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# An Efficiency-Based Approach for Selecting Electronic Markets in Sustainable Electronic Business: A SME's Perspective

Hepu Deng <sup>1,2</sup> , Sophia Xiaoxia Duan <sup>3,\*</sup> , Donghui Jie <sup>1</sup> and Jiangjing Fu <sup>1</sup>

<sup>1</sup> School of Business and Law, Foshan University, Foshan 528000, China; hepu.deng@rmit.edu.au (H.D.); jiedonghui@sina.com (D.J.); fujiangjing63@126.com (J.F.)

<sup>2</sup> School of Business Information Technology and Logistics, RMIT University, Melbourne, VIC 3000, Australia

<sup>3</sup> School of Management and Marketing, Charles Sturt University, Albury, NSW 2640, Australia

\* Correspondence: sduan@csu.edu.au; Tel.: +61-2-6051-9715

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**Abstract:** This paper develops an efficiency-based approach for evaluating the performance of available electronic markets (e-markets) in the active pursuit of sustainable electronic business through the selection of specific e-markets for small and medium-sized enterprises (SMEs). An efficiency-oriented evaluation model using data envelopment analysis is developed first for identifying efficient e-markets. A multicriteria decision making model is then proposed for solving the e-markets selection problem with respect to the specific characteristics of e-markets and the unique nature of SMEs in specific situations. Such a model can adequately consider the imprecision and uncertainty in the decision-making process using linguistic variables approximated by fuzzy numbers to express the subjective assessments of the decision maker when evaluating the overall performance of individual e-markets. As a result, the most appropriate e-market in a specific situation for individual SMEs can be selected for the development of a sustainable electronic business. A real-life example is given for demonstrating the effectiveness of the proposed approach for addressing the e-market selection problem in the real world.

**Keywords:** electronic markets; small and medium-sized enterprises; data envelopment analysis; multicriteria decision making; fuzzy theory; performance evaluation; sustainable electronic business

## 1. Introduction

An electronic market (e-market) is a virtual marketplace in which buyers and sellers are brought together in a centralized place for conducting electronic business with the exchange of goods, services, and information [1]. It is becoming increasingly popular for all types of organizations in the development of sustainable electronic businesses. Such popularity is due to the benefits of e-markets including strengthened customer relationships, improved operation efficiency, reduced total costs, and sustained competitive advantages [2–4]. A search online shows that over seven and half million active e-markets are present worldwide [5]. Such e-markets are serving more than four billion customers across different geographical regions [6].

The potential benefits of e-markets have attracted numerous small and medium-sized enterprises (SMEs) in their pursuit of sustainable business development across the world [3]. With the adoption of e-markets, SMEs are becoming more competitive [4]. The presence of diverse e-markets with unique characteristics, however, create numerous challenges for SMEs in their selection of appropriate e-markets. The bursting of the Internet bubble further makes SMEs more cautious in pursuing sustainable business development. Consequently, selecting appropriate e-markets for SMEs in their pursuit of sustainable electronic businesses becomes a challenging task [2].

This paper presents an efficiency-based approach for assessing the performance of available e-markets in facilitating the selection of an appropriate e-market for sustainable electronic business from the perspective of SMEs. An efficiency-oriented evaluation model using data envelopment analysis (DEA) is developed first for identifying efficient e-markets. A multicriteria decision making model is then proposed for tackling the e-market selection problem taking into account the specific characteristics of e-markets and the unique nature of SMEs. Such a model can adequately consider the imprecision and uncertainty in the evaluation process using linguistic variables represented by fuzzy numbers to express the subjective assessment of the decision maker in evaluating the overall performance of individual e-markets. Such a process leads to the selection of the most appropriate e-market for SMEs in their pursuit of sustainable business development in specific situations.

In subsequent sections, a review of the e-market evaluation studies is presented in Section 2. This is followed by the formulation of the e-market evaluation and selection process as a multicriteria decision making problem in Section 3. An efficiency-based approach is then proposed in Section 4. An example is presented in Section 5 for showing the applicability of the efficiency-based approach for addressing the e-market selection problem in SMEs. In Section 6, the contributions of this study, and their implications for the development of sustainable electronic businesses in the world, have been discussed. In Section 7, some concluding remarks have been presented.

## 2. Existing Approaches for E-Market Evaluation and Selection

Evaluating the performance of individual e-markets to facilitate the selection of specific e-markets for SMEs in their pursuit of sustainable electronic businesses is complex and challenging. In such an evaluation process, the decision maker is usually required to consider both the specific characteristics of available e-markets and the nature of the SME. The specific characteristics of e-markets can often be categorized from multiple perspectives including the orientation, the competency, and the attractiveness [7]. The nature of SMEs is usually reflected from the requirement and the expectation of these SMEs in relation to the benefits that the adoption of e-markets can offer, the financial and the technical readiness of the SME for the adoption of e-market, and the support of top management for the adoption of e-markets [4]. When evaluating available e-markets for adoption, subjectiveness and imprecision are always present, due to the existence of (a) abundant, ambiguous, and subjective information and (b) conflicting evidence [8].

