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WEBOMETRIC RANKING OF UNIVERSITIES USING FUZZY ANALYTICAL HIERARCHICAL PROCESS (FAHP) MODEL

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ABSTRACT

Webometric ranking of Universities done by Cybermetrics Laboratory has gained international recognition and acceptance for the ranking of Universities and other tertiary institutions' global academic capability and impact. The reliability of this ranking is an issue that needs to be examined particularly when the ranking model used by Cybermetrics Laboratory appears to be the simplest and most controversial of the three basic models for ranking alternatives. This paper considers one of the alternative models to the Linear Weightage model used by Cybermetrics Laboratory – the Fuzzy Analytical Hierarchical Process (FAHP) model, for the ranking of Universities instead. Our results affirm the reliability of the world webometric ranking.

INTRODUCTION

The global academic capability and impact of universities is now being adjudged by their webometric ranking. The webometric ranking of the world's tertiary institutions is done by Cybermetrics Laboratory, Spain, using the following four indicators: Web Size, Rich Files, Google Scholar (research output) and Web Visibility (http://www.webometrics.info/) as input to the Weightage model for ranking alternatives. In this model, decision makers assign weights to each criterion in order to determine the relative importance of each one. These weights play a vital role in decision making process and extremely affect the final decision (Nissom and Kulathuramaiyer, 2012). This decision process of assigning weights accommodate subjective information, and allows the application of experience, insight and intuition, besides, the process could be bias. Obviously, different opinions from the weightage of each criterion as captured in Figure1 can alter the webometric ranking of world Universities. This brings the world webometric ranking of universities into question.

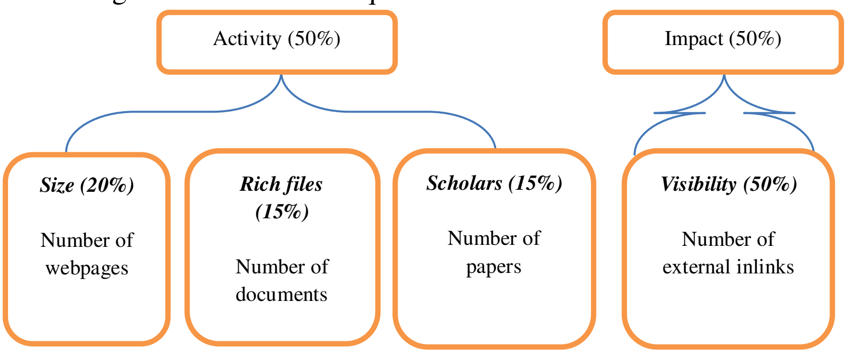

Figure 1: Academic model of the Webometric Ranking indicator (Aguillo, 2009).

An alternative model void of this decision process of assigning weights like the Analytical Hierarchical Process (AHP) and Fuzzy Analytical Hierarchical Process (FAHP) models are therefore preffered (Dominic and Jati, 2011). This work is the application of FAHP model to the ranking of some selected university websites. These universities are University of Benin, Benson Idahosa University, Ambrose Alli University and Igbenedion University, all in Edo State, Nigeria.

MATERIALS AND METHOD

This work adopts the four web indicators of Cybermetrics Laboratory (http://www.webometrics.info/). These web indicators as used by Cybermetrics Laboratory are highlighted as follows:

