

AHP AND DEA: AN ALTERNATIVE APPROACH TO EVALUATING ONLINE REVIEWS

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ABSTRACT

The use of the Internet and its applications has radically transformed the ways in which consumers communicate, obtain information and make purchasing decisions. This work aims to identify innovative solutions to facilitate and make the process of searching and booking restaurant services by users who use digital platforms more efficient. The main objective is to analyze the intrinsic complexity of the user's decision-making process, highlighting the main critical issues and difficulties with perception and possible information distortions, in order to design a support tool capable of offering a highly personalized and high-quality choice experience. The contribution proposes an advanced decision-making model that integrates the use of two multi-criteria methodologies: the Analytic Hierarchy Process (AHP) and the Data Envelopment Analysis (DEA). These tools make it possible to simultaneously consider a multiplicity of qualitative and quantitative criteria, configuring an evaluation much more adherent to the real preferences of users. The combined adoption of these two approaches constitutes a methodological innovation capable of providing each user with a dynamic, personalized and efficient search path, significantly improving the quality of decisions and the level of perceived satisfaction. This model, which overcomes the limitations of traditional recommendation systems based on simple averages is proposed as a reference tool for the design of online platforms dedicated to catering, with potential extensions to other service sectors.

Keywords: multi-criteria methods; AHP; DEA; efficiency; customer satisfaction

1. Introduction

In recent years, the restaurant industry has undergone a digital revolution, which is radically transforming the way restaurants operate and interact with customers who have changed their purchasing habits. Online booking channels have developed to meet customer needs and offer personalized dining experiences. The Internet has increased consumers' organizational freedom and independence and made access to information quick and easy for everyone. This information not only comes from professional channels managed by restaurateurs who give their customers the opportunity to review their restaurant, making this information freely and quickly available to any visitor to the portal but, also from portals managed directly by users (Crouch & Brent Ritchie, 1997). Social media, or virtual networks, are structured around discussions and blogs that are accessible to everyone without registration and free of charge. A growing number of

individuals within these online platforms share their stories and exchange ideas, experiences, and opinions, sometimes without any selection criteria.. It is clear that the new “do-it-yourself” user finds reassurance in the knowledge of other consumers’ experiences. This is why review sites are becoming increasingly popular, as they offer the possibility of providing users with a complete and more personalized service and of understanding trends and habits of travelers from all over the world. They help travelers become real foodies by providing them with a wide selection of restaurants. The study examines the effects of using two multi-criteria methods, Data Envelopment Analysis (DEA) and Analytical Hierarchy Process (AHP), to choose the best alternative. These methods offer a different way of approaching the problem and propose an alternative evaluation method to those used by various review sites. In particular, the use of DEA is suggested (Charnes et al., 1978); its application could be used by the portals themselves as an additional service for their customers, helping them choose and book a restaurant, and by an external portal that compares the performance of the different restaurants present on the network. The study aims to examine the decision-making process in its complexity, highlighting the problems and critical issues that emerge, in particular in cases where the perceived risk of error is high, as in the case of purchasing goods or services; and provide a completely personalized user experience. In the literature, decision-making processes have been proposed that can be useful and fast; however, these methods do not take into account the needs and priorities of each user. These methods are based on the objective calculation of the efficiencies of each restaurant offer (Vincova, 2005).

In this study, the first analysis concerns the application of the “AHP-DEA”. In other words, the AHP is applied among the choice alternatives to determine those that satisfy the specific needs and priorities of the decision maker (Enea et al., 2001), specifically, the needs and specificities of two types of users, lazy or enterprising. To highlight any discrepancies between the final results of the comparison, the needs and priorities of the two subjects were voluntarily chosen in an antithetical way. After obtaining the ranking for the two types of users, DEA was applied to determine the real efficiency of each of the restaurants examined.

The second analysis involves the application of the “DEA-AHP” approach; therefore, the DEA is calculated first and then the AHP. In this case, it is assumed that there is a priority need to identify efficient alternatives at a general and objective level (through the DEA), thus allowing an initial screening among the initial alternatives, and subsequently implementing a more subjective distinction.

The difference between the two methods is not only the order in which they are used, but also the gradual selection process. In the first approach, the primary AHP does not reduce the number of alternatives, but adds information and data that characterize each alternative, so that the calculation of the DEA takes into account the specific needs of the decision maker. In the second case, the DEA allows for an initial screening, which is subsequently completed by the results of the AHP. The combination of these two methods provides effective solutions that take into account the unique needs of each user. Despite this, the “DEA-AHP” application mode proved to be the most intriguing and effective because it highlighted a single solution, distinguished according to the specific needs of each user.