Several methods have been developed for solving the e-market evaluation and selection problem [1,3,7,9–11]. Buyukozkan [7], for example, proposes an index-oriented approach for evaluating the e-market performance using fuzzy analytic hierarchical process [8]. Such an approach recognizes the multi-dimensional nature when evaluating e-markets with the consideration of the economic value, the e-market performance, the transformation of the industry, and the transformation of processes in the decision making process. It is capable of dealing with the uncertainty in the e-market evaluation and selection process adequately. As a consequence, better management decisions can be made when evaluating e-market performance in organizations.

Sharifi et al. [9] develop an alignment-based approach for selecting e-markets in the pursuit of sustainable electronic business in organizations. A demand network alignment model is developed for better evaluating the performance of specific e-markets in a given circumstance. Specific evaluation criteria including the product nature, the e-market ownership, and the e-market functionality have been taken into consideration in the decision making process. The applicability of such an approach in evaluating and selecting e-markets under specific circumstances is demonstrated.

Hopkins and Kehoe [10] develop a matrix-based approach for solving the e-market evaluation problem with a specific focus on the requirements of individual customers. Such an approach specifically considers the membership scheme, the service range, the functionality type, the product range, and the technology platform when evaluating the performance of e-markets. The application of such an approach in the evaluation of e-markets shows that it is beneficial for both e-market operators

when designing specific e-markets with respect to requirements of customers, and for organizations when selecting a suitable e-market for sustainable electronic business.

Duan et al. [3] propose a multicriteria decision making approach for facilitating the selection of e-markets in organizations. Such an approach recognizes the multi-dimensional nature of the e-market evaluation issue with careful consideration of various criteria including the economic value, the e-market performance, the market capability, and the electronic business maturity in a given situation. It adequately handles the subjectiveness and imprecision involved in the evaluation process. The use of the proposed approach leads to the selection of effective e-markets for sustainable electronic business as demonstrated in the case study.

Storto [11] develops a hybrid approach through the integration of the theory of cognition and DEA for e-markets evaluation from the user perspective. Such an approach specifically considers the e-market evaluation problem with respect to the user information processing capacity and the cognitive effort requirement. The focus of such an approach is on better understanding the requirement and expectation of individual users in their evaluation and selection of specific e-markets. It is useful to e-market operators when designing specific e-markets to meet the expectation and requirement of individual users.

Duan et al. [1] propose an integrated approach through the integration of DEA and Tobit regression analysis for evaluating the performance of e-markets from the perspective of organizational efficiency. The use of such an approach allows individual organizations to effectively pinpoint the efficiency-oriented drivers in existing e-markets in specific situations. The performance of existing e-markets, therefore, can be better improved.

The approaches discussed above have demonstrated their applicability respectively for tackling the problem of evaluating and selecting e-markets from different perspectives. They are, however, not completely satisfactory, mainly due to (a) the need for adequately considering the nature of e-markets and the unique characteristics of SMEs, (b) the presence of subjectiveness and imprecision in the evaluation process, and (c) the computational efforts required in the evaluation process. SMEs are unique organizations with distinct characteristics. Their adoption of e-markets is often affected by the lack of technical and financial resources, the inadequacy of funding and organizational planning, and the high reliance on business partners [12]. To help individual SMEs select a preferred e-market for the active pursuit of sustainable electronic business, it is, therefore, desirable to develop a tailored approach for evaluating the performance of e-markets that is capable of fully considering the specific nature of SMEs and the characteristics of e-markets.

### 3. E-Market Evaluation and Selection

The performance of individual e-markets is often reflected from different perspectives in respect to the nature of SMEs and the characteristics of e-markets in a given circumstance [1]. A comprehensive evaluation of the nature of e-markets and the characteristics of SMEs shows that various evaluation criteria in the adoption of e-markets in SMEs can be classified into four categories including: (a) e-market capability (b) e-market attractiveness, (c) SME's capacity, and (d) business environment. Figure 1 shows the criteria for the e-markets selection in SMEs.

The e-market capability is a reflection of the capacity of an individual e-market to deploy its resources and functions for meeting the needs of SMEs [13]. It usually can be measured by (a) the market orientation, (b) the revenue model and (c) the technological competency of individual e-markets. The market orientation is concerned with the specific segment of the customer that the e-market is designed to serve [7]. Such an orientation enables an e-market to quickly spread its influence in the target market segment and tailor its business model for matching the characteristics of target organizations [9]. The revenue model is related to how the e-market charges its customers for its services [10]. A well-designed e-market revenue model is effective in helping SMEs attract customers, thereby improving the performance of SMEs. The technological competency of e-markets is related to the capacity of the technical platform in the establishment of e-markets. Such a technical platform is

expected to be reliable, robust, and ease of use for attracting various customers in the development of sustainable electronic businesses [11].

