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Service performance evaluation using data envelopment analysis and balance scorecard approach: an application to automotive industry

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Abstract In today's competitive business environment, service providers have a strong objective to satisfy the customers with low cost to ensure a patronage/loyalty. Performance measurement defines the information or feedback on actions to meeting strategic objectives and client satisfaction. Generally, performance evaluation of the service provider is a time consuming complicated process, depends customer satisfaction. Over the past two decades several researchers have proposed methods to measure service and quality performance in order to improve the performance efficiency of the organization, since there is a considerable room exists. Hence, in this paper, we analyse efficient and inefficient levels of service performance using data envelopment analysis (DEA) and balance scorecard (BSC) techniques, to bridge the exist gap. The DEA approach has been used to measure the performance of automobile dealers from different areas to know their service levels and also treats the quality of service by making use of different cross-efficiency data envelopment analysis models to discriminate the units. Then, a BSC approach analyzes which aspects of decision making units are inefficient, grounded on four perspectives like as; customers, financial, internal business process and learning and growth, based on the study carried out on ten automobile dealers from various areas. The results identify that dealers are inefficient in learning about customer's growth, which help the dealers to transform from inefficient into efficient. In addition, this study also focused on various insights related to performance evaluation and provide some useful recommendations which can be practiced in future.

Keywords Performance measurement · Data envelopment analysis (DEA) · Balanced scorecard (BSC) · Automotive industry

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1 Introduction

In recent days, it is mandate to ensure and strive to achieve the growing influences of competitiveness across various business and industry has led organization to achieve the objectives along with continuous performance improvement, can only be obtained through periodic measurement of organization process performance (Neely et al. 2002). Hence, performance measurement gained some focus among several researchers; according to Chan (2003), performance measurement defines the information or feedback on activities regarding meeting strategic objectives jointly with customer satisfaction. Performance measurement assists the organization to reveal their exact status of their unsatisfactory performance areas, which further leads them to make the strategy for organization efficiency and quality improvement (Bhagwat and Sharma 2007). Though there are many operations intertwined in the success of organization, since supply chain holds a firm position, hence, emphasize supply chain's prominence in organization performance measurement is essential to manage supply chain through balancing the effectiveness along with competitiveness. In the process of performance measurement, performance indicators have strong hands in decision making especially with the concern of supply chain, where the uncertainties are more common. These quantitative indices are highly focused to evaluate the current system and also assist the management in complex situations. (Gunasekaran et al. 2004; Jalali Naini et al. 2011). It is obvious that each indicator presents a partial view from a specific viewpoint with there being no single performance indicator to give a total picture of performance measurement, generally, in the past, companies concentrate more on financial indicators (Rajesh et al. 2012), but recent practitioners and scholars become well aware that solely the financial improvements wouldn't serve full beneficiary on organization's growth, hence the focus slightly shifted from financial performance to other areas which gives birth to the non-financial and even intangible indicators in an organization's performance measurement system (Kaplan 1998).

But contrary to Kaplan, some studies (Cho et al. 2012; Giannakis 2011) argued that the recent service sectors more focused on monetary growth in each and every aspects of organizations, which clearly explains the conceptual conflicts exists between the literatures. Also according to Smith et al. (2007) industrial revolution not only affects the manufacturing sectors but also made an impact on service sectors too. But contrary to that, there are countless papers are exist in manufacturing operational performance strategies (Neely et al. 2002; Cho et al. 2012) and comparatively very limited studies (Yasin and Gomes 2010) were focused on service sector performance. Meanwhile, services cover intangibility and inseparability, hence it is tough to visualize and amount the service supply chain performance (Cho et al. 2012). However, this lack of literature and complexity on performance measures and measurement in service operations of supply chains urge the researchers to focus to analyze the performance efficiency of service sector. Though there are some studies exist in service sector performance, for an instance, Fitzgerald et al. (1991) proposed six dimensions of service performance including financial, competitiveness, quality of services, flexibility, resource utilization and innovation. Parasuraman et al. (1988) suggested five dimensions including tangibility, empathy, competence, responsiveness, and reliability for service quality. Gaiardelli et al. (2006) highlighted the reputation of after-sales service in supply chains, in which they measured financial performance at a strategic level and focused on customer satisfaction, suppleness and productivity at the operational level. But these existing studies are merely focused on financial performance and rarely focus on customer relation, but fails to include the learning objectives and business processes. Hence, this study itself take the responsibility to explore the service operation supply chain performance with the assistance of four dimensions, customers, financial, internal business process and learning and growth where previous studies were limited. In order to fulfil the aim of the study, this study adapts two methodologies namely data envelopment analysis (DEA) and balance score card (BSC), the detailed description on each methodology is as follows.

DEA is a widely recognized mathematical programming method for a frontier analysis of inputs and outputs that computes the relative efficacy of multiple decision-making units (DMUs) on the basis of pragmatic inputs and outputs, uttered with diverse sorts of metrics (Charnes et al. 1978, 1994; Eilat et al. 2008). The perception of frontier analysis recommended by (Farrell 1957) formulates the foundation of DEA. According to Seiford (1996), DEA in its present form was first introduced by Charnes et al. (1978) and expanded upon by Banker et al. (1984), who suggested an innovative technique merging transmuting multiple inputs and outputs into a single effectiveness index (Liu et al. in press). The preliminary notion of DEA is to amount the efficiency of a specific DMU against a predictable point in an “efficiency frontier” (Eilat et al. 2008). An efficient DMU has an effectiveness score of 1. to optimize the relative efficiency score of each DMU, the weights related with the inputs and outputs of each DMU are processed through mathematical programming. DEA also can provide evidence on the effect of each input/output on overall efficiency, besides the amount by which inputs must be reduced and the outputs to be increased to convert inefficient DMUs to efficient units (Wu et al. 2010). The helpfulness of DEA in assessing multi-criteria systems and providing development goals for systems are stated in the large amount of its applications, as discussed by (Eilat et al. 2008).

The application of DEA extending by various commercialists and academicians for both theoretical formulation and with the intense of several industrial and non-industrial contexts, including health care (Gouveia et al. 2015; Shwartz et al. 2016), education (Johnes 2006; Qi 2015), manufacturing (Kwon et al. 2016; Li and Lin 2016), retailing (Alves and Portela 2015; Balios et al. 2015; Zervopoulos et al. 2016), banking (Camanho and Dyson 2005; Edirisinghe and Zhang 2007; Paradi and Zhu 2013; Avkiran 2015; Stoica et al. 2015), management (Lee and Farzipoor Saen 2012; Mannino et al. 2008; Ji et al. 2015; Azadi et al. 2015), supplier selection (Liu and Hai 2005; Weber et al. 1998; Azadeh et al. 2016), agriculture (Hong et al. 2015; Zhang 2015) and so on.

A method which enables periodical and organized systems management is the balanced scorecard (BSC) system suggested and established by Kaplan and Norton (1992a, 1996a). Kaplan and Norton (1996a) offered four important viewpoints that are required to be well-adjusted in performance measurement: financial, customer, internal business process, and learning and development perspectives. In the row, Yuksel and Dagdeviren (2010) development a strategic management model through BSC approach by considering both l financial measures and non-financial measures including customers, in-house business procedures and learning and development BSC scores as a strategic administration system and enhances strategic non-financial performance measures to customary financial metrics. It helps executives and administrators to comprehend the inter-relationships and compromises among alternative performance dimensions, thereby lead to better decision making and problem solving (Kaplan and Norton 1996a; Rajesh et al. 2012; Yuksel and Dagdeviren 2010). The BSC mainly focuses on two key glitches in business organizations: performance measurement effectiveness and the assessment of fruitful execution of an organization’s strategy (Grigoroudisn et al. 2012). Currently BSC is widely used successfully by a large number of organizations. Koning (2004) mention that at least 60 % of the major administrations in Fortune 500 group use the BSC methodology for their performance evaluations. Gumbus (2005) also indicates that, 64 % of U.S Companies use BSC methodology for performance assessment in 2005. There is sign that organizations are progressively accepting BSC in their long term developments (Jalali Naini et al. 2011).