2. Materials and methods

2.1 Literature review

Many papers with recent applications concern integrated approaches of the AHP and DEA (AHP/DEA and DEA/AHP). Today's changing business landscapes require the most efficient and effective ways to manage an organization's operations in every application area of multi-criteria decision making (MCDM). Measuring and optimizing performance and efficiency requires AHP/DEA integration. Apart from this, it can be used to measure and rank various products or services in any industry, such as on review sites, in manufacturing, in politics, for management and so on. Numerous researchers have studied levels of efficiency, quality, performance and rank; the AHP and DEA are just two of the many techniques and tools that have been used. Shirouyehzad et al. (2013) presented a study regarding an integrated method based on the AHP and DEA to classify service units considering service quality dimensions. Customer perceptions are one output and five service quality gaps are the inputs in the proposed DEA model. Experts completed a pairwise comparison questionnaire in order to establish the weights of the input criteria. Lastly, the approach to service quality and the suggested integrated DEA/AHP model were used to calculate the hotel ranking. Ar and Kurtaran (2013) suggested a study that used an integrated method that incorporates DEA and the AHP to analyze the relative efficiency of 13 commercial banks in Turkey for the year 2011. In terms of production technique, it employed two inputs (number of branches and personnel expenses) and four outputs (deposits in national currency, deposits in foreign currency and precious metal, cash loans, and non-cash loans). Empirical findings indicated that state-owned commercial banks are effective in both the Banker-Charnes-Cooper (BCC) and CCR (Charnes-Cooper-Rhodes) models. According to the findings, inefficient banks should concentrate on reducing their annual staff costs and enhancing their non-cash lending in particular. Furthermore, scale inefficiency affects more than half of the commercial banks. Sueyoshi et al. (2009) solved the problem of selecting and evaluating important business units in a car rental company by combining the results of DEA and AHP. Ramanathan (2006) proposed DEA to demonstrate performance evaluation and efficiency measurement in several examples. In this study, DEA was used to define the local weights of alternatives from the pairwise comparison judgment matrices used in the AHP. Mahapatra et al. (2015) used a unique method to evaluate an organization's performance by combining DEA and the AHP. The model overcomes the limitations of both methods without altering their characteristics. This strategy reduces the inefficiency of the DEA in classification and allows it to classify all Decision Making Units (DMUs) under consideration. Finally, the article presented an appropriate example of an Indian integrated steel mill using the proposed model to measure organizational performance. In order to assess the bridge hazards associated with hundreds or thousands of bridge structures, Wang et al. (2008) offered an integrated AHP–DEA approach. This methodology was used to determine the bridge structures' maintenance priorities. The proposed AHP–DEA methodology employed the following techniques: DEA to ascertain the values of the linguistic terms; simple additive weighting (SAW) to aggregate bridge risks under various criteria into an overall risk score for each bridge structure; and the AHP to determine the weights of criteria. A two-stage model for fully rating organizational units with numerous inputs and outputs was presented by Sinuany-Stern et al. (2000). The DEA was performed independently for every pair of units in the first step. Using the pairwise evaluation matrix created in the first stage, the units were ranked scaled using the AHP in the second stage. One can statistically test the consistency of this

AHP/DEA evaluation. Non-parametric tests can be used to assess the goodness of fit with the DEA categorization (to efficient/inefficient). A combination of the AHP and DEA was proposed for the assessment of the efficiency of R&D management activities in universities by Feng et al. (2004) in an effort to develop a better tool for the assessment of the management performance of R&D activities in research-oriented universities. To address a plant layout design problem, Yang and Kuo (2003) suggested an AHP and DEA approach. Quantitative DMU outputs and a large number of layout choices were produced using a computer aided layout-planning program. The AHP was used to weight the qualitative performance criteria. Next, the multiple-objective layout problem was solved using DEA. An integrated robust DEA-AHP was presented by Foroughi and Esfahani (2012) to assess the relative efficiency of comparable units. When compared to the exclusive use of DEA or the AHP, the suggested methodology is thought to be able to provide more efficient results. A real-world case study of the airport business was used to illustrate how the suggested model was implemented. Finally, a study incorporating DEA and the AHP was proposed by Lin et al. (2011) as a means of assessing the economic development attained by Chinese local governments. The suggested DEA/AHP integrated model has the ability to rank and assess various options. Furthermore, the Malmquist productivity index (MPI) was used to compare the economic performances of Chinese local governments over a period of time, and the results showed a trend toward economic growth.

2.2 AHP model

The AHP method is one of the most popular multi-criteria decision-making models in recent years. It was created by Thomas Saaty in the 1970s in response to the need to find a uniformly shared strategy that could solve decision-making problems in situations where information, criteria and decision-makers were very different and difficult to combine. Saaty wanted to create an automatic and simple decision-making and weighting process; in fact, the AHP focuses on goal grouping and when used, leads to rational decisions (Ishizaka & Labib, 2011). The method breaks down the decision-making problem into a hierarchical structure that underlines the relationship between the goal (or general purpose), the objectives (or criteria) and the choice of alternatives.

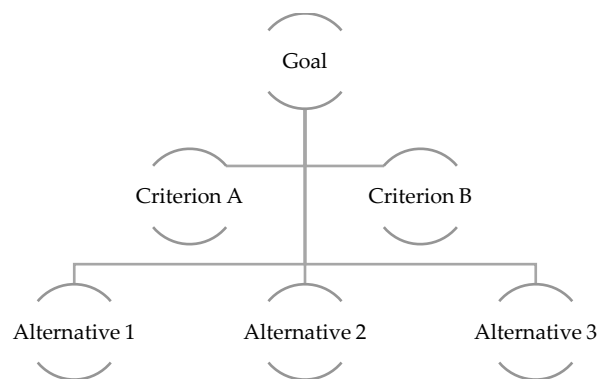


Figure 1 AHP hierarchical structure

Another important feature of the AHP method is that it allows decision makers to construct weights rather than assigning them arbitrarily (Ishizaka & Nemery, 2013). The method uses pairwise comparisons (between alternatives to the criteria and between

criteria to the overall goal) and produces a measure of the consistency of these comparative judgments. A significant aspect of the process is the measurement of consistency. The pairwise comparison used in the AHP method is based on the rating scale proposed by Thomas Saaty (1977), which includes both verbal and numerical comparative methods.