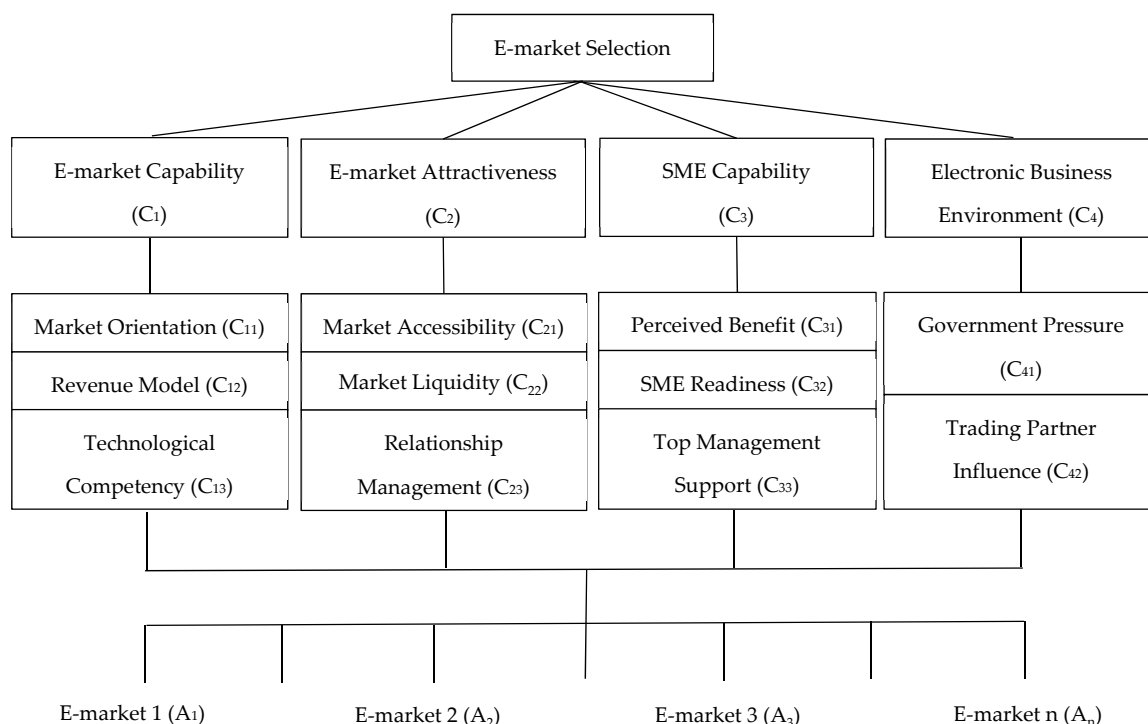


Figure 1. An overview of criteria for e-market selection in small and medium-sized enterprises (SMEs).

The e-market attractiveness is related to the capability that the adoption of e-markets can provide to SMEs for conducting their respective electronic business in a sustainable manner [2]. It is assessed by (a) market accessibility, (b) market liquidity, and (c) relationship management. The market accessibility concerns with the knowledge of an industry, the expertise of the market and the determination of the right product or service when it comes to creating a strong value proposition for its target customers [7]. The market liquidity focuses on the transaction volume of the e-market [14]. The greater the volume of transactions, the more likely the SMEs in the e-market would survive. Relationship management involves the trust issues in the adoption of e-markets [15]. The higher the trust of a particular e-market, the more likely that an SME would choose that specific e-market.

The capacity of SMEs in the adoption of an e-market is usually related to (a) the perceived benefit, (b) the SME readiness, and (c) the top management support. The perceived benefit refers to the degree to which SMEs believe that the adoption of a particular e-market would produce specific benefits including the ability to access trading partners, saving operations costs, improving the image, and enhancing the relationship with business partners [15,16]. The SME readiness reflects the level of financial and technical resources that an organization can use for the adoption of e-markets. The top management support is related to the availability of a supportive climate in SMEs for promoting the adoption of e-markets [12]. Such support can ensure that limited resources can be allocated to meet the needs of adopting a specific e-market in a given circumstance.

The electronic business environment consists of external factors that affect the adoption of e-market in SMEs. Such an environment often determines the extent to which SMEs believe that e-markets are essential for their sustainable electronic business. The electronic business environment is usually measured by (a) the government pressure and (b) the trading partner influence. The government pressure is related to the strategies and policies of individual governments that encourage the adoption of the latest technologies for sustainable electronic business. This pressure directly affects the decision of SMEs in the adoption of an e-market. The trading partner influence is

another catalyst for SMEs to consider when adopting a specific e-market. SMEs naturally have little control over their business environment. Often what their larger trading partners are doing directly affect their decisions in the adoption of e-markets [4].

To select an appropriate e-market for SMEs in their pursuit of sustainable electronic business, every available e-market has to be adequately evaluated. Subjectiveness and imprecision often arise when deciding the relative importance of the selection criteria and evaluating the performance of individual e-markets in relation to a specific criterion. To facilitate the adoption of e-markets in SMEs, the next section presents an integrated approach for evaluating the performance of e-markets so that a preferred e-market can be selected for SMEs in their pursuit of sustainable electronic business.