Despite widespread use and strengths of the BSC method, many authors have identified weak points in BSC. For an instance, some researchers stated that in a complex virtual scenario, without benchmarking exercise, BSC can't able to classify the inefficiencies in the time of usage and documentation of resources. Also according to Amado et al. (2012), the incorporation of DEA with BSC can over loop the limitation of resources inefficiencies. Hence this study integrate the DEA with BSC in order to measure the service performance, Initially DEA will be used to analyse the efficiency, in which the inefficient units are sorted out to make them efficient using BSC.

The remaining sections of the paper are as follows. Section 2 explores the existing literatures in the core filed (performance measurement system) and solution methodologies (DEA and BSC). Problem was described in Sect. 3. Sections 4 and 5 discussed the application of the proposed model in case industry and analysis the result obtained from the study respectively. Finally, the conclusion of the study along with its limitation and future insights were dealt in Sect. 6.

2 Literature review

This section consists of three categories, in which one category focused on core field, i.e., performance measurement system and other two were focused on solution methodologies, namely data envelopment analysis (DEA) and balance score card (BSC).

2.1 Performance measurement system (PMS)

Performance measurement system is nothing but the process of measuring the effectiveness and efficiency of the business actions or even the process or any related target system (Neely et al. 1995, 1996, 2002). Effectiveness and efficiency are the intertwining terms used in the performance measurement, in which, effectiveness is the level of meeting the compliance with customer requirements and efficiency is used to measure the firm's economic resource utilization towards improving the satisfaction level of customers. Earlier studies state that a performance measurement system should enable informed decisions to be made and actions to be taken as it quantifies the efficiency and effectiveness of past actions, in addition captures the flavours of organizational performance (Cho et al. 2012). From the review of literature, it is clearly evident that there is a high correlation between the performance measures and organizational objectives and strategies, also according to Neely et al. (1997) and Gunasekaran et al. (2004), through measuring the planning and controlling elements, decision makers can ensure whether their focused objectives are achieved. According to Amaratunga and Baldry (2002), a strategic performance management system is one that uses performance information to produce a positive change in organizational processes, culture and systems. Gomes et al. (2004) mentions some of the key characteristics of PMS that includes:

- With the support of the key business success factors, it monitors both financial and non-financial performances through strategic framework. Follows strategy dynamically and monitors the business results.
- Measures and related systems are based on organizational objectives, critical success factors and are customer oriented.
- Long-term strategy, ease to understand and implement worthy.

Many authors (Globerson 1985; Neely et al. 1996; Beamon 1999; Bourne et al. 2000; Lohman et al. 2004; Kaplan and Norton 2006; Chen 2008; Phusavat et al. 2009; Tan and

Platts, K.H. Tan, K.W. Platts, 2009; Folan et al. 2007; Franco-Santos et al. 2007) explore the hypothetical basis of PMS and highlights the necessary of integrating performance measures with organizational strategy. Several papers (Chan and Qi 2003; Gunasekaran et al. 2004; Huang et al. 2005; Kroes and Ghosh 2010; Lockamy and McCormack 2004; Shepherd and Gunter 2006 and Vachon and Klassen 2008; Acar et al. 2010) focused on operational features of supply chain management, comprising the usage of information systems for performance measurement and also proposed a process-based systematic perspectives to account the performance of supply chains.

2.2 Data envelopment analysis (DEA)

Data envelopment analysis (DEA) is a technique to regulate the relative efficiencies of a set of similar organizational units termed decision making units (DMUs). Generally, the efficiency of the DMU can be accounted based on the proportion of multiple inputs and multiple outputs employed in it. This DEA methodology based on a linear programming model to assess the relative efficiency of DMUs was established by Charnes et al. (1978) and later extended by Banker et al. (1984). The original DEA model tried to make the DMU efficient by assigning favourable weights to inputs and outputs. Data envelopment analysis is a technique that measures technical efficiency and delivers a means to calculate deceptive efficiency levels within a cluster of organizations. The efficiency of an organization is calculated, relative to the groups perceived finest practice.

Researchers in many of arenas have documented that DEA is an outstanding and effortlessly applicable methodology to model operational process for performance evaluations, for an instance, Emrouznejad et al. (2008) reported that since its inception, more than 4000 studies were published under various high referred journals. Such rapid growth in the last three decades witnessing acceptance of DEA methodology is testimony to its strengths and applicability. DEA consists of family of models with numerous assumptions on input and output relations and their properties. An application of DEA and Hybrid DEA in various fields is addressed by various authors (Srdjevic et al. 2005; Johnes 2006; Chauhan et al. 2006; Andes 2002; Chiou and Chen 2006; Khodabakhshi and Aryavash 2014; Cook et al. 2014; Emrouznejad 2014; Chen et al. 2015; Park and Kim 2016. In particular, Eilat et al. (2006, 2008) combined DEA and BSC method to evaluate R&D projects. Oral et al. (1991) used DEA cross efficiencies in combined decision making of portfolio analysis. Zeydan and Çolpan (2009) used fuzzy TOPSIS (the technique for order of preference by similarity to ideal soultion) and DEA to measure performance of the air supply and Maintenance Center in Turkey. Wang et al. (2008) measured production and advertising efficiencies in the printed circuit board industry using grey relation analysis (GRA) and data envelopment analysis (DEA) techniques. Sevkli et al. (2007) proposed a hybrid method (DEAHP- data envelopment analysis (DEA) approach embedded into analytic hierarchy process (AHP) for supplier selection of a Turkish appliance company. In this paper cross efficiency based DEA is applied on original constant returns to scale model and it is more suitable when evaluating units are homogenous.

Given a set of 'n' units, each functioning with 'm' inputs and 's' outputs, let y_{rj} be the amount of rth output from the DMU_j and x_{ij} be the amount of ith input in the jth unit. Agreeing with the classical DEA model developed by Charnes et al. (1978), i.e. constant returns to scale (CRS) model, the relative efficiency of a particular unit DMU_o is obtained by the optimal value of the objective function formulated as a linear programming problem (LPP) for input oriented model is given by

$$\begin{aligned} &\delta^* = Max \sum_{r=1}^{s} u_r y_{ro} \\ s.t.\ &\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \le 0 \qquad j = 1, 2, \ldots, n \\ &\sum_{i=1}^{m} v_i x_{io} = 1 \\ &u_r \ge 0, \quad r = 1, 2, \ldots s \\ &v_i \ge 0, \quad i = 1, 2, \ldots m \end{aligned} \tag{1}$$

2.2.1 Cross-efficiency ranking methods in DEA

Sometimes in DEA, a DMU achieves efficiency by weighting input and a single output, while the rest are accorded zero weights. This occurs once the DMU is best at one factor and eventually takes extreme weights. This way of achieving efficiency is prevented by taking cross-efficiency measures. As an extension to DEA, cross-efficiency evaluation eradicates idealistic DEA weighting outlines without necessitating prior evidence on weight limitations. The cross-evaluation method was developed by Sexton et al. (1986) who pioneered ranking in DEA. The main idea of DEA cross evaluation is noble evaluation instead of self-evaluation. It eradicates unrealistic weighting schemes and gives aunique ordering of the DMUs. Cross efficiency assessment has been used in numerous applications. Owing to the advantages many studies applied with different filed of efficiency analysis, for an instance, nursing homes efficiency , R&D projects efficiency (Oral et al. 1991) and rank preference voting (Green et al. 1996).