Table 1
Saaty scale

Saaty scale	Equivalent verbal description	Interpretation
1	Equally important	Two elements contribute equally to the goal
3	Moderately more important	One element is more favorable than the other
5	Much more important	One element is strongly favored
7	Strongly much more important	One element is strongly dominant over the other
9	Extremely more important	Extreme advantage of one element over the other
2, 4, 6, 8	Intermediate values	Possibly used to indicate a value between two judgments

The verbal component of the Saaty scale not only helps find the true value of the numerical scale, but also makes it easier for a non-expert decision maker to compare pairs. It is clear that verbal judgments are fundamental to decision-making processes because humans are accustomed to using verbal expressions to measure the intensity of preferences with respect to a property of the object in question (Forman & Peniwati, 1998). Asking the decision maker for a non-generic judgment, but one relating to a specific objective, is another characteristic of the pairwise comparison proposed by the AHP. In fact, it is possible to determine the weight to assign to each alternative with respect to a certain criterion or with respect to the general objective using pairwise comparisons. To achieve this, you need to transfer the comparison pair data into a symmetric square matrix:

	A_1	A_2	A_j	...	A_n
A_1	a_{11}	a_{12}	a_{1j}	...	a_{1n}
A_2	a_{21}	a_{22}	a_{2j}	...	a_{2n}
A_i	a_{i1}	a_{i2}	a_{ij}	...	a_{in}
...	...	...	...	...	...
A_n	a_{n1}	a_{n2}	a_{nj}	...	1

where a_{ij} is the value coefficient, of the Saaty scale, which describes the importance of the alternative A_i compared to A_j . Note that if the attribute A_j in the column is judged to be more important than the attribute A_i in the row, then, given the value a_{ij} , we set $a_{ji} = 1/a_{ij}$. A matrix is therefore defined as consistent such that (Greco et al., 2019):

$$a_{ij} = \frac{1}{a_{ji}} \text{ for every } i \text{ and every } j \text{ where } a_{ii} = 1$$

$$a_{ij} = a_{ik} \cdot a_{kj} \text{ for every } i, \text{ every } k \text{ and every } j$$

The measure of how consistent the judgments expressed in a matrix are is obtained by evaluating the main eigenvalue λ_{max} of the matrix (Cavallo & D'Apuzzo, 2009). The difference between λ_{max} and n measures the actual consistency of the matrix; more precisely, consistency is generally evaluated by means of the Consistency Index (CI):

$$CI = \frac{(\lambda_{max} - n)}{(n-1)} \quad (1)$$

If $CI = 0$, i.e. $\lambda_{max} = n$, A is consistent; while if $CI > 0$, then the matrix is inconsistent (Brunelli & Cavallo, 2020).

As for the procedure for determining the vector of weights to be associated with the alternatives, a main eigenvector of the matrix A is considered, i.e. an eigenvector of A corresponding to the eigenvalue λ_{max} . Once normalized, this eigenvector provides the eigenvector of the weights w that best fits the comparative evaluations contained in A. From a practical point of view, it is possible to determine reasonable approximations of both w and λ_{max} as follows. To determine w it is sufficient to normalize each column of A to 1 and consider the averages per row. Once the approximation of the main eigenvector has been obtained, using the condition $Aw = \lambda w$, we have n approximations of λ_{max} (one for each row). The average of these approximations will constitute a valid approximation of λ_{max} (Saaty, 2003).

2.3 DEA model

The DEA offers a rating that is based on efficiency. It was first presented in 1978 by Charnes, Cooper and Rhodes (1994). It proposes an objective method to evaluate the

efficiency of a production unit (also known as a “DMU” or Decision Making Unit) relative to a given set of production units chosen for comparison. The process starts with the assumption that each production unit is composed of a flow of inputs and outputs; the former are made up of the resources used in production, while the latter are made up of the results of production. For comparison, the group of units must satisfy certain characteristics of homogeneity, autonomy and independence. In particular, inputs and outputs must be consistent with each other, each unit must have the same type of resources and results; what changes is, in general, the quantity of both. The independence constraint requires that each DMU produces independently of the other comparison DMUs (Moriarty & Bateson, 1982). This means that their processes do not have to be linked to each other, for example, it is not possible for one unit to power another. Each DMU must also be able to manage its production process autonomously. The concept of efficiency must be clarified before talking about DEA. Measuring the efficiency of an economic entity means evaluating its ability to transform inputs into outputs. It can be calculated in absolute terms or by comparing it with that of the other decision-making units in question (Yu et al., 1996). Absolute efficiency is the ratio between input and output, that is, between results and the resources needed to produce them, when a single resource is used in quantity z and a single type of output is produced in quantity k :

$$E_a = \frac{k}{z} \quad (2)$$

Instead, relative efficiency is measured by comparing the absolute efficiencies of all DMUs in question. This process also helps find the highest relative efficiency, which can serve as a comparison for other DMUs. A relative efficiency measure for each unit j where $j: (1, 2, \dots, n)$ is given by:

$$e_j = \frac{E_j}{E^*} \quad (3)$$

where $E^* = \max_j E_j$; also, note that dividing each absolute efficiency by the maximum efficiency normalizes all relative efficiencies to one (Mardani et al., 2017).