#### 4. An Integrated Approach

Usually numerous e-markets are available for evaluation and selection in a given situation [1]. This makes the selection of specific e-markets both time consuming and complex. To facilitate the selection of a preferred e-market in SMEs, an effective screening procedure is desirable for shortlisting e-markets before proceeding to the e-market selection.

To achieve this objective, this paper proposes an integrated approach with two stages for effectively addressing the problem of e-market evaluation and selection. Stage one involves the development of a DEA model for shortlisting efficient e-markets from available e-markets. Such an efficiency-oriented evaluation model helps effectively screen existing e-markets based on their efficiencies in a simple manner, therefore allowing SMEs to target the efficient e-markets in the e-market selection process. In the second stage, a multicriteria analysis model is presented for effectively selecting an appropriate e-market for SMEs from the efficient e-markets.

DEA is a mathematical method for measuring the relative efficiency of comparable business organizations in relation to multiple outputs and inputs under certain circumstances [17]. It is popular due to its unique advantages in (a) the ability to handle multiple inputs and multiple outputs simultaneously [18], (b) the capacity to adapt to different scales to measure inputs and outputs, (c) the absence of a well-defined mathematical function in the modelling process, and (d) the ability to identify the inefficiencies for each organization under evaluation [19,20]. With the use of the DEA model, the relative efficiency of existing e-markets can be assessed based on the ratio between the total weighted outputs and the total weighted inputs for each and every e-market under consideration. Such a model can select the most favorable set of weights for each e-market to automatically maximize the efficiency score, while other e-markets do not generate an efficiency index larger than one using the same set of weights [17]. This helps determine the relatively efficient e-markets for SMEs to be considered further.

A set of  $n$  e-markets are identified for evaluation. The  $p_{th}$  ( $p = 1, 2, \dots, n$ ) e-market generates  $s$  outputs  $y_{rp}$ , ( $r = 1, 2, \dots, s$ ) with the use of  $m$  inputs  $x_{ip}$ , ( $i = 1, 2, \dots, m$ ).  $u_r$  and  $v_i$  are the weights applied to the  $r_{th}$  output and the  $i_{th}$  input respectively ( $u_r, v_i \geq 0$ ). To determine the efficient e-markets, the relative efficiency of individual e-markets represented by the efficiency score  $E_p$  ( $p = 1, 2, \dots, n$ ) can be determined by Equation (2):

$$E_p = \min \sum_{i=1}^m v_i x_{ip}, \quad (1)$$

Subject to:

$$\sum_{r=1}^s u_r y_{rp} = 1, \quad \sum_{r=1}^s u_r y_{rj} - \sum_{i=1}^m v_i x_{ij} \leq 0 \quad j = 1, 2, \dots, n \quad (2)$$

Several steps are involved in the e-market selection process. First, the efficient e-markets  $A_i$  ( $i = 1, 2, \dots, n$ ) need to be shortlisted, followed by the determination of multiple evaluation and selection criteria  $C_j$  ( $j = 1, 2, \dots, m$ ) and their associated sub-criteria  $C_{jk}$  ( $k = 1, 2, \dots, p_j$ ). Second, the performance rating of individual e-markets based on the selection criteria  $x_{ij}$  and sub-criteria  $y_{jk}$  needs to be assessed. Third, the criteria weights  $W = (w_1, w_2, \dots, w_j)$  and their associated sub-criteria

weights  $W_j = (w_{j1}, w_{j2}, \dots, w_{jk})$  need to be determined. Fourth, the determined performance rating of e-markets, the criteria and the sub-criteria weightings need to be aggregated for calculating the overall performance index of individual e-markets, based on which a selection decision can be made.

To effectively handle the subjectiveness and imprecision involved in the assessment process, triangular fuzzy numbers are used to represent the decision makers' subjective assessment of the criteria weightings and the performance ratings [21]. Linguistic variables Performance and Importance are used to represent the performance ratings and the criteria weightings respectively in the assessment process. The approximate distribution is shown in Table 1.

Table 1. The approximate distribution of linguistic variables.

Linguistic Variable	Performance	Very Poor (VP)	Poor (P)	Fair (F)	Good (G)	Very Good (VG)
	Importance	Very Low (VL)	Low (L)	Medium (M)	High (H)	Very High (VH)
Fuzzy Numbers		(0.0,0.0,0.3)	(0.1,0.3,0.5)	(0.3,0.5,0.7)	(0.5,0.7,0.9)	(0.7,1.0,1.0)

The multicriteria analysis model starts with identifying the performance ratings of e-markets using the linguistic variable Performance presented in Table 1. The fuzzy decision matrix can be presented in Equation (3):

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1m} \\ x_{21} & x_{22} & \dots & x_{2m} \\ \dots & \dots & \dots & \dots \\ x_{n1} & x_{n2} & \dots & x_{nm} \end{bmatrix}. \tag{3}$$

In the above decision matrix,  $x_{ij}$  represents the subjective evaluation of the decision maker on the performance rating of individual e-market  $A_i$  in relation to the evaluation criterion  $C_j$ . Such performance ratings are either decided by the decision maker using linguistic variable Performance as defined in Table 1 or aggregated from a lower-level decision matrix for its associated sub-criteria.