The CE method computes the efficiency score of each DMU n times, using optimal weights appraised by the n LPs. The results of all the DEA cross-efficiencies can be summarized in a cross-efficiency matrix as shown below

$$e_{kj} = \frac{\sum_{r=1}^{s} u_{rk} y_{rj}}{\sum_{i=1}^{m} v_{ik} x_{ij}}, \quad k = 1, \ldots, n; \quad j = 1, \ldots, n$$

e_{kj} signifies the score given to unit 'j' in the DEA run of unit 'k' i.e. unit 'j' is assessed by the weights of unit k. All components in the matrix are between 0 and 1, $0 \le e_{kj} \le 1$ and elements in the diagonal e_{kk} characterize the normal DEA efficiency score, $e_{kk} = 1$ for efficient units and, $e_{kk} < 1$ for inefficient units. The cross efficiency ranking method in the DEA background uses the results of the cross efficiency matrix e_{kj} to rank scale the units.

The average cross efficiency score given to unit 'k' is

$$\overline{e_k} = \frac{\sum_{j=1}^{n} e_{kj}}{n}$$

$\overline{e}_k$ is an equivalent or is more representative than e_{kk}, as all the components of the cross efficiency matrix are considered. Further, the optimal solution obtained by the linear programming is not unique. This implies that the weights produced by efficient DMUs in DEA formulation are arbitrary. Consequently, cross efficiencies obtained could also differ and thus be misled. To offset this, limitation goal programming techniques can be applied to choose between finest solutions. Secondary goals may be either aggressive or benevolent formulations. Aggressive formulation assumes that given a choice among several optimal alternative solutions, it will choose weights so that its own efficiency rating is maintained and it minimizes cross efficiency of other DMUs. Benevolent formulation attempts to enhance cross efficiency ratings of other DMUs along with its own efficiency.

The linearized surrogate model for benevolent cross efficiency formulation for the DMU_o was established by Doyle and Green (1994) is given by

$$
\begin{aligned}
Max\ & \sum_{r=1}^{s}\left(u_r \sum_{j\neq o}^{n} y_{rj}\right) \\
s.t\ & \sum_{i=1}^{m}\left(v_i \sum_{j\neq o}^{n} x_{ij}\right) = 1 \\
& \sum_{r=1}^{s} u_r y_{ro} - e_{jj}\sum_{i=1}^{m} v_i x_{io} = 0 \qquad j = 1, \ldots, n \\
& e_{jo} \leq 1 \qquad \text{for all } j \neq o \\
& u_r \text{ and } v_i \geq 0
\end{aligned} \tag{2}
$$

Aggressive formulation of the cross efficiency model is the same as the above model except the objective function is to be minimized.

More recently Liang et al. (2008) extended the above model by developing three dissimilar secondary objective functions to regulate the ultimate cross efficiencies. These three models which can be applied in diverse situations provide more or less the same solutions. One of the alternative secondary goals is to minimize the total deviation from the ideal point. The benevolent cross efficiencies formulation model for the DMU_d is given by

$$
\begin{aligned}
Min\ & \sum_{j=1}^{n} \alpha'_j \\
s.t\ & \sum_{r=1}^{s} u_r^d y_{rj} - \sum_{i=1}^{m} v_i^d x_{ij} + \alpha'_j = 0; \quad j = 1, 2, \ldots, n \\
& \sum_{i=1}^{m} v_i^d x_{id} = 1 \\
& \sum_{r=1}^{s} u_r^d y_{rd} = 1 - \alpha_d^* \\
& u_r^d, v_i^d, \alpha'_j \geq 0 \quad for\ all\ i, r, j \\
& \text{where } \alpha_d^* \text{ is the CCR inefficiency of } DMU_d
\end{aligned} \tag{3}
$$

The model (3) minimizes the sum of inefficiencies. It is naturally attractive in the spirit of all DMUs trying to take full advantage of their individual performances. As pointed out by Liang et al. (2008) model (3) is appropriate for cross evaluation when the DMUs are presumed to be in a non-cooperative and fully competitive mode.

The second approach is minimizing the maximal inefficiency. It maximizes the minimal efficiency among ‘n’ efficiencies. The resulting efficiencies of the other DMUs may enforce a closer value. This attempts to show worst performing DMU under possible light. The model is given by

$$
\begin{aligned}
& Min \quad \theta \\
& s.t \quad \sum_{r=1}^{s} u_r^d y_{rj} - \sum_{i=1}^{m} v_i^d x_{ij} + \alpha'_j = 0 \quad ; j = 1, 2, \ldots, n \\
& \sum_{i=1}^{m} v_i^d x_{id} = 1 \\
& \sum_{r=1}^{s} u_r^d y_{rd} = 1 - \alpha_d^* \\
& \theta - \alpha'_j \geq 0, \quad j = 1, \ldots, n \\
& u_r^d, v_i^d, \alpha'_j \geq 0 \quad for\, all\, i, r, j \\
& \text{where } \alpha_d^* \text{ is the CCR inefficiency of } DMU_d
\end{aligned} \tag{4}
$$

The third alternative secondary goal is to lessen variation among efficiencies of DMUs by minimizing the mean absolute deviation from their mean. This concept is formulated by Liang et al. (2008) through linear programming.

$$
\begin{aligned}
& Min \quad \frac{1}{n} \sum_{j=1}^{n} (a'_j + b'_j) \\
& s.t \quad \sum_{r=1}^{s} u_r^d y_{rj} - \sum_{i=1}^{m} v_i^d x_{ij} + \alpha'_j = 0; \quad j = 1, 2, \ldots, n \\
& \sum_{i=1}^{m} v_i^d x_{id} = 1 \\
& \sum_{r=1}^{s} u_r^d y_{rd} = 1 - \alpha_d^* \\
& a'_j - b'_j = \alpha'_j - \frac{1}{n} \sum_{j=1}^{n} \alpha'_j, \quad j = 1, \ldots, n \\
& u_r^d, v_i^d, a'_j, b'_j, \alpha'_j \geq 0 \quad for\, all\, i, r, j \\
& \text{where } \alpha_d^* \text{ is the CCR inefficiency of } DMU_d
\end{aligned} \tag{5}
$$

In the models (3), (4) and (5) we obtain 'n' optimal weight vectors $W_d^* = (v_1^{d*}, \ldots, v_m^{d*}, u_1^{d*}, \ldots, u_s^{d*})$, $d = 1, \ldots, n$. The cross efficiency for any DMU$_j$ is then calculated for

$$
E_j(w_d^*) = \frac{\sum_{r=1}^{s} u_r^{d*} y_{rj}}{\sum_{i=1}^{m} v_i^{d*} x_{ij}}; \quad d, j = 1, \ldots, n
$$

For DMU$_j$ the average of all $E_j(w_d^*)$ is

$\bar{E}_j = \frac{1}{n} \sum_{d=1}^{n} E_j(w_d^*)$ and this is the cross efficiency score for the DMU$_j$.

These models are used to know the stability of cross efficiency with regard to multiple DEA weights. These models with their diverse objective functions can be applied under different environments. An aggressive formulation of the cross efficiency model is as same as the models 3, 4 and 5 except that objective function is to be maximized.