1. **Size:** This deals with the number of pages usually in HTML or assimilated formats obtained from search engines such as Google, Yahoo, MSN (bing) and Exalead using the syntax – site: domain_name. For example, to obtain the number of pages in University of Benin website, we entered "site: uniben.edu" in Google search engine and had 393,000 (time in seconds) displayed at the top left of the search results. It is important to note that this value remain the same irrespective of the browser type. We repeated this for the four search engines and took the average of each university as the size of the various University website. The choice of these search engines by Cybermetrics Laboratory is traceable to their age.
2. **Rich files**: This is the number of documents in Adobe (.pdf), Word (.doc) and Powerpoint (.ppt) formats. The success of self-archiving and other repositories related initiatives can be roughly represented from rich file and scholarly data. This include pdf, doc, and ppt files. Similar procedure as with the size indicator is followed for each of the file type using the syntax – .file_type: domain_name e.g. '.pdf: uniben.edu'. The averages from each search engine for the various file type was aggregated to get the size of organisation's Rich files.
3. **Number of Papers**: This is measured by the number of organisation's scholars publication indexed in Google Scholar. Google Scholar (http://www.scholar.google.com) is a freely accessible web search engine that indexes the full text of scholarly literature across an array of publishing formats and disciplines. To get the number of papers we entered the domain name of the institution on google scholar and the value at the top of the search result is the required number.
4. **Visibility:** This has to do with the unique external links received (inlinks) by a site and can be confidently obtained from only Yahoo search (Ortega et al, 2006). For example, to obtain the number of inlinks to University of Benin website using Yahoo search, we entered "link: uniben.edu" in Yahoo search and had "16,400 results" displayed at the bottom right of the search results.

These data capture was done using an HP note book with a Visafone 3G internet modem between the hours of 10.30am and 2.30pm of Saturday, 18th of January, 2014 at the Department of Computer Science, University of Benin, Benin City, Edo State, Nigeria.

Fuzzy Analytical Hierarchical Process (FAHP) Model

In spite of the benefit of AHP (Ozden and Karpak, 2005; Tahriri *et al*, 2008; Dominic and Jati, 2011), it has been criticized due to its inability to adequately handle uncertainty and imprecision associated with the mapping of the exact numbers (Deng, 1999). The conventional AHP approach does not reflect human thinking for the simple fact that decision makers feel more confident to give interval judgments rather than express their judgments in the form of single numeric values and so Fuzzy Analytical Hierarchical Process (FAHP) is capable of capturing a human's appraisal of ambiguity when complex multi-attribute decision making problems are considered (Erensal *el al*, 2006). A new approach to a precise theory of approximation and vagueness based on generalization of standard set theory to fuzzy sets was introduced by Zadeh (1965). Since fuzziness and vagueness are common characteristics in many decision-making problems, a fuzzy AHP (FAHP) method should be able to tolerate vagueness or ambiguity (Mikhailov, 2003). Fuzzy sets and fuzzy logic are powerful mathematical tools for modelling nature and humanity, uncertain systems in industry, and facilitators for common-sense reasoning in decision making in the absence of complete and precise information. Their role is significant when applied to complex phenomena not easily described by traditional mathematical methods, especially when the goal is to find a good approximate solution. Fuzzy set theory is an extension of classical set theory where elements have degrees of membership (Zadeh, 1965). The theory of fuzzy set was a generalization of classic set theory which allows the membership functions to operate over the range of real numbers [0, 1]. The main characteristic of fuzziness is the grouping of individuals into classes that do not have sharply defined boundaries (Hansen, 2005). The uncertain comparison judgment can be represented by the fuzzy number. In the FAHP method, the pair-wise comparisons in the judgment matrix are fuzzy numbers and use fuzzy arithmetic and fuzzy aggregation operators. Triangular fuzzy numbers were introduced into the conventional AHP in order to enhance the degree of judgment of decision maker.

Triangular Fuzzy Number (TFN)

A triangular fuzzy number is a convex fuzzy set with a grade of membership between 0 and 1. It is a special class of fuzzy number whose membership is defined by three real numbers. In applications it is often convenient to work with TFNs because of their computational simplicity (Giachetti and Young, 1997; Moon and Kang, 2001), and they are useful in promoting representation and information processing in a fuzzy environment (Liang and Wang, 1993).

Implementing the FAHP Model

Given a web indicator values of University portals (Table 1) which is in the form A = n X m matrix where n denotes the number of criteria and m the number of Universities. In our case, n = m = 4. Perform the following steps:

Step 1: Perform column operation on each University column of matrix A.