A lower-level fuzzy decision matrix can be determined as in Equation (3) if there are sub-criteria  $C_{jk}$  for criterion  $C_j$ . In Equation (4),  $y_{jk}$  is the decision maker's subjective assessment on the performance rating of individual e-market  $A_i$  in relation to the sub-criteria  $C_{jk}$  of the criteria  $C_j$ .

$$Y_{C_j} = \begin{bmatrix} y_{11} & y_{12} & \dots & y_{n1} \\ y_{21} & y_{22} & \dots & y_{n2} \\ \dots & \dots & \dots & \dots \\ y_{1p_j} & y_{2p_j} & \dots & y_{np_j} \end{bmatrix}. \tag{4}$$

Similarly, the evaluation criteria  $C_j$  and their associated sub-criteria  $C_{jk}$  can be determined using the linguistic variable Importance as presented in Table 1, the weighting vectors are shown as in Equation (5) and Equation (6) respectively,

$$W = (w_1, w_2, \dots, w_j), \tag{5}$$

$$W_j = (w_{j1}, w_{j2}, \dots, w_{jk}). \tag{6}$$

The decision vector  $X_{ij} (x_{1j}, x_{2j}, \dots, x_{nj})$  across all the alternatives in relation to criteria  $C_j$  in Equation (3) can then be calculated by Equation (7):

$$(x_{1j}, x_{2j}, \dots, x_{nj}) = \frac{W_j Y_{C_j}}{\sum_{k=1}^{p_j} w_{jk}}. \tag{7}$$



The selection of e-markets involved in prioritizing individual e-markets is based on the overall performance index of each and every e-market in a comprehensive manner. The process of calculating the overall performance index of individual e-markets across all selection criteria begins by determining the overall weighted performance matrix of all alternatives in relation to various selection criteria by multiplying the criteria weightings  $w_j$  and the alternative performance rating  $x_{ij}$ , as shown in Equation (8):

$$Z = \begin{bmatrix} w_1x_{11} & w_2x_{12} & \dots & w_mx_{1m} \\ w_1x_{21} & w_2x_{22} & \dots & w_mx_{2m} \\ \dots & \dots & \dots & \dots \\ w_1x_{n1} & w_2x_{n2} & \dots & w_mx_{nm} \end{bmatrix}. \quad (8)$$

Ranking fuzzy utilities is usually needed in the fuzzy multicriteria decision making. Such a process is often complex and unreliable [22,23]. To avoid the process of comparing and ranking fuzzy utilities [21,24], a defuzzification method is applied to Equation (8). Such a defuzzification method presented in Equation (9) is based on the geometric centre of a fuzzy number, in which  $S_{ij}$  is the support of fuzzy number  $w_jx_{ij}$  in Equation (8).

$$r_{ij} = \frac{\int_{S_{ij}} x\mu_{w_jx_{ij}}(x)dx}{\int_{S_{ij}} \mu_{w_jx_{ij}}(x)dx}. \quad (9)$$

A weighted performance matrix in the crisp value format as shown in Equation (10) can then be determined by applying Equation (9) on Equation (8),

$$R = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{1m} \\ r_{21} & r_{22} & \dots & r_{2m} \\ \dots & \dots & \dots & \dots \\ r_{n1} & r_{n2} & \dots & r_{nm} \end{bmatrix}. \quad (10)$$

To effectively prioritize alternatives based on Equation (10), the positive-ideal and the negative-ideal solution concept can be used [24]. The positive-ideal solution  $A^+$  and the negative-ideal solution  $A^-$  represent the best possible and the worst possible results respectively among the alternatives across all evaluation criteria, as presented in Equations (11) and (12):

$$A^+ = (r_1^+, r_2^+, \dots, r_m^+), A^- = (r_1^-, r_2^-, \dots, r_m^-), \quad (11)$$

in which

$$r_j^+ = \max(r_{1j}, r_{2j}, \dots, r_{nj}), r_j^- = \min(r_{1j}, r_{2j}, \dots, r_{nj}). \quad (12)$$

Based on Equation (11) and Equation (12), the distance between the e-market  $A_i$  and the positive-ideal and the negative-ideal solution can be calculated respectively using Equation (13):

$$d_i^+ = \sqrt{\sum_{j=1}^m (r_j^+ - r_{ij})^2}; \quad d_i^- = \sqrt{\sum_{j=1}^m (r_{ij} - r_j^-)^2}. \quad (13)$$

An alternative is preferred if it has the shortest distance from the positive-ideal solution and at the same time the longest distance from the negative ideal solution [24]. Along with this line, an overall performance index value for alternative  $A_i$  across all criteria can be calculated using Equation (14).

$$P_i = \frac{d_i^-}{d_i^+ + d_i^-}, \quad i = 1, 2, \dots, n. \quad (14)$$

The preferred alternative is the one which has the largest performance index value.