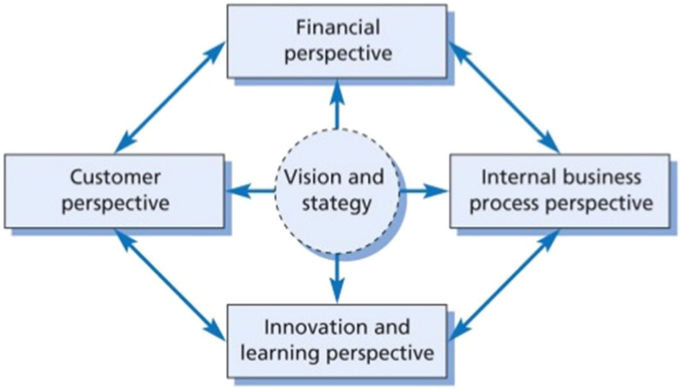

Fig. 1 The balanced scorecard (Adopted from Kaplan and Norton Kaplan and Norton 1992b)

2.3 Balanced scorecard concept

The balanced scorecard (BSC) is a performance assessment framework that was initially developed by Kaplan and Norton (1992a, b, 1996a) after comprehensive research in the early 1990s. They claimed that customary financial measures like return-on investment, revenue growth and costs give false signals for continuous improvement and present an incomplete picture of organization performance (Amado et al. 2012; Fu and Yang 2012). According to many studies (Kaplan and Norton 1996a, b; Grigoroudisn et al. 2012; Wu and Chang 2012; Amado et al. 2012; Fu and Yang 2012), the BSC is a theoretical framework (shown in Fig. 1) to convert an organization's strategic objectives into a set of performance measures within the consideration of four perspectives namely financial, customer, internal business processes and learning and growth.

Financial perspective links the company to its shareholders and those with a goal of achieving profitability and financial interest, development in sales revenue and exploiting the wealth of shareholders (Bhagwat and Sharma 2007). Financial measures mention the tangible outcomes of the company's strategy, like economic value added, revenue growth, costs, profit margins, net operating income, etc (Asosheh et al. 2010; Grigoroudisn et al. 2012).

Customer perspective Customers are the vital factor for an organization's financial accomplishments as they generate revenue by buying products/services. Measuring customers view for performance (in terms of products, services, relationships, etc.) develops a main aspect of performance measurement, as companies create value through customers (Asosheh et al. 2010).

Internal business process perspective identifies the critical internal processes which the organization must surpass. This assessment emphasizes on internal processes that will have high influence on customer value proposition, fulfillment and accomplishing an organization's financial goals (Asosheh et al. 2010; Grigoroudisn et al. 2012).

Learning and growth perspective: recognizes the infrastructure that an organization must shape to generate and improve long-term growth and future value for stakeholders. It mentions the intangible assets of an organization and internal skills and competences for supporting the value-creating internal processes (Chytas et al. 2011; Grigoroudisn et al. 2012).

The BSC was widely used in various applications and different management fields like SCM (Brewer and Speh 2000; Bhagwat and Sharma 2007), e-SCM (Wu and Chang 2012), R&D project (Eilat et al. 2006), Information technology (Asosheh et al. 2010), e-commerce (Rickards 2007), ERP (Chand et al. 2005), customer relationship management (Kim et al. 2006), third party logistics service provider (Rajesh et al. 2012) and service industries such as banking (Beechey and Garlick 1999) hotel (Denton and White 2000), healthcare organizations (Grigoroudisn et al. 2012) and other theoretical and application fields (Bhagwat and Sharma 2007; Chand et al. 2005; Milis and Mercken 2004; Wiersma 2009). To create a BSC more supple and applicable in diverse contexts, it was integrated with many methods to effectively evaluate business performance, like the mixture of analytic hierarchy process (AHP) and analytic network process ANP) (Leung et al. 2006), the fuzzy AHP (Lee et al. 2008), the fuzzy ANP (Tseng 2010; Yuksel and Dagdeviren 2010), the DEA (Garcia-Valderrama et al. 2009), and the ANP and DEMATEL (Decision making trial and evaluation laboratory) and ANP.

Although BSC has involved a lot of consideration and is greatly applied by business organizations, there are several issues that need further research. Numerous authors have identified limitations of BSC: (Chytas et al. 2011; Amado et al. 2012; Grigoroudisn et al. 2012)

- BSC system is often too general and thus managers may find it difficult to adapt it to the culture of their organization.
- Aptitude of quantitative measures to describe various aspects of a company's strategy.
- Analysis based on the BSC may fail to identify inefficiency in resources use.
- Further, it is necessary using a benchmarking exercise for identifying appropriate targets for each performance measure.
- BSC does not stipulate how compromises are to be made between dissimilar measures and among the four perspectives.
- Measures in the balanced scorecard are located in a cause and effect chain slightly a systemic approach, ignoring any feedback loops that exist.
- Measures in balanced scorecard are equally weighed. In reality, comparing measures to others, approximately measures may be more significant and have superior weight.

3 Problem description

The decision variables respectively, u = (u1…ur….us) and v = (v1…vi…vm) are the weights given to the 's' outputs and 'm' inputs. To attain the comparative efficiencies of all the units, the model (1) permits great weight flexibility and weights are only limited by non-negative values. Ten automobile dealers were selected for this research to measure their service level, to demonstrate how DEA can be effectively used for the analysis and decision making necessary to provide satisfactory levels for the numerous dimensions that contribute to automobile dealer's service quality. To calculate performance efficiency, there should be inputs and outputs and the aim of the dealer is to maximize output measures that form the objective function in this application. It has been optional that there is an best level of service excellence that each dealer ought try to attain. It is clearly known that a better approach to management of the various dimensions of service quality can lead to good marketing; that is, the preservation of a well-established business is meeting the customer's needs and desires. By getting sufficient information, the same information might be efficiently used to figure strategic decisions in allocating resources in areas which are inefficient.

Table 1 Inputs and outputs used in the study

Inputs	Outputs
Physical aspects Physical aspects of the automobile dealers refer to its appearance and the convenience of its physical layout	*Customer perception towards service* The level of facility provided to customers to earn a reputation
Reliability Reliability is the extent to which the dealer's service provides what is promised and when it is promised	*Number of customers serviced per day* Ability to service maximum number of customers
Customer relationship through personal interaction: relates to the behaviour of the working employees towards customers	*Profit* refers to net profit as a percentage of sales
Problem solving the ability of dealers to make service recoveries	*Order processing time* refers how the order is processed by dealers quickly
Policy the extent to which the policy a dealer has adopts to meet needs of customer	*Complaints handled* refers to quick handling of complaints

4 Application of the model in the case study

A survey was conducted at each dealer (ten automobile dealers) from different areas where customers come for service. Some statements were framed for each input measure and data obtained from customer based survey. Statements under each input measures are given below. A Likert scale of 1–7 is used to obtain response data. The input and output related works that explains dimensions of service quality at the automobile dealers end are shown in the Table 1. This survey was conducted over a 10 week period in 2012 and targeted an age group of 20 and above. Before commencing this work, the group of targeted respondents were invited and explained about the importance of survey, survey tools and outcomes of the research, which may impact on rigid response. The respondents (customers) were contacted through the assistance of automobile dealers, initially our team approached 200 customers at the rate of 20 customers from each dealer through mails and telephonic enquires. However, only 110 customers are willing to participate in the survey which is good response rate nearly above 50 %.

Physical aspects

- This service centre has modern equipment and fixtures.
- Physical facilities at this service centre are visually appealing.
- This service centre has an orderly arrangement of spare parts.
- The layout at this service centre makes it easy for customers to know the status of their vehicles.
- The layout at this service centre makes it easy for customers to move around without any obstruction.

Reliability

- When the service centre agrees to do somewhat in a certain time, it will do so.
- This service centre needs spare parts at any time as replacement, if a problem persists.
- This service centre insists on error-free sales and maintained records.

Customer relationship through personal interaction

- The service personat the centre has good knowledge to answer customer queries.

