A Website Selection Model in Programmatic Advertising using Fuzzy Analytic Hierarchy Process and Similarity Methods

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***Abstract*—The Web has already become a platform that reshapes business models, thus spawning new opportunities for growth. Furthermore, the Web constitutes an effective media rich communication channel for businesses to contact their customers, support their transactions and promote their products and service through digital marketing. This paper focuses on the applicability of fuzzy logic techniques to assessing web sites performance with respect to digital marketing objectives. This research utilizes the Fuzzy Delphi Method (FDM) the Fuzzy Analytic Hierarchy Process (FAHP) and similarity methods in order to select the web sites that mostly satisfy digital marketing targets that are set by a Communications Company (CC) in Greece. Data on a large number of digital marketing parameters is collected, representing the performance of the CC on the web over a period of time. This paper aims to identify the criteria that can be used for assessing web sites, to determine their relative importance and to rank web sites according to their contribution to CC objectives. Fuzzy logic is utilised to deal with the subjectivity inherent in setting a company's priorities. FDM is used to capture the managers' views regarding the assessment criteria and the FAHP is used for determining the criteria's weights.**

Keywords-Fuzzy Delphi Method; Fuzzy Analytic Hierarchy Process; Similarity Methods; Web Site selection.

I. INTRODUCTION

Digital advertising spending is growing globally. According to [1], for countries such as the UK, China, Norway and Canada, digital advertising has already become the dominant advertising channel, which accounts for more than 50% of the total ad spending. It is also expected [1] that the global spending on digital ads will increase by 17.6% to reach $333.25 billion. As regards to the top digital ads sellers, Google is expected to outperform their competitors being the largest digital ad seller in the world in 2019, attracting 31.1% of the global ad spending, or $103.73 billion. Facebook will be No. 2, with $67.37 billion in net ad revenues, followed by China-based Alibaba, at $29.20 billion [1]. Investments in Digital Marketing (DM) are driven by companies' aims to improve cost effectiveness, as well as by changes in customer behaviour. However, DM increase is attributed to the fact that results from DM initiatives are more easily accountable for compared to those of traditional marketing [2]-[5]. Furthermore, as customers are increasingly using digital channels for their transactions with business, marketers have realized the need to track these transactions and to measure their performance [6]. In another survey [7], also discussed in [8], 65% of marketing leaders surveyed in the USA plan to increase their spending on digital advertising, due to factors that impose a continuing and consistent shift of offline media spending to digital advertising, a decline of organic social in favor of paid social and the rising importance of video, which is more expensive than other digital techniques.

For this purpose, firms have already started using Web Analytics (WA) for collecting data and assessing digital marketing performance. WA can be defined as the process of collecting, storing, analysing and reporting of Internet data aiming at understanding and optimizing Web usage and e-business performance. A recent work [2] found that digital marketing performance measurement represents a top-priority for businesses.

With the proliferation of web sites, businesses have many opportunities to showcase their brand online. Globally there are over 1.5 billion with around 200 million of them being active. The development of a DM investment plan requires the analysis of websites performance. WA provides a quite comprehensive set of websites traffic data that can be used to assess DM alternative plans. In addition, available are programmatic digital marketing platforms for automated bidding on advertising inventory in real time, that give businesses access to websites traffic data and the opportunity to show an ad to a specific customer, in a specific context.

From there, a DM agency will help businesses determine which digital channels, i.e., websites, should be used to reach their ideal buyers. DM agencies evaluate businesses' website traffic, determine the best online platforms to invest in, and continually maintain the balance between your marketing activities and the results they provide. Programmatic Advertising (PA), as a new format of online precision marketing, has sparked a new wave of explosive growth in display advertising markets [9]. In USA, the PA promotion spending reaches 32.56 billion dollars in 2017, taking up the 80% market share of the online display advertising; in the UK, programmatically traded ads account for more than 75% of online display advertising spending by the end of 2017; and in China, the PA market scale is about 11.69 billion dollars in 2017, and will grow to 29.6 billion in 2019 with the average growth rate of about 35% [9]. PA has evolved as a new model in advertising that facilitates the precise matching between advertisements and target audiences in a real-time manner, as well as it allows for the effective allocation of the limited ad resources, thus leading to the improved performance in market promotions [7]. Therefore, one critical decision that arises in the context of PA is ad inventory allocation, i.e., determining how to allocate the limited ad impressions (ad inventory) to the demanding advertisers as to optimize the publishers' various objectives [7]. Advertisement impressions allocation has been widely considered as one of the most critical decisions for publishers in PA markets [10][11].