So far, the problem of economic entities with only one input and one output has been considered. However, these cases are rare. The analysis of DMUs with multiple inputs and outputs is more realistic. In this case, each of the m decision-making units DMU_j ($j = 1, 2, \dots, m$) must be considered as a set of n inputs, indicated with $i = 1, 2, \dots, n$, to produce t outputs, indicated with $o = 1, 2, \dots, t$. In this case, the comparison between efficiencies is no longer so simple. In reference to the o -th output produced and the i -th input used to produce it, it is necessary to introduce weights w_o and u_i , respectively, to highlight the importance that each input and each output assume in the production process, of a unit decision-making (Su, 2024). If we indicate with z_{ij} the quantity of the i -th input used by the j -th unit and with k_{oj} the quantity of the o -th output produced by the j -th economic unit, it is possible to define a “global” output in which all the outputs produced by the j -th economic entity are included (Liu et al., 2010), considered with their relative importance, and a “global” input which includes all the inputs to the j -th economic entity, considered with their criticality:

$$O_j = \sum_{o=1}^t w_o k_{oj} \quad (4)$$

$$I_j = \sum_{i=1}^m u_i z_{ij} \quad (5)$$

A new efficiency index can then be defined for the j -th economic entity which takes into account the weight vectors w and u (Amirteimoori & Kordrostami, 2005):

$$E_j(w, u) = E_j(w_1, \dots, w_t, u_1, \dots, u_m) = \frac{\sum_{o=1}^t w_o k_{oj}}{\sum_{i=1}^m u_i z_{ij}} = \frac{O_j}{I_j} \quad (6)$$

with $j = 1, 2, \dots, n$.

Once all the $E_j(w, u)$ have been calculated, the relative efficiencies are compared and identified; in this case, however, it is necessary that the weights are the same for all economic entities, given the homogeneity constraint, the lack of which would nullify the comparison.

2.4 CCR model

The DEA offers a variety of models for determining appropriate weights; the most famous of these is the CCR, which was created by Charles, Cooper and Rogers (1978). This type of model was used for the first time in 1978 to adapt the measure of technical efficiency (single output/single input), designed by Farrel (1957) to cases with multiple outputs and inputs. In addition to the characteristics of homogeneity and independence, it is essential that the definition of the inputs and outputs is correct so that they include all the relevant activities of the DMUs taken into consideration in the calculation of the efficiencies proposed by the CCR model (Pokushko et al., 2025). The CCR model aims to determine the factors that improve the efficiency of each DMU; once found, the model allows the DMU to be declared inefficient because, despite the use of the “most favorable” weights, it has obtained a relatively lower efficiency compared to even just one of the relative efficiencies of the other DMUs calculated with these weights. Charles, Cooper and Rogers therefore consider the following maximization problem; where the subscript “0” indicates the DMU under examination (Charnes et al., 1994):

$$\max e_0(w, u) = \frac{E_0(w, u)}{E^*(w, u)} \quad (7)$$

where $E^* = \max_j E_j(w, u)$ and $0 \leq e_0(w, u) \leq 1$.

If the maximum efficiency of the DMU considered (DMU_0), calculated with the most favorable weights, is less than 1, it means that there is at least one other unit that manages to produce more with the same resources or consume less with the same results. It can be shown how Equation 7 can be rewritten as follows; the weights w_o^* and u_i^* the relative efficiency e_0^* are obtained as the optimal solution by solving the CCR problem. If $e_0^* < 1$ the DMU is not efficient, it means that there is another unit that has a relative efficiency greater than or equal to 1, despite weights that favor the first unit (Tone, 2001).

$$CCR: \max e_0 = \frac{\sum_{o=1}^t w_o k_{o0}}{\sum_{i=1}^m u_i z_{i0}} \quad (8)$$

$$\frac{\sum_{o=1}^t w_o k_{o0}}{\sum_{i=1}^m u_i z_{i0}} \leq 1 \quad \forall j = 1, 2, \dots, n$$

$$w_o, u_i \geq 0 \quad \forall o = 1, 2, \dots, t; \forall i = 1, 2, \dots, m.$$

3. Results

3.1 Data

The goal is to be able to show the user the restaurant that offers the best quality/price ratio; it is an objective and comparative search between proposals from multiple review sites. It is important to specify that there are already online portals that offer this comparison for free allowing the user to choose the one that is the most convenient; however, these are based only on the price. This study proposes a comparison based on the quality/price ratio of each establishment. Through one of these existing sites for online comparison, the search for the best portal was started, among The Fork, OpenTable, MyTable, that offers the best price for each establishment. The search was carried out based on the following characteristics:

- Location: Rome
- Average price: between 80 and 200 euros
- Dietary needs: mediterranean diet
- Period of stay: dinner on April 25, 2024, for two people