Table 2 Service quality dimensions for inputs

Dealers	Input 1	Input 2	Input 3	Input 4	Input 5
1	6.24	6.29	6.10	6.36	6.35
2	6.22	6.28	6.09	6.35	6.32
3	6.24	6.27	6.22	6.33	6.30
4	6.27	6.14	6.08	6.38	6.39
5	6.20	6.26	6.08	6.37	6.34
6	6.25	6.28	6.27	6.29	6.08
7	6.36	6.15	6.18	6.29	6.08
8	6.28	6.19	6.21	6.31	6.49
9	6.24	5.96	6.24	6.31	6.34
10	6.15	6.28	6.09	6.36	6.32

- The attitude of service person in the service centre increases confidence of customers.
- The service centre gives confidence and satisfaction to customers through valuable service and guarantee.
- The service person in the centre gives prompt service to customers.
- The information centre at the service centre provides proper information to customers.
- The service persons are courteous with customers whenever they are asked for help .

Problem solving

- When a customer has any problem, the service centre solves it with sincerity.
- The service centre can handle customer complaints in a timely manner.
- The service centre solves problems as per the procedures and methods.

Policy

- The service centre offers high quality service at low cost.
- The service centre serves at the customers' convenient times.
- The service centre makes it easy to pay by cheque.
- The service centre makes it easy to pay by a credit/ATM Card
- The service centre provides enough parking place for their customer's vehicles.

4.1 Dimension level input data

To exemplify the use of DEA, service quality performance inputs have been intended by first averaging the responses for each service quality item across all the surveys obtained for a particular dealer. The subsequent dimension level swift measures, for all of the dealers, included in the study is given in the Table 2.

4.2 Data collection for outputs

Data collected from all for the output measures from the ten dealers is given in the Table 3.

5 Result analysis

Table 4 provides the cross-efficiency score for ten automobile dealers with their ranks using different cross-efficiency models with the assistance of MATLAB. In order to validate the

Table 3 Service quality dimensions for outputs

Dealers	Output 1 (SURVEY)	Output 2 (NO.S)	Output 3 (%)	Output 4 (MTS.)	Output 5 (NO.S)
1	7.32	19	6.20	30	11
2	6.50	10	6.14	27	6
3	6.86	11	6.21	34	10
4	6.36	12	5.2	21	14
5	6.20	10	6.10	27	9
6	6.48	27	6.12	25	18
7	8.48	24	8.15	32	19
8	7.46	18	6.75	36	13
9	6.80	13	5.5	29	8
10	7.24	16	7.15	40	9

proposed model, it has been compared with three high cited models developed by Sexton et al. (1986), Doyle and Green (1994) and Liang et al. (2008) for different approach of benevolent and aggressive formulations. Table 4 consists of decision making units (automotive dealers) and their cross efficiency score along with their ranks. For an instance, in the Sexton et al. (1986) model, Column 1 represents the dealers and column 2 and 3 provides the cross efficiency scores and their corresponding ranks. Likewise the remaining models were represented with their concluded cross efficiencies and ranks for the relevant decision making units.

The cross efficiency scores for the 10 dealers were obtained by the Sexton et al. (1986) model, in which three of the dealers (7, 8 and 10) scores were greater than 0.9, which shows that those dealers are efficient. Also from the score it is come to know that the efficient dealers are consistent in different approaches including both benevolent and aggressive models. Other than the above mentioned three dealers remaining dealers are inefficient, hence further it is need to be analyzing the root cause of the inefficiencies exhibit among the inefficient dealers. It can analyze by exploring the wastage of resources/facilities/efforts made by the dealers in all dimensions of operations. Furthermore, the inefficient dealers have to engage in benchmark practices with efficient dealers, by which the inefficient can easily deal with the weak areas and possibly improve the management policies and strategies in order to make them efficient. However, the inefficient dealers were identified from the DEA, now it is time to analyze the inefficient dealers weak point, i.e., in which dimension (financial, customer, internal business process, and learning and growth) the inefficient dealers are poorly performing, here it can achieved through BSC as discussed earlier. Hence, the inefficient dealers are only considered for BSC along with identifying the measures and objectives of all above mentioned four perspectives, however the general objectives and measures were already discussed.

Table 5 provides the data for the objectives and measures for the inefficient dealers. It is better to discuss their inefficiencies under the term of perspectives, for making clear clarifications. Hence, the dealers are categorized into four groups based on their inefficient perspectives.

Inefficient dealers: financial perspective

Mostly all the inefficient dealers are efficient in financial perspectives, because most the undeveloped service firms looking more on financial profit and strategies rather than other dimensions, hence even these inefficient dealers are make them as efficient in financial per-

Table 4 DEA efficiency scores

DMU	Sexton et al. (1986)		Ben. D&G		Ben. Liang et al. (2008) model (3)		Ben. Liang et al. (2008) model (4)		Ben. Liang et al. (2008) model (5)		Agg. D&G		Agg. Liang et al. (2008) model (3)		Agg. Liang et al. (2008) model (4)		Agg. Liang et al. (2008) model (5)	
	E	Rank	E	Rank	E	Rank	E	Rank	E	Rank	E	Rank	E	Rank	E	Rank	E	Rank
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	0.8441	4	0.8780	4	0.878	4	0.8753	4	0.8582	4	0.8079	4	0.8079	4	0.8106	4	0.8277	4
2	0.7186	8	0.7647	8	0.7647	8	0.7603	8	0.7414	8	0.6753	9	0.6753	9	0.6797	9	0.6986	9
3	0.8155	5	0.8649	5	0.8649	5	0.8524	5	0.8378	5	0.7867	6	0.7867	6	0.7992	6	0.8138	5
4	0.6671	10	0.7014	10	0.7014	10	0.7051	10	0.7117	10	0.6612	10	0.6612	10	0.6575	10	0.6509	10
5	0.7119	9	0.7527	9	0.7527	9	0.7472	9	0.7361	9	0.6830	8	0.683	8	0.6885	8	0.6996	8
6	0.8005	6	0.7971	7	0.7971	7	0.7943	7	0.7974	6	0.7968	5	0.7968	5	0.7996	5	0.7965	6
7	0.9826	1	1	1	1	1	1	1	1	1	0.9662	1	0.9662	1	0.9662	1	0.9662	1
8	0.9106	3	0.9486	3	0.9486	3	0.9372	3	0.923	3	0.8791	3	0.8791	3	0.8905	3	0.9047	3
9	0.7666	7	0.8118	6	0.8118	6	0.8048	6	0.7899	7	0.7295	7	0.7295	7	0.7365	7	0.7514	7
10	0.9351	2	0.9806	2	0.9806	2	0.9627	2	0.934	2	0.8891	2	0.8891	2	0.907	2	0.9227	2

spectives. However, when comparing the dealers, somewhat dealer 5 and 9 are slightly lower than other inefficient dealers.

Inefficient dealers: customer perspective

From the Table 5, it is observed that the dealers 2, 3, 6 and 9 are inefficient in customer satisfaction perspective, which was clearly revealed from the customer satisfaction index. It highlights that the customers are not satisfied with the service of the dealers in some way, it may include service person behaviour towards customers, lack of prompt delivery, inaccurate information, time consuming for solving problems, work inexperience, lack of quick response and lack of good service.

Inefficient dealers: internal business process perspective

It is also observed that dealers 2, 3 and 9 are inefficient in investing new services. Due to lack of financial support, these dealers are not able to make investment money for new services. Dealers 1, 2, 5 and 9 are having less number of vehicles compared to the other dealers. Regarding convenient operating hours, dealers 2 and 6 spend very less time to achieve their target

Inefficient dealers: learning and growth perspective

It is come to know that the dealers 1, 4, and 5 are inefficient in learning and growth aspect, based on their scores acquired. It is owing to that they do not have certified personnel in the working area leading to increase in service time. Due to the lack of learning and experience, such dealers create a bad impression and they fail to satisfy customers in terms of technical services. Moreover, training programmes are not conducted as per their plan; consequently service personnel do not acquire knowledge and enough skills. The lack of training hinder them to update the technical knowledge relevant to the working area, however the learning and growth level has to be constantly improving according to the market innovative fluctuations. From the above results, it is clearly evident that most of the dealers are inefficient in internal business process perspective; in above group categorization dealers 1,2,3,5, 6 and 9 are came under this perspective. Hence, the service dealers need to more focused on business process related dimensions by formulating various strategies including awareness, training, financial outreaches and so on.