This study suggests a methodology based on multicriteria analysis and fuzzy logic in order to identify and quantify the websites selection criteria in programmatic advertising. This paper also proposes the use of similarity methods in order to identify websites that have been overlooked, therefore they can be considered as an investment option.

This paper suggests the use of FDM in order to determine the selection criteria. The FDM is well established and used in similar studies [12]. The (FAHP) is proposed for it allows decision makers, e.g., marketing managers, to express their beliefs regarding the relative importance of selection criteria, and then it aggregates their opinions in order to produce a hierarchical model that quantifies their relative of the selection criteria. This study also utilizes similarity methods in order to identify and recommend websites for investment.

Thus, this research aims to:

- Identify the selection criteria that marketing managers adopt when allocating resource during the PA decision process.
- Propose a multi-criteria approach for identifying and assessing Websites and allocate resources in the context of PA.

The rest of the paper is structured as follows: Section II, discusses the proposed methodology and the methods utilized for the data analysis. The empirical study and the data analysis are presented in Section III. The paper concludes and indicates future research in Section IV.

II. METHODOLOGY AND METHODS

This section discusses the proposed methodology and the methods used in this study.

A. *Methodology for identifing and quantifing websites selection criteria that can be used in programmatic advertising*

This study proposes a multi-criteria approach in order to identify selection criteria upon which PA managers could evaluate the performance of websites and decide how to allocate their ad impressions and subsequently their investment budget. Data is collected from two sources. Firstly, from the management of a digital marketing agency that participated in our case study. Then data were collected from the agency's PA platform regarding multiple advertisement campaigns that have been run on behalf of a multinational telecommunication company operating in Greece. The data is analyzed by utilizing the FDM and FAHP multicriteria analysis methods. In recent years, many researchers adopted Multi-Criteria Decision Making (MCDM) approaches for solving problems such as assessing alternative solutions, selection problems, strategic analysis [13]-[18] etc. The steps of the proposed methodology adopted follow.

Step 1: Collect data from the management team of the digital marketing agency in Greece. The collected data refers to the management perspective of what selection criteria should be used in PA decision making. The agency manages traffic data for one its customer a big multinational telecommunication company. A group of five (5) managers, dealing with digital marketing and programmatic advertising, had agreed to participate in our study. At first, the managers were introduced to the topic of this research they were informed about procedures regarding their involvement and the methods to be used. Next, the managers were asked to review the data (variables) that were retrieved from a PA platform that the agency uses to follow the performance of advertisement campaigns. Next, they were asked to select a list of variables they would consider most important. The FDM [19]-[21] was utilized in order to prioritize and finally select managers' suggestions. The linguistic variables and corresponding Triangular Fuzzy Numbers (TFNs) that were used in FDM, for the managers to express their priorities are shown in Table I:

TABLE I. THE LINGUSTIC SCALES AND CORRESPONDING TFNS USED IN FDM

Linguistic scale	Triangular fuzzy reciprocal scale
Not Important	(0,1,3)
Somewhat Important	(1,3,5)
Important	(3,5,7)
Very Important	(5,7,9)
Extremely Important	(7,9,10)

The linguistic scale for the FDM was adopted by Sun [22]. The final list of parameters as resulted from the FDM is shown in Table II:

TABLE II. THE MANAGEMENT CRITERIA RELATED TO THE WEBSITES SELECTION DURING THE PA DECISION PROCESS

The management team Criteria as identified from the FDM
Served impressions
Total Recordable Impressions (video msg)
Total Viewable Impressions
Unique Impressions
Interactions
Clicks
Unique Interacting Users
Unique Clicking Users
Unique Browsers/Users
Page Views

A FAHP questionnaire was then developed and sent to five managers of the agency that participated in this case study. The questionnaire consisted of questions that referred to the relative importance of the selected criteria as perceived by the each one of the managers. The linguistic variables and corresponding (TFNs) that were used in FAHP, for the managers to express their beliefs are shown in Table III:

TABLE III. THE LINGUSTIC SCALES AND CORRESPONDING TFNS USED IN FAHP

Linguistic scale	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Equally important	(1, 1, 1)	(1, 1, 1)
Weakly important	(2/3, 1, 3/2)	(2/3, 1, 3/2)
Fairly more important	(3/2, 2, 5/2)	(2/5, 1/2, 2/3)
Strongly more important	(5/2, 3, 7/2)	(2/7, 1/3, 2/5)
Extremely more important	(7/2, 4, 9/2)	(2/9, 1/ 4, 2/7)

The linguistic scale was adopted by Kilincci et al. [23] and Lee et al. [24]. With respect to sample sizes used in AHP or FAHP, expert group sizes range from 1 in [23] to 5 in [25], 9 in [26] and 24 experts in [24]. The sample size of five is therefore adequate for applying FAHP.