The reference sample consisted of about 30 subjects, with different demographic, geographic and behavioral characteristics. They were asked to judge a generic future dinner, regarding what they would have liked the offer to guarantee them. A questionnaire was used, in which the first question served to classify the user as lazy or enterprising. Then, each decision maker was asked to answer, using the Saaty scale, other questions. It is important to highlight that the method of predefined differential classes was applied to the case study to complete the decision-making process of the AHP. In fact, appropriate ranges of values were defined that arbitrarily defined predefined differential classes and their corresponding evaluation in the Saaty scale. The choice to use ranges of values corresponding to predefined categories was made for two main reasons. The first is because this method was preferred to a comparison based on the relative difference between one alternative and another. It has in fact been found that a comparison of alternatives based on each criterion that is based on percentage differences and not on absolute differences, does not effectively achieve the objective of the comparison itself. The second reason we chose to use a comparison with predefined differential classes was to avoid the criticism raised against the AHP method which is called rank reversal. To overcome this criticism, Thomas Saaty stated that to avoid this limitation of the scale one must use predefined differential classes in the pairwise comparison (Saaty, 1987). The method has the advantage of reducing the number of comparisons required, but above all, each time a new alternative is inserted to be evaluated, the estimate can be carried out simply by calculating the difference between this and the other possible choices, thus not requiring a recalculation of all the alternatives among themselves. The disadvantage of the method, however, lies in the arbitrariness of the classes; by modifying, even slightly, the differential margins, the evaluation of the alternatives can change significantly.

From the resulting alternatives, 10 were identified as having a good average rating, a number of reviewers greater than one hundred and a different number of stars. Table 2 shows the data for calculating the DEA method. For each restaurant, the best price is indicated (which constitutes the input), the review site that offers it and the average rating expressed by guests via The Fork, OpenTable, and MyTable portals (representing the outputs).

Table 2
Data for the application of AHP and DEA

Restaurant (including stars)	Best price	Average rating The Fork	Average rating MyTable	Average rating OpenTable
TAKO **	€110	7.1	3.6	4.3
Sospiro Trastevere **	€121	7.2	3.4	3.7
Osteria degli stolti ***	€156	8.6	3.5	4.5
Mille 13 Bistrò ***	€155	7.8	3.7	4.8
Il Forchettone ****	€192	7.3	3.8	4.5
Civico 2 ***	€136	8.2	4.3	4.5
Condominio Marconi ***	€117	8.4	4.2	5.2
The Vista Rooftop ****	€144	8.4	4.8	5.2
Vitti il Ristorante ****	€121	8.2	3.8	5
Santinumi *****	€131	7.6	4.2	5.2

3.2 AHP-DEA model

The AHP method was applied so that the priorities relating to a particular type of user could be identified. The comparison between alternatives involved comparing the opinions obtained on The Fork for each criteria (cuisine, service, atmosphere, waiting times, noise and quality-price ratio), combining them with the specific priorities and preferences provided by the individual decision maker, and considering the vector of weights obtained both on the basis of the priorities expressed by a hypothetical “lazy foodie” (Table 3) and hypothetical “enterprising foodie” (Table 4).

Table 3
Hypothetical “lazy foodie” priorities

	Cuisine	Service	Ambience	Waiting time	Noise	Quality/Price	Weight vector
Cuisine	1	7	9	3	9	1	0.368
Service		1	3	0.2	1	0.11	0.067
Ambience			1	1	7	0.33	0.085
Waiting time				1	9	1	0.212
Noise					1	0.11	0.024
Quality/Price						1	0,243

Table 4
Hypothetical “enterprising foodie” priorities

	Cuisine	Service	Ambience	Waiting time	Noise	Quality/Price	Weight vector
Cuisine	1	0.2	0.2	1	0.2	1	0.066
Service		1	1	5	5	1	0.275
Ambience			1	5	5	1	0.275
Waiting time				1	1	0.2	0.055
Noise					1	0.2	0.087
Quality/Price						1	0.243

The matrices are based on the Saaty scale and through this data it was possible to obtain the respective weight vectors for each user. Once the importance attributed by each user to the individual items was calculated, the restaurants taken into consideration were compared using pairwise comparison matrices based on each evaluation item. This means that the scores in Table 5 must be reported on a scale between 1/9 and 9 as proposed by Saaty. Table 6 shows the matrix of pairwise comparisons regarding the first evaluation item considered, i.e. “cuisine”; Table 7 indicates the vector of weights obtained.

Table 5
Average ratings for each item on The Fork

Alternatives	Restaurants	Cuisine	Service	Ambience	Waiting time	Noise	Quality/Price
A	Santinumi ****	8.3	7.2	8.6	7	8.1	5.8
B	Vitti il Ristorante ****	9.2	8.5	7	8.1	8	7.9
C	The Vista Rooftop ****	9	8.6	7.8	8.3	8.6	7.8
D	Condominio Marconi ***	8.8	8.6	8.6	8.3	8.1	7.9
E	Civico 2 ***	8.6	7.4	9.6	7.8	8.3	7
F	Il Forchettone ****	7.8	6.6	8.8	7	7.7	6.3
G	Mille 13 Bistrò ***	8.6	7.5	7.9	6.9	7.4	6.5
H	Osteria degli stolti ***	9.3	8.2	8.9	8.3	9	7.7
I	Sospiro Trastevere **	7.2	6.1	8.6	6.3	7.7	7
L	TAKO **	6.8	6	8.7	6.2	8	7.2

Table 6
Matrix of pairwise comparisons regarding “cuisine”

Cuisine	A	B	C	D	E	F	G	H	I	L
A	1	0.2	0.2	0.2	0.333	3	0.333	0.2	5	7
B		1	3	3	3	7	3	0.33	9	9
C			1	3	3	7	3	0.33	9	9
D				1	3	5	3	0.33	9	9
E					1	5	1	0.2	7	9
F						1	0.2	0.33	3	5
G							1	0.2	7	9
H								1	9	9
I									1	3
L	<i>Incos. 0.09</i>									1