6 Conclusion

The survival of any industry particularly service sector depends on performance efficiency. This can be achieved through practicing various healthy strategies includes customer support and service, low cost innovative products, timely innovation, quality, response time and inter-functional incentives for continuous improvements. Owing to the interaction of various operations and strategies in performance efficiency, it became a tough task to evaluate the organization performance, particularly with the focus of service sectors. Hence, there is need to develop new set of performance evaluation methods which should apt for contemporary business environment. Minding the gap, this study established a set of suitable performance evaluation measures based on DEA and BSC. DEA helped to identify inter-relationships of the various service quality dimensions as they contribute to an overall level of service quality. Using different cross-efficiency DEA models, and efficiency scores, the performance

Table 5 Balanced scored card for inefficient dealers

Perspectives	Dealers													
	1		2		3		4		5		6		9	
	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual
Financial														
Revenue from new vehicles launch	4,900,000	4,700,000	4,550,000	4,220,000	5,000,000	4,450,000	4,850,000	4,350,000	4,500,000	4,200,000	5,500,000	5,120,000	5,000,000	4,600,000
% of sales from new applications	30	27	35	33	30	28	35	34	25	22	30	26	32	29
New service methods	57,000	50,000	50,000	48,000	50,000	46,000	50,000	47,500	50,000	45,000	50,000	47,500	50,000	47,000
% revenue from new customers	10	8	10	8	10	8	15	11	10	7	10	8	10	7
Customer														
On-time-delivery (%)	98	97	98	97	98	96	99	96	98	95	99	95	98	96
Customer Satisfaction Index	8	7	8	5	9	5	9	7.5	9	7.5	9	5	9	5
H.C.S I.	8	7	8	7	8	7	9	8	9	8	8	7	9	8
L.C.S.I	8	7	8	2	9	2	9	7	8	7	9	2	8	2
Internal business process														
Investment in new service	1,300,000	1,150,000	1,000,000	800,000	1,500,000	1,000,000	1,100,000	1,050,000	1,200,000	1,100,000	1,000,000	850,000	1,500,000	1,000,000
No. of vehicles serviced	340	310	350	320	320	300	340	320	330	300	300	280	350	320
Convenient operating hours	15	11	24	14	16	14	18	14	14	10	20	15	16	13
Investment in spare parts	250,000	210,000	300,000	250,000	300,000	275,000	300,000	280,000	200,000	175,000	280,000	250,000	300,000	280,000

Table 5 continued

Perspectives	Dealers													
	1		2		3		4		5		6		9	
	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual	Target	Actual
Service time (Major) (h)	3	>3	3	3	3	3	3	3	3	>3	3.5	3.5	3	3
Service time (Minor) (h)	1	>1	1	1	1	1	1	1	1	>1	1	1	1	1
Learning and growth														
No. of training programmes conducted	9	3	10	8	8	6	9	4	8	3	9	8	8	7
No. of certified persons	7	3	6	4	7	5	6	2	6	2	6	4	7	5

efficiency is obtained for the 10 automobile dealers in this study. DEA weights are not exclusive and subsequently cross efficiency may not be exclusive. To overcome this limitation we used diverse secondary objective purposes to determine ultimate cross-efficiency for various dealers. Various models give consistent results for all listed inefficient dealers out of the ten, based on customer view. Once the service level is known, the next step is to maintain it, if the unit is efficient or to analyze reasons for inefficiency.

Further to rectify inefficiency, a BSC is used to discover weakness of inefficient dealers in sixteen characteristics based on four perspectives namely; Financial, Customer, Internal business process and Learning and Growth and the results provide evidence on areas of improvement. Appropriately constructed, a BSC expresses the story of the business unit's strategy. Every selected measurement for a BSC is an component in a chain of cause-and-effect relationships that interconnects the meaning of the business unit's strategy with respect to the perspectives. Finally, this study provides a better framework to assess service performance levels of automobile dealers. However, in recent competitive business world, customer satisfaction is pivotal to survival and this study is helpful for dealers to improve their performance and to increase customer satisfaction levels. Future research in this field should focus on using regression analysis to define the relative influence of each service excellence dimension on general service excellence. The regression model will predict the score of the individual automobile dealers. This information can be used to further improve the service quality that has the most effect on overall service excellence insight.

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References

Acar, Y., Kadipasaoglu, S., & Schipperijn, P. (2010). A decision support framework for global supply chain modelling: An assessment of the impact of demand, supply and lead-time uncertainties on performance. *International Journal of Production Research*, *48*, 3245–3268.

Alves, M. E. D., & Portela, M. C. S. (2015) Performance evaluation of PARFOIS retailing stores. In: *Operational research* (pp. 1–17). Berlin: Springer.

Amado, C. A. F., Santos, S. P., & Marques, P. M. (2012). Integrating the data envelopment analysis and the balanced scorecard approaches for enhanced performance assessment. *Omega*, *40*, 390–403.

Amaratunga, D., & Baldry, D. (2002). Moving from performance measurement to performance management. *Facilities*, *20*(5/6), 217–223.

Andes, S. (2002). Measuring efficiency of physician practices using data envelopment analysis. *Managed Care*, *11*(11), 48–56.

Asosheh, A., Nalchigar, S., & Jamporazmey, M. (2010). Information technology project evaluation: An integrated data envelopment analysis and balanced scorecard approach. *Expert Systems with Applications*, *37*, 5931–5938.

Avkiran, N. K. (2015). An illustration of dynamic network DEA in commercial banking including robustness tests. *Omega*, *55*, 141–150.

Azadeh, A., Zarrin, M., & Salehi, N. (2016). Supplier selection in closed loop supply chain by an integrated simulation-Taguchi-DEA approach. *Journal of Enterprise Information Management*, *29*(3), 302–326.

Azadi, M., Jafarian, M., Saen, R. F., & Mirhedayatian, S. M. (2015). A new fuzzy DEA model for evaluation of efficiency and effectiveness of suppliers in sustainable supply chain management context. *Computers & Operations Research*, *54*, 274–285.

Balios, D., Eriotis, N., Fragoudaki, A., & Giokas, D. (2015). Economic efficiency of Greek retail SMEs in a period of high fluctuations in economic activity: A DEA approach. *Applied Economics*, *47*(33), 3577–3593.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Somemodelsforestimatingtechnical and scale inefficiencies indataenvelopmentanalysis. *Management Science*, *30*(9), 1078–1092.