Step 2: Apply FAHP and construct the hierarchical model for websites selection.

Step 3: Collect data, for to the selection criteria, from the PA platform. Data are then analyzed to assess websites performance.

Step 4: Assess websites performance. Examine the proposed model's validation.

Step 5: Apply similarity methods to identify and recommend investment opportunities in websites that currently are not considered by the agency in the advertisement portfolio of the telecommunication company.

B. The Fuzzy Delphi Method

The FDM has been extensively used in many studies seeking expert consensus on MCDM problems such as developing performance appraisal indicators for mobility of the service industries [12] for logistics and supplier evaluation [27] for lubricant regenerative technology selection [19] and for developing road safety performance indicators [20]. The FDM was proposed by Murry et al. [21] as an integration of fuzzy logic with the traditional Delphi Method [28]. Expert consensus, in MCDM methods such as the FDM or the FAHP, is usually calculated using the geometric mean, which is assumed to capture expert consensus more accurately [12][20][29][30]. This paper uses TFNs with geometric means to represent expert consensus. A TFN is denoted simply as a triple ($l_{i,j}, m_{i,j}, u_{i,j}$), where:

$$l_{i,j} = \min(e_{i,j}) \ , \tag{1}$$

represents the lowest of all experts' judgment,

$$m_{i,j} = \sqrt{\prod_{i=1}^{n} e_{i,j}} \ , \tag{2}$$

is the geometric means of $e_{i,j}$, indicating the aggregation of all experts' judgments, and

$$u_{i,j} = \max(e_{i,j}) , \tag{3}$$

represents the highest of all experts' judgment,

where i =1,…,n and j=1,…,k represent the number of experts and the number of criteria respectively, and the represents the response of the ith expert regarding the jth criterion.

C. The FAHP Method

The FAHP is an extension of Analytic Hierarchy Process (AHP) introduced in [31]. Fuzzy logic is introduced to AHP by utilizing linguistic variables and fuzzy numbers in order to deal with uncertainty in judgments. FAHP prioritizes the relative importance of a list of criteria and sub-criteria through pair-wise comparisons by experts as discussed in[32]. The extent analysis method introduced in [33] is a popular method to solving MCDM problems with FAHP. Assume that $A = (a_{ij})_{nxm}$ is a fuzzy pair-wise comparison judgment matrix and $M = (l, m, u)$ is a Triangular Fuzzy Number (TFN). According to the FAHP, each object is taken and extent analysis for each goal (gi) is performed respectively. Therefore, m extent analysis values for each object can be obtained, with the following notation:

$$M_{g_i}^1, M_{g_i}^2, \ldots, M_{g_i}^m$$

where, i = 1,2,…,n (4)

and all the $M_{g_i}^j (j = 1,2,\ldots,m)$ (j=1,2,…,m) are TFNs. The steps of FAHP are shown below:

Step 1: The value Si of the fuzzy synthetic extent with respect to the ith object is defined as:.

$$S_i = \sum_{j=1}^{m} M_{g_i}^{j} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} \tag{5}$$

$$\text{s.t.} \ \sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{j=1}^{m} l_j , \sum_{j=1}^{m} m_j , \sum_{j=1}^{m} u_j \right) \tag{6}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} = \left(\sum_{i=1}^{n} l_i , \sum_{i=1}^{n} m_i , \sum_{i=1}^{n} u_i \right) \tag{7}$$

Next, compute the inverse of the vector in Eq. (7) such that:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j} \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i} , \frac{1}{\sum_{i=1}^{n} m_i} , \frac{1}{\sum_{i=1}^{n} l_i} \right) \tag{8}$$

The TFN value of $S_i = (l_i, m_i, u_i)$ is calculated using Eqs. (5)-(8).

Step 2: The degree of possibility of $S_j = (l_j, m_j, u_j) \geq S_i = (l_i, m_i, u_i)$ (9) is defined as follows:

$$V(S_j \geq S_i) = \sup_{y \geq x} \left[\min(\mu_{S_i}(x), \mu_{S_j}(y)) \right] \quad (10)$$

which can be equivalently expressed as follows:

$$V(S_j \geq S_i) = height(S_i \cap S_j) = \mu_{S_j}(d)$$

$$= \begin{cases} 1, & if\ m_j \geq m_i \\ 0, & if\ l_i \geq u_j \\ \dfrac{l_i - u_j}{(m_j - u_j) - (m_i - l_i)}, & otherwise \end{cases}$$

where d is the ordinate of the highest intersection point D between μ_{S_i} and μ_{S_j} as shown in Figure 1.