Table 7
Vector of “cuisine” weights

Cuisine	A	B	C	D	E	F	G	H	I	L
Weight vector	0.043	0.199	0.16	0.123	0.076	0.03	0.076	0.266	0.015	0.011

Below are the comparison matrices relating to each criterion (cuisine, service, atmosphere, waiting times, noise and quality-price), calculated with the AHP method. See also Table A1 in Appendix 1. Once the vector of the weights of each pairwise comparison matrix was obtained regarding each criterion or evaluation item (cuisine, service, atmosphere, waiting times, noise and quality-price ratio), it was multiplied by both the vector of the priorities of the “lazy foodie” and the “enterprising foodie”. The results of the AHP method are presented in Table 8.

Table 8
Assigned priorities of the “lazy” and “enterprising” foodie

Foodie	A	B	C	D	E	F	G	H	I	L
Enterprising	0.075	0.159	0.159	0.161	0.106	0.048	0.086	0.152	0.033	0.019
Lazy	0.063	0.175	0.162	0.155	0.092	0.042	0.074	0.183	0.033	0.019

Limiting ourselves to the results obtained through the AHP method (D’Apuzzo et al., 2009), different rankings were found for the two types of users. For the more dynamic user (enterprising), the best restaurant is D, i.e. Condominio Marconi, while for the more sedentary user (lazy) the most suitable is the Osteria degli stolti. To estimate the actual efficiency of each of the restaurants examined, the DEA method was applied at this point. The scores obtained from each alternative were then inserted into the efficiency calculation. The DEA method was applied by considering, among the outputs, the one consisting of the scores of each restaurant based on the preferences of the “lazy foodie” (Table 9), and by analyzing those resulting from the priorities of the “enterprising foodie” (Table 10). They are considered as outputs (the number of stars, the average rating of 3 review sites and the AHP score) and as inputs (the price).

Table 9
“Lazy foodie”: Output and input for DEA application

Alternatives	Restaurants	AHP Score	Average rating TheFork	Average rating MyTable	Average rating OpenTable	Best Price
A	Santinumi ****	0.063	7.6	4.2	5.2	€131
B	Vitti il Ristorante ****	0.175	8.2	3.8	5	€121
C	The Vista Rooftop ****	0.165	8.4	4.8	5.2	€144
D	Condominio Marconi ***	0.159	8.4	4.2	5.2	€117
E	Civico 2 ****	0.093	8.2	4.3	4.5	€136
F	Il Forchettone ****	0.041	7.3	3.8	4.5	€192
G	Mille 13 Bistrò ***	0.075	7.8	3.7	4.8	€155
H	Osteria degli stolti ***	0.179	8.6	3.5	4.5	€156
I	Sospiro Trastevere **	0.032	7.2	3.4	3.7	€121
L	TAKO **	0.018	7.1	3.6	4.3	€110

Table 10
 “Enterprising foodie”: Output and input for DEA application

Alternatives	Restaurants	AHP score	Average rating TheFork	Average rating MyTable	Average rating OpenTable	Best price
A	Santinumi ****	0.075	7.6	4.2	5.2	€131
B	Vitti il Ristorante ****	0.158	8.2	3.8	5	€121
C	The Vista Rooftop ****	0.159	8.4	4.8	5.2	€144
D	Condominio Marconi ***	0.161	8.4	4.2	5.2	€117
E	Civico 2 ****	0.106	8.2	4.3	4.5	€136
F	Il Forchettone ****	0.048	7.3	3.8	4.5	€192
G	Mille 13 Bistrò ***	0.087	7.8	3.7	4.8	€155
H	Osteria degli stolti ***	0.152	8.6	3.5	4.5	€156
I	Sospiro Trastevere **	0.033	7.2	3.4	3.7	€121
L	TAKO **	0.019	7.1	3.6	4.3	€110

Table 11
DEA scores for both users

Restaurants	Lazy user score	Enterprising user score
Condominio Marconi ***	1	1
Vitti il Ristorante ****	1	0.959
The Vista Rooftop ****	0.959	0.955
TAKO **	0.950	0.951
Santinumi ****	0.907	0.908
Civico 2 ***	0.888	0.889
Sospiro Trastevere **	0.817	0.818
Osteria degli stolti ***	0.809	0.769
Mille 13 Bistrò ***	0.722	0.722
Il Forchettone ****	0.548	0.549

The application of DEA has allowed greater differentiation regarding efficient solutions for both the lazy user and the enterprising user. The application of this first approach did not allow a ranking of the alternatives, since the scores obtained showed only one efficient alternative (Table 11). However, a constraint remains in the DEA's methodological process; the number of alternatives is often too vast to guarantee the user an efficient service.

3.3 DEA-AHP model

A second method of combining the two techniques was applied, namely the "DEA-AHP" approach, which involves calculating the DEA and then the AHP. Starting from the data in Table 2, Table 12 shows 4 restaurants found to be efficient according to the application of the DEA model. These restaurants show different characteristics both in price and in average rating. The TAKO restaurant, for example, despite only having two stars, is as efficient as the Vitti il Ristorante which has four, or the Marconi Condominium which has three. This is due to the fact that this lack of quality is compensated for by a lower price; in fact, the TAKO restaurant appears to be the restaurant that offers the lowest price (Table 2). In the case of The Vista Rooftop, despite having a higher price (with the same stars) than the Santinumi, it is more efficient than the latter which is because it has a better web reputation, which increases the weight and compensates for a greater expense required for the service.

