Inversion: where.$\tilde{a}^{-1} = \langle (a_4^{-1}, a_3^{-1}, a_2^{-1}, a_1^{-1}); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle a_1, a_2, a_3, a_4 \neq 0$

Multiplication by a scalar number:

$$\lambda\tilde{a} = \begin{Bmatrix} \begin{cases} \langle (\lambda a_1, \lambda a_2, \lambda a_3, \lambda a_4); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda > 0 \\ \langle (\lambda a_4, \lambda a_3, \lambda a_2, \lambda a_1); \alpha_{\tilde{a}}, \beta_{\tilde{a}}, \gamma_{\tilde{a}} \rangle, & \lambda < 0 \end{cases} \end{Bmatrix}$$

Definitions 3 and 4 refer to single-valued triangular neutrosophic number when the condition a2 = a3, [56-58]. For simplicity, we use the linguistic scale of triangular neutrosophic numbers, see Table 1 and also compare it with the scale defined in[59]. The levels of importance or weighting of the criteria are estimated using paired comparisons between them. This comparison is carried out using a scale, as expressed in equation (6)[60].

$$S = \left\{\frac{1}{9}, \frac{1}{7}, \frac{1}{5}, \frac{1}{3}, 1,3,5,7,9\right\} \quad (5)$$

We can find in [59] the theory of the AHP technique in a neutrosophic framework. Thus, we can model the indeterminacy of decision-making by applying neutrosophic AHP or NAHP for short. Equation 7 contains a generic neutrosophic pair-wise comparison matrix for NAHP.

$$\tilde{A} = \begin{bmatrix} \tilde{1} & \tilde{a}_{12} & \cdots & \tilde{a}_{1n} \\ \vdots & & \ddots & \vdots \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \cdots & \tilde{1} \end{bmatrix} \quad (6)$$

The matrix must satisfy the condition, based on the inversion operator of Definition 4. $\tilde{A}$ $\tilde{a}_{ji} = \tilde{a}_{ij}^{-1}$

To convert neutrosophic triangular numbers into crisp numbers, there are two indexes defined in [59].

They are the so-called score and accuracy indexes, respectively, see Equations 7 and 8:

$$S(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} - \gamma_{\tilde{a}}) \quad (7)$$

$$A(\tilde{a}) = \frac{1}{8}[a_1 + a_2 + a_3](2 + \alpha_{\tilde{a}} - \beta_{\tilde{a}} + \gamma_{\tilde{a}}) \quad (8)$$

Saaty's scale	Definition	Neutrosophic Triangular Scale
1	Equally influential	$\tilde{1} = \langle(1,1,1); 0.50, 0.50, 0.50\rangle$
3	Slightly influential	$\tilde{3} = \langle(2,3,4); 0.30, 0.75, 0.70\rangle$
5	Strongly influential	$\tilde{5} = \langle(4,5,6); 0.80, 0.15, 0.20\rangle$
7	Very strongly influential	$\tilde{7} = \langle(6,7,8); 0.90, 0.10, 0.10\rangle$
9	Absolutely influential	$\tilde{9} = \langle(9,9,9); 1.00, 1.00, 1.00\rangle$
2, 4, 6, 8	Sporadic values between two close scales	$\tilde{2} = \langle(1,2,3); 0.40, 0.65, 0.60\rangle$
		$\tilde{4} = \langle(3,4,5); 0.60, 0.35, 0.40\rangle$
		$\tilde{6} = \langle(5,6,7); 0.70, 0.25, 0.30\rangle$
		$\tilde{8} = \langle(7,8,9); 0.85, 0.10, 0.15\rangle$

Table 1: Saaty's scale translated to a neutrosophic triangular scale.

Step 1 Select a group of experts.

Step 2 Structure the neutrosophic pair-wise comparison matrix of factors, sub-factors, and strategies, through the linguistic terms shown in Table 1.

The neutrosophic scale is attained according to expert opinions [61]. The neutrosophic pair-wise comparison matrix of factors, sub-factors, and strategies are as described in Equation 6.

Step 3 Check the consistency of experts' judgments.

If the pair-wise comparison matrix has a transitive relation, ie., Aik = aijajk for all i, j and k, then the comparison matrix is consistent, focusing only on the lower, median, and upper values of the triangular neutrosophic number of the comparison matrix.