As discussed above, the integrated approach can be summarized in the following steps:

- Step 1: Obtain a list of fully efficient e-markets to proceed to the selection process using Equation (2).
- Step 2: Determine the fuzzy decision matrix using Equation (3).
- Step 3: Identify the fuzzy performance rating of alternatives by Equation (4).
- Step 4: Determine the fuzzy weighting vector by Equations (5) and (6).
- Step 5: Determine the weighted fuzzy performance matrix using Equation (8).
- Step 6: Obtain a crisp value format of the weighted performance matrix using Equation (10).
- Step 7: Identify the positive-ideal and the negative-ideal solution by Equations (11) and (12).
- Step 8: Determine the distance of individual e-markets to the positive-ideal and the negative-ideal solution using Equation (13).
- Step 9: Calculate the overall preference value for each e-market by Equation (14).
- Step 10: Prioritize the e-markets in the descending order of their preference values.

## 5. An Example

To demonstrate the applicability of the proposed approach for effectively selecting e-markets for SMEs in their pursuit of sustainable electronic business, a case study involved in the evaluation and selection of twenty-six e-markets is conducted. The selection of these twenty-six e-markets as examples in the study is based on three reasons. First, the e-market should generate revenue through online sales. Second, the financial information of the e-market is available from Reference [25] or Reference [26]. Third, the number of monthly visitors and the page rank are available from Reference [27] and Reference [28], respectively.

The application of DEA in shortlisting efficient e-markets requires that the total number of e-markets for analysis is larger than three times the total number of inputs and outputs in this situation. This is to ensure that the discrimination level is sufficient between efficient and inefficient e-markets [19]. In this case, there are twenty-six e-markets, which are more than three times the total number of inputs and outputs ( $3 \times (2 + 4) = 18$ ). This shows that the size of twenty-six e-markets is an adequate sample for conducting DEA analysis.

To adequately formulate the e-market performance evaluation process using DEA, a careful selection of the inputs and outputs is required [19]. E-markets are virtual marketplaces that achieve their objectives of obtaining revenue and generating an impact on the market by consuming labor and expenditure [29]. The main difference between e-markets and the traditional markets is in their online presence. As a result, the well-established inputs for evaluating the performance of traditional markets including the number of employees and the capital can be used in the efficiency analysis for e-markets. The capital occupied is related to the assets consumed for operating the e-market. It includes the current assets, the fixed assets and the intangible assets.

The selection of outputs in the efficiency analysis must meet the objectives of operating an e-market. As discussed, the main objectives for the operation of an e-market are for making profits and for generating an impact on the market to gain greater market share. The former objective is in line with that of traditional markets. As a result, the widely used financial measures including sales and profit for the efficiency evaluation of traditional markets are used in this study.

To select appropriate output measures for reflecting the latter objective of e-markets, a comprehensive review of the performance measures of websites is conducted. There are various variables used for evaluating the performance of websites, for example, the number of visitors, the average time spent, and the page depth [29]. Limited by the availability of the data, the number of monthly visitors of an e-market is chosen in this study as one of the outputs for reflecting the impact of an e-market on the market. The rationale behind this decision is (a) visitors are the potential customers and (b) it is an indicator of customer loyalty and satisfaction on a particular e-market [29].

Another measure that reflects the impact of an e-market over the Internet is the page rank. Page rank is a link analysis algorithm used by Google to measure the relative importance of a



website [30]. Such an algorithm assigns a number from 0 to 10 to each website by considering more than 500 million variables and 2 billion terms to reflect the importance of the website. The page rank is chosen as an output mainly because it is a comprehensive and objective measurement of the impact of a website on the market over the Internet [29].

By using the inputs and outputs discussed as above and the DEA model in Equation (2), the efficiency score of individual e-markets can be calculated, as shown in Table 2. Six e-markets denoted as  $A_1$  to  $A_6$  are fully efficient with their respective efficiency scores at one. The results of the constant return to the scale of these six e-markets indicate that they have been utilizing their resources in an optimal status for providing SMEs with specific services. They are, therefore, shortlisted to the next stage for further evaluation and selection.