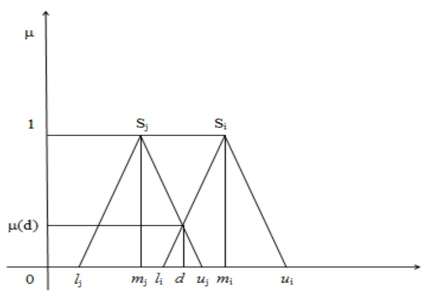

Figure 1. The intersection of μ_{S_i} and μ_{S_j}.

In order to compare the Si and Sj, we need both the values of $V(S_i \geq S_j)$ and $V(S_j \geq S_i)$

Step 3: The minimum degree of possibility for a convex fuzzy number to be greater than k convex fuzzy numbers Si (i = 1, 2,…, k) can be defined by the following equation (11):

$$V(S \geq S_1, S_2, \ldots, S_k) = V[(S \geq S_1) and (S \geq S_2) and \ldots and (S \geq S_k)]$$

$$= \min V(S \geq S_i),\ i = 1,2,3, \ldots k.$$

Assume that

$$d'(A_i) = \min V(S_i \geq S_k), \quad for\ k = 1,2,\ldots,n\ and\ k \neq i$$

Then the weight vector is given by:

$$W' = (d'(A_1), d'(A_2), \ldots, d'(A_n))^T \quad (12)$$

where Ai (i=1,2,…,n) are n elements.

Step 4: Obtain the normalized weight vectors as follows: $W = (d(A_1), d(A_2), \ldots, d(A_n))^T$ (13)

where W is a non-fuzzy number and it represents the priority weights of one alternative over another.

Step 5: Calculating the Consistency Ratio (CR)

The CR is calculated by adopting the approach used in [34], who computed CR for modal values of the fuzzy numbers in the pair-wise matrices.

III. EMPIRICAL STUDY AND DATA ANALYSIS

After all responses from the group of the five managers were collected, the FAHP was applied (eqs. 5-13) returning the importance weights for the selection criteria. The results are shown in Table IV.

TABLE IV. THE SELECTION CRITERIA IMPORTANCE WEIGHTS

The management team Criteria as identified from the FDM	**Weights resulted from FAHP**
Unique Clicking Users	0,199881601
Unique Interacting Users	0,152037255
Clicks	0,143605756
Interactions	0,126324699
Total Viewable Impressions	0,122097554
Unique Browsers/Users	0,069015474
Unique Impressions	0,064870753
Total Recordable Impressions	0,054865414
Served impressions	0,035889417
Page Views	0,031412076

The results show that the agency management was concerned more about the number of users (e.g., clicks unique and interacting users) who were attracted from an ad, than other criteria, e.g., the number of impressions that have been viewed or served. Therefore, the most important key success factor for a digital ad is to firstly attract the attention of the potential customer. Next, the websites were ranked by using advertising campaigns data that were retrieved from the PA platform that the agency had access and the selection criteria weights. The campaigns data measure the performance of every website considered by the agency, in terms of the selection criteria. A sample of the ranking is shown in Table V.

TABLE V. THE WEBSITES RANKING

Website	CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9	CR10	Total
WBS34	0,050951	0,040426	0,033822	0,035183	0,237703	0,027539	0,144043	0,031899	0,047729	0,091641	0,078343
WBS1	0,022802	0,024948	0,03431	0,033572	0,032729	0,121241	0,083735	0,118752	0,019154	0,013645	0,066985
WBS31	0,017084	0,017528	0,02886	0,023843	0,025443	0,105437	0,068137	0,107226	0,019135	0,010507	0,05738

The results indicate the overall ranking as well as the ranking for each individual criterion. So, the agency management could know how each website performed in total and for each individual criterion. Next the websites were grouped in their relevant subject categories. The FAHP

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was then performed to rank the websites by their category. The results are shown in Table VI.