For example, to obtain a column operation matrix for University of Benin, we carried out the following column operation:

$$\begin{bmatrix} \mathrm{a11} = \frac{a11}{a11} & \mathrm{a12} = \frac{a11}{a21} & \mathrm{a13} = \frac{a11}{a31} & \mathrm{a14} = \frac{a11}{a41} \\ \mathrm{a21} = \frac{21}{a11} & \mathrm{a22} = \frac{a21}{a21} & \mathrm{a23} = \frac{a21}{a31} & \mathrm{a24} = \frac{a21}{a41} \\ \mathrm{a31} = \frac{31}{a11} & \mathrm{a32} = \frac{31}{a21} & \mathrm{a33} = \frac{a31}{a31} & \mathrm{a34} = \frac{a31}{a41} \\ \mathrm{a41} = \frac{41}{a11} & \mathrm{a42} = \frac{41}{a21} & \mathrm{a43} = \frac{41}{a31} & \mathrm{a44} = \frac{a41}{a41} \end{bmatrix}$$

From the above operation, the result of the column operation will be of the form:

$$\mathrm{Ak} = \begin{bmatrix} \mathrm{a11} & \mathrm{a12} & \mathrm{a13} & \mathrm{a14} \\ a21 & a22 & a23 & a24 \\ a31 & a32 & a33 & a34 \\ a41 & a42 & a43 & a44 \end{bmatrix} \quad (1)$$

The above process was repeated for each of the Universities.

Step 2: Obtain judgement matrices $A^L_{i,j}$, $A^M_{i,j}$, $A^H_{i,j}$ based on pair-wise comparison of all Ak

$$A^M_{i,j} = \sqrt{A^L_{i,j} * A^H_{i,j}} \quad \forall \text{ Ak and } i \neq j \text{ otherwise } A^M_{i,j} = 1 \quad (2)$$

where

$$A^L_{i,j} = \min(\mathrm{Ak}_{i,j}) \ \forall \ \mathrm{Ak} \quad (3)$$

$$A^H_{i,j} = \max(\mathrm{Ak}_{i,j}) \ \forall \ \mathrm{Ak} \quad (4)$$

Step 3: Normalize each column of matrices $A^L_{i,j}$, $A^M_{i,j}$, $A^H_{i,j}$ to get a new judgment matrices A^L, A^M and A^H respectively of the form:

$$A^N = \begin{bmatrix} \mathrm{a11} & \mathrm{a12} & \mathrm{a13} & \ldots & \mathrm{a1n} \\ a21 & a22 & a23 & \ldots & a2n \\ a31 & a32 & a33 & \ldots & a3n \\ & & \vdots & & \\ a41 & a42 & a43 & \ldots & ann \end{bmatrix} = \begin{bmatrix} \frac{a11}{\sum_{i=1}^n i1} & \frac{a12}{\sum_{i=1}^n i2} & \frac{a13}{\sum_{i=1}^n i3} & \frac{a1n}{\sum_{i=1}^n in} \\ \frac{a21}{\sum_{i=1}^n i1} & \frac{a22}{\sum_{i=1}^n i2} & \frac{a23}{\sum_{i=1}^n i3} & \frac{a2n}{\sum_{i=1}^n in} \\ \frac{a31}{\sum_{i=1}^n i1} & \frac{a32}{\sum_{i=1}^n i2} & \frac{a33}{\sum_{i=1}^n i3} & \frac{a3n}{\sum_{i=1}^n in} \\ & \vdots & & \\ \frac{an1}{\sum_{i=1}^n i1} & \frac{an2}{\sum_{i=1}^n i2} & \frac{an3}{\sum_{i=1}^n i3} & \frac{ann}{\sum_{i=1}^n in} \end{bmatrix} \quad (5)$$

Step4: Sum up each row of normalized judgement matrix A^N to get weight vector V.

$$V = \begin{bmatrix} v1 \\ v2 \\ v3 \\ . \\ . \\ . \\ vn \end{bmatrix} = \begin{bmatrix} \sum_{j=1}^{n} 1j \\ \sum_{j=1}^{n} 2j \\ \sum_{j=1}^{n} 3j \\ . \\ . \\ . \\ \sum_{j=1}^{n} nj \end{bmatrix} \quad (6)$$