**Table 2.** An overview of the efficiency evaluation results of twenty-six e-markets.

E-Markets	Overall Efficiency	Technical Efficiency	Scale Efficiency	Return-To-Scale
A <sub>1</sub>	1.00	1.00	1.00	Constant
A <sub>2</sub>	1.00	1.00	1.00	Constant
A <sub>3</sub>	1.00	1.00	1.00	Constant
A <sub>4</sub>	1.00	1.00	1.00	Constant
A <sub>5</sub>	1.00	1.00	1.00	Constant
A <sub>6</sub>	1.00	1.00	1.00	Constant
A <sub>7</sub>	0.97	1.00	0.97	Decreasing
A <sub>8</sub>	0.85	1.00	0.85	Decreasing
A <sub>9</sub>	0.82	1.00	0.82	Decreasing
A <sub>10</sub>	0.75	1.00	0.75	Decreasing
A <sub>11</sub>	0.67	1.00	0.67	Decreasing
A <sub>12</sub>	0.56	1.00	0.56	Decreasing
A <sub>13</sub>	0.42	1.00	0.42	Decreasing
A <sub>14</sub>	0.45	0.95	0.48	Increasing
A <sub>15</sub>	0.81	0.93	0.87	Increasing
A <sub>16</sub>	0.47	0.92	0.51	Increasing
A <sub>17</sub>	0.34	0.91	0.37	Increasing
A <sub>18</sub>	0.58	0.90	0.65	Increasing
A <sub>19</sub>	0.90	0.90	1.00	Constant
A <sub>20</sub>	0.57	0.88	0.65	Increasing
A <sub>21</sub>	0.34	0.86	0.40	Increasing
A <sub>22</sub>	0.66	0.85	0.77	Increasing
A <sub>23</sub>	0.85	0.85	1.00	Constant
A <sub>24</sub>	0.56	0.84	0.67	Increasing
A <sub>25</sub>	0.64	0.84	0.76	Increasing
A <sub>26</sub>	0.36	0.70	0.52	Increasing

To select a preferred e-market for SMEs from the six efficient e-markets, the second stage of evaluation and selection is conducted. The performance of every alternative e-market in relation to the evaluation sub-criteria of each criterion is determined based on the assessment of the decision maker with the use of the linguistic variable Importance as presented in Table 1. Tables 3–6 show the assessment results.

**Table 3.** Decision matrix for C<sub>1</sub> e-market capability.

C <sub>1</sub>	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	A <sub>5</sub>	A <sub>6</sub>
C <sub>11</sub>	VG	F	P	F	P	VG
C <sub>12</sub>	P	G	VG	P	F	P
C <sub>13</sub>	F	VG	P	P	VG	F

**Table 4.** Decision matrix for C<sub>2</sub> e-market attractiveness.

C <sub>2</sub>	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	A <sub>5</sub>	A <sub>6</sub>
C <sub>21</sub>	F	G	G	G	VG	F
C <sub>22</sub>	VG	F	F	F	P	P
C <sub>23</sub>	G	G	P	VG	P	F

**Table 5.** Decision matrix for C<sub>3</sub> SME’s capability.

C <sub>3</sub>	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	A <sub>5</sub>	A <sub>6</sub>
C <sub>31</sub>	G	P	G	P	VG	G
C <sub>32</sub>	G	VP	VG	VG	P	G
C <sub>33</sub>	P	F	G	VG	F	P

**Table 6.** Decision matrix for C<sub>4</sub> business environment.

C <sub>4</sub>	A <sub>1</sub>	A <sub>2</sub>	A <sub>3</sub>	A <sub>4</sub>	A <sub>5</sub>	A <sub>6</sub>
C <sub>41</sub>	G	F	VG	G	F	P
C <sub>42</sub>	P	G	P	F	P	G

The weightings of the criteria and their associated sub-criteria for the selection of e-markets as shown in Table 7 is determined by the decision maker using subjective assessment represented by linguistic variable Importance as shown in Table 1.

**Table 7.** Criteria and sub-criteria weightings for the selection of e-market.

Criteria	Importance	Sub-Criteria	Importance
C <sub>1</sub>	H	C <sub>11</sub>	VH
		C <sub>12</sub>	H
		C <sub>13</sub>	L
C <sub>2</sub>	L	C <sub>21</sub>	H
		C <sub>22</sub>	M
		C <sub>23</sub>	VH
C <sub>3</sub>	VH	C <sub>31</sub>	M
		C <sub>32</sub>	VH
		C <sub>33</sub>	H
C <sub>4</sub>	M	C <sub>41</sub>	M
		C <sub>42</sub>	H

To determine the fuzzy decision matrix for six alternative e-markets in relation to multiple selection criteria as shown in Equation (3), lower-level fuzzy performance matrices of all the e-markets with regards to the sub-criteria of each criterion identified from Tables 3–6 are aggregated with the sub-criterion weightings in Table 7 using Equation (7). Table 8 shows the fuzzy decision matrix of six alternative e-markets.

**Table 8.** Fuzzy decision matrix for the evaluation of six e-markets.

	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C <sub>4</sub>
A <sub>1</sub>	(0.24, 0.68, 1.38)	(0.27, 0.70, 1.49)	(0.21, 0.57, 1.32)	(0.13, 0.47, 1.35)
A <sub>2</sub>	(0.22, 0.65, 1.55)	(0.27, 0.65, 1.47)	(0.07, 0.23, 0.85)	(0.21, 0.62, 1.63)
A <sub>3</sub>	(0.18, 0.55, 1.27)	(0.16, 0.47, 1.20)	(0.34, 0.84, 1.63)	(0.16, 0.59, 1.44)
A <sub>4</sub>	(0.11, 0.40, 1.08)	(0.32, 0.79, 1.53)	(0.33, 0.84, 1.50)	(0.19, 0.58, 1.58)
A <sub>5</sub>	(0.12, 0.48, 1.25)	(0.17, 0.52, 1.17)	(0.17, 0.52, 1.22)	(0.21, 0.57, 1.32)
A <sub>6</sub>	(0.24, 0.68, 1.38)	(0.15, 0.45, 1.12)	(0.09, 0.38, 1.18)	(0.18, 0.53, 1.45)

The overall weighted decision matrix of six e-markets with respect to the selection criteria is then calculated using Tables 7 and 8, based on Equation (8). The fuzzy numbers in the overall weighted decision matrix are then converted into crisp numbers with the use of Equation (9). Table 9 shows the results.