Table 12
Ranking of efficiency calculated using DEA

Ranking	DMU	Efficiency score
I	TAKO **	1
I	Condominio Marconi***	1
I	Vitti il Ristorante****	1
I	The Vista Rooftop****	1
V	Santinum	0.973
VI	Civico 2	0.889
VII	Sospiro Trastevere	0.936
VIII	Osteria degli stolti	0.769
IX	Mille 13 Bistrò	0.731
X	Il Forchettone	0.629

The AHP calculation was applied only to these efficient restaurants (Table 13); in Appendix A, Table A2 shows the pairwise comparison matrices for each criterion and then the calculation of their weights. As already shown in Table 5, the average scores for each evaluation item (present on The Fork portal) were considered as if they were the criteria of the AHP hierarchy. Afterwards, the priorities of the two foodies (lazy and enterprising) already used previously are reused (Tables 3 and 4). The synthetic priorities reported in Table 14 are then obtained.

Table 13
Average ratings of CCR-efficient alternatives

Restaurants	Cuisine	Service	Ambience	Waiting time	Noise	Quality/Price
TAKO	6.9	6	8.7	6.2	8	7.2
Condominio Marconi	8.8	8.6	8.6	8.3	8.1	7.9
Vitti il Ristorante	9.1	8.6	7	8.1	8	7.9
The Vista Rooftop	9	8.6	7.9	8.4	8.7	7.7

Table 14
AHP scores for both users

Foodie	TAKO	Condominio Marconi	Vitti il Ristorante	The Vista Rooftop
Lazy	0.1257	0.289	0.2501	0.3352
Enterprising	0.1155	0.3377	0.2286	0.3182

Based on these, two different classifications of solutions were identified that are respectively more suitable for the lazy user and the enterprising user (see Tables 15 and 16). Furthermore, unlike the result obtained with the application of the first combined method, “AHP-DEA”, with this approach it was possible to identify a ranking of efficient alternatives, compared to the 10 alternatives initially selected.

Table 15
“Lazy foodie” ranking

The Vista Rooftop	1
Condominio Marconi	2
Vitti il Ristorante	3
TAKO	4

Table 16
 “Enterprising foodie” ranking

Condominio Marconi	1
The Vista Rooftop	2
Vitti il Ristorante	3
TAKO	4

3.4 Discussion

The integration of the AHP and DEA methods made it possible to innovatively address the problem of selecting an online restaurant service, taking into account both the subjective priorities of the user and the objective efficiency of the available alternatives. The discussion phase of the results highlights some key points, both at qualitative and quantitative level.

In the first case, the combination of the two approaches allowed the selection of alternatives to be adapted to the specific preferences of the users (“lazy foodie” and “enterprising foodie”), overcoming the limits of the simple arithmetic averages adopted by traditional portals. The DEA methodology allowed a first screening of the alternatives, improving the efficiency of the search. However, the isolated application of the DEA highlighted the presence of multiple efficient alternatives, requiring the intervention of the AHP to establish a final ranking. Finally, the comparison between the AHP-DEA and DEA-AHP approaches demonstrated that the order of application of the methods significantly affects the results, with the DEA-AHP showing a better ability to synthesize and a clearer identification of the best alternative.

Quantitatively, by applying the DEA to the 10 alternatives, it was found that 40% of the restaurants were efficient, with a high level of competition between the selected places; hence, the need for the second phase of priority definition through the AHP. The AHP-DEA approach highlighted different rankings for the two types of users; in fact, the “lazy foodie” preferred the Osteria degli Stolti, while the “enterprising foodie” chose the Condominio Marconi. The correlation index between the two AHP rankings is moderately low, indicating that personalization based on user profiles has a significant impact. With the DEA-AHP approach, the ranking among the 4 efficient alternatives was further narrowed. For the “lazy foodie” the best restaurant is The Vista Rooftop; for the “enterprising foodie” the best restaurant is Condominio Marconi. The final AHP values showed a significant distance between the first and the following positions, highlighting a clear preference and reducing the ambiguity in the choice. For the “enterprising foodie”, the first ranked (0.3377) alternative was about 5.9% higher than the second ranked (0.3182).

In conclusion, the integration of the two methodologies has therefore allowed the objectivity in the selection of the most efficient alternatives to increase, provided a final choice strongly guided by the specific needs of the user and reduced the complexity of the decision-making process through a multi-stage structuring.