Do this for each of the matrices $A_{i,j}^{L}$, $A_{i,j}^{M}$, $A_{i,j}^{H}$

Step5: Concatenate matrices $A_{i,j}^{L}$, $A_{i,j}^{M}$, $A_{i,j}^{H}$ to form a new matrix RS, the fuzzy number vector, of the form:

$$RS = \begin{bmatrix} rs1 \\ rs2 \\ rs3 \\ rs4 \end{bmatrix} = \begin{bmatrix} \sum_{j=1}^{4} l1j & \sum_{j=1}^{4} m1j & \sum_{j=1}^{4} u1j \\ \sum_{j=1}^{4} l2j & \sum_{j=1}^{4} m2j & \sum_{j=1}^{4} u2j \\ \sum_{j=1}^{4} l3j & \sum_{j=1}^{4} m3j & \sum_{j=1}^{4} u3j \\ \sum_{j=1}^{4} l4j & \sum_{j=1}^{4} m4j & \sum_{j=1}^{4} u4j \end{bmatrix} \quad (7)$$

Step6: Compute the fuzzy synthetic extent value vector S.

$$S = \begin{bmatrix} s1 \\ s2 \\ s3 \\ . \\ . \\ . \\ sn \end{bmatrix} = \begin{bmatrix} \frac{l1}{\sum_{i=1}^{n} ui} & \frac{m1}{\sum_{j=1}^{n} mi} & \frac{u1}{\sum_{j=1}^{n} li} \\ \frac{l2}{\sum_{i=1}^{n} ui} & \frac{m2}{\sum_{j=1}^{n} mi} & \frac{u2}{\sum_{j=1}^{n} li} \\ \frac{l3}{\sum_{i=1}^{n} ui} & \frac{m3}{\sum_{j=1}^{n} mi} & \frac{u3}{\sum_{j=1}^{n} li} \\ . & . & . \\ . & . & . \\ . & . & . \\ \frac{ln}{\sum_{i=1}^{n} ui} & \frac{mn}{\sum_{j=1}^{n} mi} & \frac{un}{\sum_{j=1}^{n} li} \end{bmatrix} \quad (8)$$

Step 7: Get the non-fuzzy weight vector V

$$V = \begin{bmatrix} v1 \\ v2 \\ v3 \\ v4 \end{bmatrix} = \begin{bmatrix} \min V(S1 \geq Sj) \\ \min V(S2 \geq Sj) \\ \min V(S3 \geq Sj) \\ \min V(S4 \geq Sj) \end{bmatrix} \qquad \forall\, j = 1\ (1)\ n \quad (9)$$

$$\text{Where } V(Si \geq Sj) = \begin{cases} 1, & \text{if } M_i \geq M_j \\ 0, & \text{if } L_j \geq U_i \\ (Lj - Ui)/((Mi - Ui) - (Mj - Lj)), & \text{otherwise} \end{cases} \quad (10)$$

Step 8: Define the final normalization weight vector W.

$$W = \begin{bmatrix} w1 \\ w2 \\ w3 \\ . \\ . \\ . \\ wn \end{bmatrix} = \begin{bmatrix} \frac{v1}{\sum_{i=1}^{n} vi} \\ \frac{v2}{\sum_{i=1}^{n} vi} \\ \frac{v3}{\sum_{i=1}^{n} vi} \\ . \\ . \\ . \\ \frac{vn}{\sum_{i=1}^{n} vi} \end{bmatrix} \quad (11)$$

Step 9: For each i = 1 (1) n, compute matrix A' = Wi $*$ Aij $\forall$ j = 1(1) m (12)

Step 10: Compute vector $P_j = \sqrt[4]{\prod_{i=1}^{n} A'}$ $\forall$ j = 1(1) m (13)

Step 11: Compute vector $R_j = Pj / \sum_{j=1}^{m} Pj$ $\forall$ j = 1(1) m (14)

Step12: R_j defines the ranking of the Universities

We call step1 to step 11 the Faithfull Eleven (FE) of FAHP.