Step 4 Calculate the weight of the factors from the neutrosophic pair-wise comparison matrix, by transforming it into a deterministic matrix using Equations 9 and 10. To get the score and the accuracy degree of the following equations are used:$\tilde{a}_{ji}$

$$S(\tilde{a}_{ji}) = 1/S(\tilde{a}_{ij}) \quad (9)$$

$$A(\tilde{a}_{ji}) = 1/A(\tilde{a}_{ij}) \quad (10)$$

With compensation by accuracy degree of each triangular neutrosophic number in the neutrosophic pair-wise comparison matrix, we derive the following deterministic matrix:

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & 1 \end{bmatrix} \quad (11)$$

Determine the ranking of priorities, namely the Eigen Vector X, from the previous matrix:

1. Normalize the column entries by dividing each entry by the sum of the column.
2. Take the total of the row averages.

Note that Step 3 refers to consider the use of the calculus of the Consistency Index (CI) when applying this technique, which is a function depending on λ_{max}, the maximum eigenvalue of the matrix. Saaty establishes that consistency of the evaluations can be determined by the equation:

$$CI = \frac{\lambda_{max} - n}{n - 1} \text{ [62]}, \quad (12)$$

where n is the order of the matrix. In addition, the Consistency Ratio (CR) is defined by equation:

$$CR = \frac{CI}{RI} \quad (13)$$

RI is given in Table 2.

Order (n)	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Table 2: RI associated with every order.

If CR≤0.1 we can consider that experts' evaluation is sufficiently consistent and hence we can proceed to use NAHP. We apply this procedure to matrix "A" in Equation 12.

3 Results

For a case study, the following bibliography was consulted [2-24] where we found that the most representative criteria for the analysis in question are:

- Customer satisfaction in previous services
- Type of work to be done
- Distance between the client and the company
- Availability of material and human resources to carry out the work
- Type of work carried out by the client
- Increased number of services offered to customers
- Clients that bring greater benefits to the company
- Service request order
- Facilities assured by the client
- Mobility towards the client

For the ratification of these criteria, we consulted through the snowball method a panel of experts who are related to information technologies and work in various institutions, both in companies and in entities budgeted. A semi-structured interview was applied to them to determine criteria for the prioritization of information technology services through software. From the interviews carried out with the experts, the influence of the criteria was determined, which was plotted using a Pareto Diagram. As shown in Figure 1, 6 criteria that influence 80% of the most important criteria were selected.

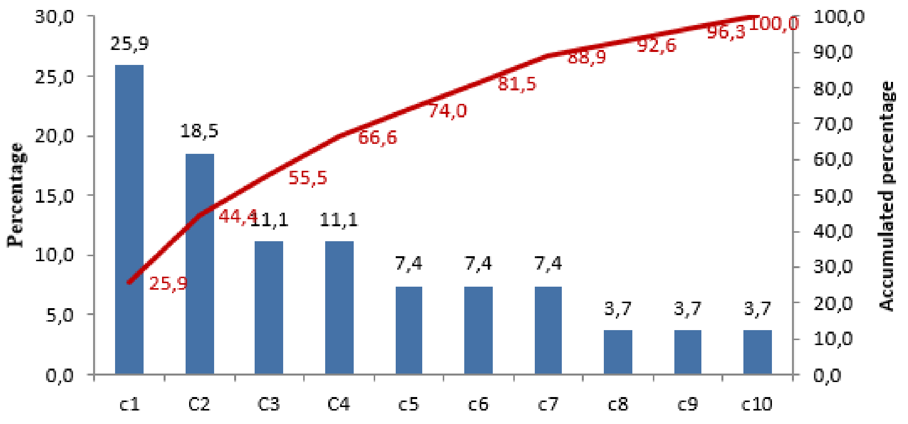

Figure 1: Pareto chart for the selection of criteria.

Legend: Criteria

1. Request order
2. Type of work to be done
3. Clients with greater financial solvency and joint work time
4. Priority of the work performed by the client
5. Mobility towards the client
6. Availability of material and human resources
7. Distance between the client and the company
8. Facilities provided by the client
9. Greater number of services offered per client
10. Customer satisfaction

As a result, the AHP Saaty is applied to the following criteria: Order of the service request; Type of work to be done; Clients that bring greater benefits to the company; Type of work carried out by the client; Mobility towards the client and Availability of material and human resources to carry out the work

Criteria	c1	c2	c3	c4	c5	c6
c1	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(4,5,6); 0.80,0.15,0.20⟩	⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(4,5,6); 0.80,0.15,0.20⟩
c2	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(4,5,6); 0.80,0.15,0.20⟩	⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(2,3,4); 0.30,0.75,0.70⟩
c3	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(2,3,4); 0.30,0.75,0.70⟩
c4	1 / ⟨(4,5,6); 0.80,0.15,0.20⟩	1 / ⟨(4,5,6); 0.80,0.15,0.20⟩	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(1,1,1); 0.50,0.50,0.50⟩
c5	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(1,1,1); 0.50,0.50,0.50⟩
c6	1 / ⟨(4,5,6); 0.80,0.15,0.20⟩	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	1 / ⟨(2,3,4); 0.30,0.75,0.70⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(1,1,1); 0.50,0.50,0.50⟩	⟨(1,1,1); 0.50,0.50,0.50⟩

Table 3: AHP Saaty Neutrosophic paired matrix.