TABLE VI. RANKING WEBSITES BY THEIR RELEVANT SUBJECT CATEGORY

Category	CR1	CR2	CR3	CR4	CR5	CR6	CR7	CR8	CR9	CR10	1
NEWS & INFORMATION	0,5850	0,5136	0,4891	0,4958	0,3333	0,3682	0,3141	0,2984	0,4367	0,4065	0,397939
LIFESTYLE & ENTERTAINMENT	0,1304	0,1671	0,1802	0,1458	0,0303	0,1280	0,1410	0,1775	0,1723	0,1114	0,140187
PORTAL	0,0586	0,0816	0,0901	0,0736	0,3139	0,0220	0,1254	0,0465	0,1324	0,1703	0,11583
WEB TV	0,0416	0,0384	0,0433	0,0400	0,0387	0,2015	0,1674	0,2235	0,0286	0,0164	0,102763
FINANCE	0,0562	0,0824	0,0705	0,0668	0,2096	0,0168	0,0230	0,0157	0,0378	0,0497	0,064086
OTHER	0,0327	0,0434	0,0410	0,0602	0,0155	0,0811	0,0789	0,1131	0,0089	0,0111	0,055892
SPORTS	0,0338	0,0291	0,0349	0,0661	0,0115	0,0604	0,0754	0,0519	0,0819	0,1135	0,05184
FEMALE	0,0344	0,0353	0,0378	0,0371	0,0367	0,0670	0,0555	0,0457	0,0439	0,0290	0,044316
MALE	0,0201	0,0054	0,0079	0,0115	0,0090	0,0476	0,0163	0,0234	0,0099	0,0029	0,01615
PRICE ENGINE	0,0072	0,0038	0,0051	0,0032	0,0014	0,0074	0,0030	0,0042	0,0476	0,0892	0,010998

The results indicate that the best performing campaigns for the telecommunication company were those ran by the agency in the *News and Information* sector, with the *Lifestyle and Entertainment* following second. However, the effectiveness of the investment in advertising depends on the budget that is spent on each website and on each sector. After normalizing the spending the ranking of each website and each sector were recalculated. The results regarding the sectors are shown in Table VII.

TABLE VII. THE COST-BENEFIT CONTRIBUTION OF EACH SECTOR

CATEGORIES	ACTUAL TOTAL CONTRIBUTION INDEX
NEWS & INFORMATION	0,73
LIFESTYLE & ENTERTAINMENT	1,33
PORTAL	0,86
WEB TV	2,66
SPORTS	2,64
FEMALE	1,37
FINANCE	1,04
MALE	3,11
PRICE ENGINE	4,82
OTHER	3,48

By taking into account the budget spent for advertising in each sector, the ranking changes. So, despite the *News and Information* sector's achievement to outperform all the other sectors, the amount of money that was spent for advertising in this sector seems to be larger than it should be being disproportioned with the sectors performance results.

The websites evaluation based on the selection criteria as well as on the advertising budget, does not highlights the best performing sites but it also reveals investment opportunities. By calculating the Chi-Square similarity method as discussed in [35], websites of similar performance but with much lower level of investments may represent a promising alternative for advertising. This study analyzed data from 123 websites. So, the resulting similarity matrix is (123x123) matrix. The values in the matrix show how much a website is similar to all the rest. The closer the value is to +1, the more similar the websites are. On contrary, values closer to -1, indicate dissimilarity. The sample of the similarity matrix shown in Table VIII indicates that WS1 Website is very much similar to WS8 with a similarity degree of 0.946.

TABLE VIII. THE SIMILARITY AMONG WEBSITES

	WS1	WS2	WS3	WS4	WS5	WS6	WS7	WS8
WS1	1	0,575793	-0,47329	0,492775	0,62571	0,449098	0,387247	0,946222
WS2	0,575793	1	-0,29653	0,357916	0,148567	0,305917	0,568012	0,647365
WS3	-0,47329	-0,29653	1	-0,28154	-0,48859	0,408093	-0,34409	-0,44875

If the advertising spending on the WS1 and WS8 is far apart then an investment opportunity is worth considering. Assuming that the budget spent on WS1 is much lower that the WS8, then the WS1 is already a promising alternative for serving impressions.

IV. CONCLUSIONS AND FUTURE WORK

Programmatic advertising and digital marketing attract a lot of attention since the focus of interacting with customers is already shifted on digital channels. Web analytics and PA platforms play an important role in assessing the effectiveness of digital marketing. Challenging decisions should be made by management teams when devising an advertising plan. There are millions of websites and other digital channels that need to be considered for serving impressions. Currently, analytics tools do not provide a comprehensive list of parameters to consider and analyze in PA related decision making. This study by utilizing multicriteria methods, such as the FDM and the FAHP, proposes a methodology to identify and analyze the relative importance of websites selection criteria and use them in developing a hierarchical model that could assist decision making in the PA. This research also suggests that similarity methods can be utilized to highlight investments opportunities in an attempt to assist PA management to revise their options. Furthermore, this research suggests that, Web analytics tools should improve their functionality by combining MCDM methods, in order to enhance their value in assessing digital marketing strategies.

Future research should focus on developing methods and tools that take into consideration time-dependent factors in a real-time manner and develop the required functionality in analyzing and managing the interactions among investment performance and customer interactions.

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