**Table 9.** Weighted decision matrix in crisp numbers.

	$C_1$	$C_2$	$C_3$	$C_4$
$A_1$	0.61	0.33	0.68	0.41
$A_2$	0.65	0.32	0.38	0.50
$A_3$	0.54	0.25	0.90	0.45
$A_4$	0.44	0.35	0.86	0.48
$A_5$	0.51	0.25	0.62	0.42
$A_6$	0.61	0.24	0.54	0.44

With the use of Equations (11) to (13), the overall performance index value for each alternative e-market in all selection criteria can be calculated. Results are shown in Table 10.

**Table 10.** Ranking of the e-markets.

E-Market	Distance		Performance Index	Rank
	$A^+$	$A^-$	$P_i$	
$A_1$	0.24	0.36	0.60	3
$A_2$	0.53	0.25	0.32	6
$A_3$	0.16	0.54	0.78	1
$A_4$	0.22	0.50	0.69	2
$A_5$	0.34	0.25	0.43	4
$A_6$	0.38	0.25	0.39	5

An analysis of Table 10 shows that alternative e-market  $A_3$  is the preferred choice, due to its highest performance index value. From the perspective of SMEs, e-market  $A_3$  is the best choice for their pursuit of sustainable electronic business.

## 6. Discussion

Evaluating the performance of available e-markets, so that the most appropriate e-market can be selected for the development of sustainable electronic businesses for SMEs, is not an easy task. This is mainly due to the existence of a large number of e-markets and the presence of multiple and often conflicting evaluation criteria. The use of the subjective and imprecise assessments in the evaluation process further complicates the selection process. The above example has demonstrated the applicability of the integrated approach proposed for adequately solving the e-market evaluation and selection problem in SMEs. The DEA-based evaluation model is employed in the first stage for effectively shortlisting efficient e-markets. A multicriteria decision making model is adopted in the second stage for comprehensively selecting the best performing e-market for SMEs from the identified efficient e-markets with respect to the nature of individual e-markets and the specific characteristics of the SME. Such an integrated approach provides SMEs with a simple and practical tool for selecting the most appropriate e-markets for sustainable electronic business.

This study makes a major contribution to the e-market research from both the theoretical and practical perspectives. E-markets have been a major source of competitive advantages [31,32], as well as a cost-effective way [4] for SMEs to reach customers globally and to compete with their counterparts globally. Selecting appropriate e-markets for SMEs in their pursuit of sustainable electronic business, however, is a challenging task which has not been addressed comprehensively in the literature. Theoretically this study fills this gap by proposing an effective approach for evaluating and selecting e-market in SMEs for their pursuit of sustainable electronic business.

Practically this study leads to several valuable findings for various stakeholders involved in the adoption of e-market including SMEs and e-market operators. To SMEs, this study offers an effective approach for evaluating and selecting the most appropriate e-market for sustainable electronic business so that SMEs can make full use of the benefits of e-markets [31] for competing with their larger counterparts across the world. To the e-market operators, this study offers a useful evaluation framework for the development of sustainable e-markets. The viability of an e-market depends highly on its ability to attract a sufficient number of participants [13]. As a result, any initiatives for promoting the e-market adoption in organizations, especially SMEs as the important contributors to the economy, are beneficial for the continuous development of e-markets.

## 7. Conclusions

This paper proposes an efficiency-based approach for effectively evaluating the performance of e-markets to facilitate the selection of a preferred e-market for the pursuit of sustainable electronic business from the perspective of SMEs. The efficiency-oriented evaluation model with the use of DEA is developed first for effectively shortlisting efficient e-markets. A multicriteria decision making model using multi-criteria decision making analysis and the fuzzy theory is presented for addressing the e-market evaluation and selection problem taking into account the specific characteristics of e-markets available and the unique nature of SMEs.

The proposed model adequately tackles the imprecision and uncertainty in the decision-making process by effectively using fuzzy numbers to approximate the linguistic variables that are commonly used in expressing the subjective assessments of the decision maker and adequately aggregating the subjective assessments for calculating an overall performance index value for individual e-markets in relation to the selection criteria. Using a real-life example of twenty-six e-markets for selection, the proposed approach has demonstrated its effectiveness and efficiency in adequately solving the e-markets selection problem from the perspective of SMEs, due to the comprehensibility of its underlying concepts and the straightforward computation process.

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