Beamon, B. (1999). Measuring supply chain performance. *International Journal of Operations and Production Management*, *19*(3), 275–292.
Beechey, J., & Garlick, D. (1999). Using the balanced scorecard in banking. *Journal of the Australian Institute of Bankers*, *113*(1), 28–31.
Bhagwat, R., & Sharma, M. K. (2007). Performance measurement of supply chain management: A balanced scorecard approach. *Computers and Industrial Engineering*, *53*, 43–62.
Bourne, M., Mills, J., Wilcox, M., Neely, A., & Platts, K. (2000). Designing, implementing and updating performance measurement systems. *International Journal of Operations and Production Management*, *20*(7), 754–771.
Brewer, P. C., & Speh, T. W. (2000). Using the balanced scorecard to measure supply chain performance. *Journal of Business Logistics*, *21*(1), 75–94.
Camanho, A. S., & Dyson, R. G. (2005). Cost efficiency measurement with price uncertainty: A DEA application to bank branch assessments. *European Journal of Operational Research*, *161*, 432–446.
Chan, F. T. S. (2003). Performance measurement in a supply chain. *International Journal of Advanced Manufacturing Technology*, *21*, 534–548.
Chan, F. T. S., & Qi, H. J. (2003). An innovative performance measurement method for supply chain management. *Supply Chain Management: An International Journal*, *8*, 209–223.
Chand, D., Hachey, J. H., Owhoso, V., & Vasudevan, S. (2005). A balanced scorecard based framework for assessing the strategic impacts of ERP systems. *Computers in Industry*, *56*, 558–572.
Charnes, A., Cooper, W. W., Lewin, A., & Seiford, L. M. (1994). *Data envelopment analysis: Theory, methodology and applications*. Massachusetts: Kluwer Academic Publishers.
Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the efficiency of decision making units. *European Journal of the Operational Research*, *2*, 429–444.
Chauhan, N. S., Mohapatra, P. K. J., & Pandey, K. P. (2006). Improving energy productivity in paddy production through benchmarking: An application of data envelopment analysis. *Energy Conversion and Management*, *47*(9–10), 1063–1085.
Chen, C. C. (2008). An objective-oriented and product-line-based manufacturing performance measurement. *International Journal of Production Economics*, *112*(1), 380–390.
Chen, M. J., Chiu, Y. H., Jan, C., Chen, Y. C., & Liu, H. H. (2015). Efficiency and risk in commercial banks-hybrid DEA estimation. *Global Economic Review*, *44*(3), 335–352.
Chiou, Y. C., & Chen, Y. H. (2006). Route-based performance evaluation of Taiwanese domestic airlines using data envelopment analysis. *Transportation Research Part E: Logistics and Transportation Review*, *42*(2), 116–127.
Cho, D. W., Lee, Y. H., Ahn, S. H., & Hwang, M. K. (2012). A framework for measuring the performance of service supply chain management. *Computers & Industrial Engineering*, *62*, 801–818.
Chytas, P., Glykas, M., & Valiris, G. (2011). A proactive balanced scorecard. *International Journal of Information Management*, *31*, 460–468.
Cook, W. D., Tone, K., & Zhu, J. (2014). Data envelopment analysis: Prior to choosing a model. *Omega*, *44*, 1–4.
Denton, G. A., & White, B. (2000). Implementing a balanced-scorecard approach to managing hotel operations: The case of white lodging services. *The Cornell Hotel and Restaurant Administration Quarterly*, *41*(1), 94–107.
Doyle, J., & Green, R. (1994). Efficiency and cross-efficiency in DEA: Derivations, meanings and uses. *Journal of the Operational Research Society*, *45*(5), 567–578.
Edirisinghe, N. C. P., & Zhang, X. (2007). Generalized DEA model of fundamental analysis and its application to portfolio optimization. *Journal of Banking and Finance*, *31*, 3311–3335.
Eilat, H., Golany, B., & Shtub, A. (2006). R&D project evaluation: An integrated DEA and balanced scorecard approach. *Omega*. doi:10.1016/j.omega.2006.05.002.
Eilat, H., Golany, B., & Shtub, A. (2008). R&D project evaluation: An integrated DEA and balanced scorecard approach. *Omega*, *36*(5), 895–912.
Emrouznejad, A. (2014). Advances in data envelopment analysis. *Annals of Operations Research*, *214*(1), 1.
Emrouznejad, A., Parker, B. R., & Tavares, G. (2008). Evaluation of research in efficiency and productivity: A survey and analysis of the first 30 years of scholarly literature in DEA. *Socio-Economic Planning Sciences*, *42*, 151–157.
Farrell, M.J., (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Association Series A*, CXX, 253–281.
Fitzgerald, L., Johnston, R., Brignall, T. J., Silvestro, R., & Voss, C. (1991). *Performance measurement in service businesses*. London: CIMA.
Folan, P., Browne, J., & Jagdev, H. (2007). Performance: Its meaning and content for today's business research. *Computers in Industry*, *58*(7), 605–620.

Franco-Santos, M., Kennerley, M. P., Micheli, P., Martinez, V., Mason, S., Marr, B., et al. (2007). Towards a definition of a business performance measurement system. *International Journal of Operations and Production Management*, *27*(8), 784–801.

Fu, C., & Yang, S. (2012). The combination of dependence-based interval-valued evidential reasoning approach with balanced scorecard for performance assessment. *Expert Systems with Applications*, *39*, 3717–3730.

Gaiardelli, P., Saccani, N., & Songini, L. (2006). Performance measurement systems in the after sales service: An integrated framework. *International Journal of Business Performance Measurement*, *9*(2), 147–171.

Garcia-Valderrama, T., Mulero-Mendigorri, E., & Revuelta-Bordoy, D. (2009). Relating the perspectives of the balanced scorecard for R&D by means of DEA. *European Journal of Operational Research*, *196*, 1177–1189.

Giannakis, M. (2011). Management of service supply chains with a service oriented reference model: The case of management consulting source. *Supply Chain Management: An International Journal*, *16*(5), 346–361.

Globerson, S. (1985). Issues in developing a performance criteria system for an organization. *International Journal of Production Research*, *23*(4), 639–646.

Gomes, C. F., Yasin, M. M., & Lisboa, J. V. (2004). A literature review of manufacturing performance measures and measurement in an organizational context: a framework and direction for future research. *Journal of Manufacturing Technology Management*, *15*(6), 511–530.

Gouveia, M. C., Dias, L. C., Antunes, C. H., Mota, M. A., Duarte, E. M., & Tenreiro, E. M. (2015). An application of value-based DEA to identify the best practices in primary health care. OR Spectrum (pp.1–25).

Green, R., Doyle, J., & Cook, W. D. (1996). Preference voting and project ranking using DEA and cross evaluation. *European Journal of Operational Research*, *90*, 461–472.

Grigoroudisn, E., Orfanoudaki, E., & Zopounidis, C. (2012). Strategic performance measurement in a health-care organization: A multiple criteria approach based on balanced scorecard. *Omega*, *40*(2012), 104–119.

Gumbus, A. (2005). Introducing the balanced scorecard: Creating metrics to measure performance. *Journal of Management Education*, *29*(4), 617–630.

Gunasekaran, A., Patel, C., & McGaughey, R. E. (2004). A framework for supply chain performance measurement. *International Journal of Production Economics*, *87*, 333–347.

Hong, S., Yuedong, Z., & Gang, W. (2015). Efficiency evaluation of low-carbon agriculture development supported by public finance based on DEA—taking Heilongjiang province as an example. *Chinese Agricultural Science Bulletin*, *23*, 046.

Huang, S. H., Sheoran, S. K., & Keskar, H. (2005). Computer assisted supply chain configuration based on supply chain operations reference (SCOR) model. *Computers and Industrial Engineering*, *48*, 377–394.

Jalali Naini, S. G., Aliahmadi, A. R., & Jafari-Eskandari, M. (2011). Designing a mixed performance measurement system for environmental supply chain management using evolutionary game theory and balanced scorecard: A case study of an auto industry supply chain. *Resources, Conservation and Recycling*, *55*, 593–603.

Ji, X., Wu, J., & Zhu, Q. (2015). Eco-design of transportation in sustainable supply chain management: A DEA-like method. *Transportation Research Part D: Transport and Environment* (in press).

Johnes, J. (2006). Measuring teaching efficiency in higher education: An application of data envelopment analysis to economics graduates from UK Universities 1993. *European Journal of Operational Research*, *174*, 443–456.

Kaplan, R. S., & Norton, D. P. (1992a). The balanced scorecard as a strategic management system. *Harvard Business Review*, *6*, 1–66.