RESULTS AND DISCUSSION

It is believed that the Cybermetrics Laboratory uses only Yahoo Search engine for link visibility. Thus, the link visibility data as returned by the Yahoo search engine is captured in Table 1.

Table 1: Table showing the Link Visibility of University Portals using Yahoo Search Engine.

Link Visibility	Uniben	Ekpoma	Igbinedion	Benson Idahosa
Yahoo Search	16,400	874	78	60

The Web indicator value of the selected University Portals are captured in Table 2a and Table 2b. Table 2b captures the situation where spurious indicator values were discarded.

Table 2a: Table showing the Web Indicator value of university portals

Criteria/alternatives	Uniben	Ekpoma	Igbinedion	Benson Idahosa
Link Visilibily	129931.75	3565	5831.25	552544.5
Size	103443.75	5969.75	5659.25	2600050.75
Rich Files	184671336.8	752.5833333	68.16666667	6834255
Google scholar search	544	9	6	16
Total	184905256.3	10296.33333	11564.66667	9986866.25

Table 2b: Table showing the Web Indicator value of university portals

Criteria/alternatives	Uniben	Ekpoma	Igbinedion	Benson Idahosa
Link Visilibily	10575.66667	3565	5831.25	59.33333333
Size	103443.75	5969.75	5659.25	67.66666667
Rich Files	5357.305556	752.5833333	68.16666667	1793
Google scholar search	544	9	6	16
Total	119920.7222	10296.33333	11564.66667	1936

A careful application of the FE of FAHP on Table 2a yields Table 3a but when the link visibility row values of the table are replaced by those of Table 1, we get Table 3b. Similarly, Table 2b yields Table 3c and Table 3d respectively.

Table 3a: Table showing the Webometric Value and Ranking of Universities

Institution	Uniben	Ekpoma	Igbinedion	Benson Idahosa
Webometric Value	0.629317488	0.002022873	0.00111899	0.367540649
Ranking	1st	3rd	4th	2nd

Table 3b: Table showing the Webometric Value and Ranking of Universities

Institution	Uniben	Ekpoma	Igbinedion	Benson Idahosa
Webometric Value y	0.90511488	0.003434656	0.000918251	0.090532214
Ranking	1st	3rd	4th	2nd

Table 3c: Table showing the Webometric Value and Ranking of Universities

Institution	Uniben	Ekpoma	Igbinedion	Benson Idahosa
Webometric Value	0.876311784	0.071857568	0.039749373	0.012081275
Ranking	1st	2nd	3rd	4th

Table 3d: Table showing the Webometric Value and Ranking of Universities

Institution	Uniben	Ekpoma	Igbinedion	Benson Idahosa
Webometric Valuey	0.927713728	0.047968573	0.012824334	0.011493365
Ranking	1st	2nd	3rd	4th

It is also important to note that the exclusive use of the Yahoo search engine for link visibility did not make any difference with FAHP as was with the weightage model. Observe that the results from the webometric indicator data whose spurious values were discarded are consistent with the latest Webometric ranking result. An interesting observation is that the results of FAHP and AHP are the same. These results therefore affirm the reliability of the world webometric ranking. Spurious indicator values worked against Benson Idahosa University.

CONCLUSION AND RECOMMENDATIONS

We noted that the ranking model used by Cybermetrics Laboratory i.e. the Weightage model, may not yield the same ranking result if the weights they assign to the Web indicators as in figure1.1 are altered. We applied the FAHP model, a model not only void of the human decision process of assigning weights, in the ranking of the selected University Websites but also handles uncertainties or vagueness. Our ranking results from the data whose spurious values were discarded are consistent with the latest Webometric ranking result. These results therefore affirm the reliability of the world webometric ranking. We can confidently rely on the weightage values in the Weightage model as used by the Cybermetric Laboratory.

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