Criteria	c1	c2	c3	c4	c5	c6	WEIGHT	Ax Weight	Approx. Eigenvalues
	0.42	0.58	0.38	0.33	0.21	0.36	0.378	2.55	6.7477
	0.14	0.19	0.38	0.33	0.21	0.21	0.243	1.68	6.8892
	0.14	0.06	0.13	0.20	0.21	0.21	0.159	1.03	6.4660
	0.08	0.04	0.04	0.07	0.21	0.07	0.086	0.53	6.2251
	0.14	0.06	0.04	0.02	0.07	0.07	0.068	0.42	6,2006
	0.08	0.06	0.04	0.07	0.07	0.07	0.066	0.43	6.4918

Table 4: Determination of criteria weights applying the Neutrosophic AHP method.

When performing the consistency analysis, according to the proposed method, an eigenvalue of 6.5034 was obtained, IC = 0.10 and RC = 0.08, which allows us to affirm that the exercise was carried out correctly.

As could be seen, services should be prioritized according to the following order of criteria:

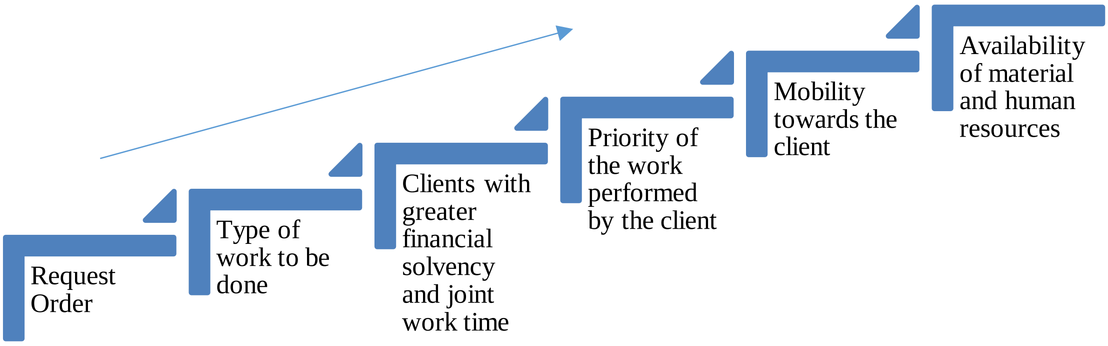

Figure 2: Criteria prioritization.

The work team in charge of programming should consider this as the primary source of data in the interface of the designed software. In this way, when the user interacts with the product, they will be able to provide feedback on the designed system.

Conclusion

Once the investigation was completed, the following conclusions were reached:

- The selection of criteria for the development of software optimizes the time to provide customer service, facilitates the presence of the product in the market and meets the skills required for this type of company. Customer satisfaction brings along increased profits for the company and the request for new services increasing the profits and prestige of the company.
- The use of neutrosophic language for the realization of the paper was important since the nature of the exercise requires it. Mainly for the determination of the criteria to work, where the application of the Pareto Diagram was successful. According to the Pareto Diagram, respect for the order of the service request by customers allows the client to feel important and empowered. The rest of the criteria that were not selected more frequently by the experts should be analyzed in the strategic themes of the company, due to their possible repercussions.
- In the case of the analysis carried out using the AHP Saaty Neutrosophic technique, it complemented what was stated in Pareto's definition. It was revealed that in order of importance, the experts place the following hierarchical order of the criteria:

  - ✓ Order of service request is a topic valued by customers;
  - ✓ Type of work to be done;
  - ✓ Clients that bring greater benefits to the company;
  - ✓ Type of work carried out by the client;
  - ✓ Mobility towards the client; and
  - ✓ Availability of material and human resources to carry out the work.

- After receiving their request, the need to please customers is important in the measurement of the AHP Neutrosophic Saaty. Given the urgency of the use of new technologies, it is essential to apply the services that a company can provide to itself, and other competing companies.

- One of the elements that must be taken into account in this work, is recommended to keep the portfolio of services that an information technology company can provide updated. In the same way that technologies are regenerated very quickly at present, the application of this type of exercise regularly, allows the company and the software to be in continuous improvement for greater customer satisfaction, which leads to the generation of greater benefits.

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