4. Conclusions

The article presents an innovative approach for the optimization of the search and selection process of online restaurant services. The analysis conducted, through the integration of the multi-criteria methodologies (AHP and DEA), highlighted that the traditional method of the simple arithmetic mean of reviews may have structural limitations, as it fails to adequately represent the complexity of users' preferences. The first method to be applied, the AHP, provided an interesting automatic search solution, but highlighted some limitations in the application, in particular, the need for active collaboration with the user, who is asked to provide information and express their priorities according to a simple, but not immediately understandable, scheme. A second multi-criteria method, the DEA was used to measure the quality/price ratio of each restaurant. This method allowed the efficiency found by users for each structure to be calculated without the need for their active involvement. The criticality in the application of the DEA method lies instead in the number of results it achieves; often there are multiple alternatives considered efficient, so the user, despite obtaining a good screening of the proposals, does not obtain a single purchasing solution. The combined adoption of the AHP and DEA made it possible to build personalized choice paths based on the profiles and priorities of the users; to measure the efficiency of the selected restaurants taking into account the qualitative and quantitative variables simultaneously. It also allowed a reduction in the number of alternatives to be presented to the users, improving the efficiency of the final decision. The DEA-AHP method defined a clear hierarchy among the efficient alternatives compared to the AHP-DEA approach. The critical points of the method, however, in a large-scale application, concern the phase of user involvement for the definition of criteria and priorities. In the future, the idea is to extend the experimentation to a greater number of users and alternatives, to further validate the robustness of the results; integrate advanced text analysis methodologies to automate the qualitative evaluation of reviews; and evaluate the application of additional multi-criteria techniques and hybrid methods to further improve the accuracy and personalization of recommendations. Finally, the work is configured as a first step towards the construction of more intelligent recommendation systems, capable of combining efficiency, personalization and ease of use.

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APPENDIX A

Table A1
“AHP-DEA” method: pairwise comparison matrices, calculated by Expert Choice program

SERVICE										
A	B	C	D	E	F	G	H	I	L	
	8.0	5.0	6.0	2.0	2.0	2.0	3.0	3.0	7.0	
		1.0	1.0	5.0	6.0	4.0	9.0	5.0	9.0	
			1.0	3.0	5.0	5.0	8.0	7.0	9.0	
				3.0	6.0	5.0	8.0	7.0	9.0	
					2.0	3.0	7.0	7.0	7.0	
						2.0	5.0	1.0	5.0	
							2.0	3.0	7.0	
								5.0	9.0	
									3.0	
										3.0
AMBIENCE										
A	B	C	D	E	F	G	H	I	L	
	8.0	3.0	4.0	5.0	3.0	2.0	2.0	2.0	2.0	3.0
		2.0	5.0	6.0	7.0	3.0	5.0	5.0	5.0	4.0
			5.0	7.0	7.0	2.0	6.0	5.0	5.0	5.0
				2.0	2.0	4.0	1.0	1.0	1.0	3.0
					2.0	5.0	2.0	3.0	3.0	4.0
						2.0	2.0	2.0	2.0	2.0
							2.0	2.0	2.0	2.0
								2.0	2.0	2.0
									2.0	2.0
										2.0
WAITING TIME										
A	B	C	D	E	F	G	H	I	L	
	5.0	5.0	7.0	3.0	1.0	3.0	7.0	5.0	3.0	
		2.0	3.0	2.0	3.0	7.0	3.0	7.0	9.0	
			3.0	4.0	6.0	7.0	3.0	5.0	7.0	
				4.0	6.0	7.0	1.0	5.0	9.0	
					3.0	5.0	5.0	7.0	7.0	
						3.0	7.0	5.0	5.0	
							7.0	5.0	5.0	
								5.0	5.0	
									5.0	
										5.0
NOISE										
A	B	C	D	E	F	G	H	I	L	
	3.0	5.0	1.0	3.0	3.0	5.0	5.0	3.0	3.0	3.0
		5.0	3.0	3.0	3.0	5.0	5.0	5.0	5.0	1.0
			5.0	3.0	3.0	5.0	5.0	5.0	5.0	3.0
				3.0	3.0	5.0	5.0	5.0	5.0	3.0
					3.0	5.0	5.0	5.0	5.0	3.0
						3.0	5.0	5.0	5.0	3.0
							3.0	5.0	5.0	3.0
								3.0	5.0	3.0
									3.0	3.0
										3.0
QUALITY/PRICE										
A	B	C	D	E	F	G	H	I	L	
	7.0	9.0	9.0	7.0	3.0	5.0	7.0	7.0	7.0	7.0
		3.0	1.0	5.0	9.0	7.0	5.0	5.0	5.0	5.0
			3.0	5.0	7.0	7.0	5.0	5.0	5.0	3.0
				5.0	9.0	7.0	5.0	5.0	5.0	5.0
					5.0	3.0	1.0	1.0	3.0	3.0
						5.0	5.0	5.0	5.0	5.0
							5.0	5.0	5.0	5.0
								5.0	5.0	5.0
									5.0	5.0
										5.0

Table A2
DEA-AHP: the pairwise comparison matrices for each criterion

CUISINE	A	B	C	D	P1
A	1	0.2	0.2	0.2	0.056
B		1	0.33	0.33	0.172
C			1	1	0.386
D				1	0.386

SERVICE	A	B	C	D	P2
A	1	0.14	0.14	0.14	0.046
B		1	1	1	0.316
C			1	1	0.32
D				1	0.32

AMBIENCE	A	B	C	D	P3
A	1	1	5	3	0.183
B		1	5	3	0.348
C			1	0.33	0.224
D				1	0.245

WAITING TIME	A	B	C	D	P4
A	1	0.2	0.2	0.2	0.26
B		1	3	1	0.349

C				1	0.33	0.155
D					1	0.235
NOISE	A	B	C	D		P5
A		1	0.33	1	0.33	0.056
B			1	3	1	0.386
C				1	0.33	0.172
D					1	0.386
Q/P	A	B	C	D		P6
A		1	0.33	0.33	0.33	0.123
B			1	1	0.33	0.376
C				1	0.33	0.125
D					1	0.376