Kaplan, R. S., & Norton, D. P. (1992b). *The balanced scorecard: Measures that drive performance*. Harvard Business Review (January–February) (pp. 71–79).

Kaplan, R. S., & Norton, D. P. (1996a). *Using the balanced scorecard as a strategic management system*. January–February. Harvard Business Review.

Kaplan, R. S., & Norton, D. P. (1996b). *The balanced scorecard—Translating strategy into action*. Boston, MA: Harvard Business School Press.

Kaplan, R. S. (1998). Innovation action research: Creating new management theory and practice. *Journal of Management Accounting Research*, *10*(89–1), 18.

Kaplan, R. S., & Norton, D. P. (2006). *Alignment: Using the balanced scorecard to create corporate synergies*. Boston: Harvard Business Press. 302.

Khodabakhshi, M., & Aryavash, K. (2014). The fair allocation of common fixed cost or revenue using DEA concept. *Annals of Operations Research*, *214*(1), 187–194.

Kim, D., Cavusgil, S. T., & Calantone, R. J. (2006). Information system innovations and supply chain management: Channel relationships and firm performance. *Journal of the Academy of Marketing Science*, *34*(1), 40–54.

Koning, G. M. J. (2004). Making the balanced scorecard work (part 1). *Gallup Management Journal*. http://gmj.gallup.com/content/12208/making-balancedscorecard-work-part.aspx.
Kroes, J. R., & Ghosh, S. (2010). Outsourcing congruence with competitive priorities: Impact on supply chain and firm performance. *Journal of Operations Management*, *28*, 124–143.
Kwon, H. B., Lee, J., & Roh, J. J. (2016). Best performance modeling using complementary DEA-ANN approach: Application to Japanese electronics manufacturing firms. *Benchmarking: An International Journal*, *23*(3), 704–721.
Lee, A. H. I., Chen, W. C., & Chang, C. J. (2008). A fuzzy AHP and BSC approach for evaluating performance of IT department in the manufacturing industry in Taiwan. *Expert Systems with Applications*, *34*, 96–107.
Lee, K. H., & Farzipoor Saen, R. (2012). Measuring corporate sustainability management: A data envelopment analysis approach. *International Journal of Production Economics*, *104*(1), 219–226.
Leung, L. C., Lam, K. C., & Cao, D. (2006). Implementing the balanced scorecard using the analytic hierarchy process and the analytic network process. *Journal of the Operational Research Society*, *57*, 682–691.
Li, K., & Lin, B. (2016). Impact of energy conservation policies on the green productivity in China's manufacturing sector: Evidence from a three-stage DEA model. *Applied Energy*, *168*, 351–363.
Liang, L., Wu, J., Cook, D. D., & Zhu, J. (2008). Alternative secondary goals in DEA cross-efficiency evaluation. *International Journal of Production Economics*, *113*, 1025–1030.
Liu, F. H. F., & Hai, H. L. (2005). The voting analytic hierarchy process method for selecting supplier. *International Journal of Production Economics*, *97*, 308–317.
Liu, J. S., Lu, L. Y. Y., Lu, W. M., & Lin, B. J. Y. (2013). Data envelopment analysis (1978–2010): A citation-based literature survey. *Omega*, *41*(1), 3–15.
Lockamy, A., & McCormack, K. (2004). Linking SCOR planning practices to supply chain performance: An exploratory study. *International Journal of Operations and Production Management*, *24*, 1192–1218.
Lohman, C., Fortuin, L., & Wouters, M. (2004). Designing a performance measurement system design: A case study. *European Journal of Operational Research*, *156*(2), 267–286.
Mannino, M., Hong, S. N., & Choi, I. J. (2008). Efficiency evaluation of data warehouse operations. *Decision Support Systems*, *44*, 883–898.
Milis, K., & Mercken, R. (2004). The use of the balanced scorecard for the evaluation of information and communication technology projects. *International Journal of Project Management*, *22*, 87–97.
Neely, A., Adams, C., & Kennerley, M. (2002). *The performance prism: The scorecard for measuring and managing business success*. London: FT Prentice-Hall.
Neely, A. D., Gregory, M., & Platts, K. (1995). Performance measurement system design: A literature review and research agenda. *International Journal of Operations and Production Management*, *15*(4), 80–116.
Neely, A. D., Mills, J., Platts, K., Gregory, M., & Richards, H. (1996). Performance measurement system design: Should process based approaches be adopted? *International Journal of Production Economics*, *46–47*, 423–431.
Neely, A. D., Richards, H., Mills, J., Platts, K., & Bourne, M. (1997). Designing performance measures: A structured approach. *International Journal of Operations and Production Management*, *17*(11), 1131–1152.
Oral, M., Kettani, O., & Lang, P. (1991). A methodology for collective evaluation and selection of industrial R&D projects. *Management Science*, *37*(7), 871–883.
Paradi, J. C., & Zhu, H. (2013). A survey on bank branch efficiency and performance research with data envelopment analysis. *Omega*, *41*(1), 61–79.
Parasuraman, A., Zeithaml, V., & Berry, L. L. (1988). SERVQUAL: A multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing*, *64*(1), 13–40.
Park, S., & Kim, J. (2016). Energy efficiency in Korea: Analysis using a hybrid DEA model. *Geosystem Engineering*, *19*(3), 143–150.
Phusavat, K., Anussornnitisarn, P., Helo, P., & Dwight, R. (2009). Performance measurement: Roles and challenges. *Industrial Management & Data Systems*, *109*(5), 646–664.
Qi, Z. (2015). Empirical research on the efficiency of resource allocation of compulsory education based on DEA—Case study of primary schools in an eastern city. *Educational Research*, *3*, 012.
Rajesh, R., Pugazhendhi, S., Ganesh, K., Ducq, Y., & LennyKohe, S. C. (2012). Generic balanced scorecard framework for third party logistics service provider. *International Journal of Production Economics*, *140*(1), 269–282.
Rickards, R. C. (2007). BSC and benchmark development for an e-commerce SME. *Benchmarking: An International Journal*, *14*, 222–250.
Seiford, L. M. (1996). Data envelopment analysis: The evolution of the state of the art (1978–1995). *Journal of Productivity Analysis*, *7*(2–3), 99–137.

Sevkli, Mehmet, Koh, S. C. Lenny, Zaim, Selim, Demirbag, Mehmet, & Tatoglu, Ekrem. (2007). An application of data envelopment analytic hierarchy process for supplier selection: A case study of BEKO in Turkey. *International Journal of Production Research*, *45*(9), 1973–2003.

Sexton, T. R., Silkman, R. H., & Hogon, A. J. (1986). Data envelopment analysis. Critique and extensions. In R. H. Silkman (Ed.), *Measuring efficiency: An assessment of DEA* (pp. 73–105). San Francisco, CA: Jossey-Boss.

Shepherd, C., & Gunter, H. (2006). Measuring supply chain performance: Current research and future directions. *International Journal of Productivity and Performance Management*, *55*, 242–258.

Shwartz, M., Burgess, J. F., & Zhu, J. (2016). A DEA based composite measure of quality and its associated data uncertainty interval for health care provider profiling and pay-for-performance. *European Journal of Operational Research*, *253*(2), 489–502.

Smith, J. S., Karwan, K. R., & Markland, R. E. (2007). A note on the growth of research in service operations management. *Production and Operations Management*, *16*(6), 780–790.

Srdjevic, B., Medeiros, Y. D. P., & Porto, R. L. L. (2005). Data envelopment analysis of reservoir system performance. *Computers and Operations Research*, *32*(12), 3209–3226.

Stoica, O., Mehdian, S., & Sargu, A. (2015). The impact of internet banking on the performance of romanian banks: DEA and PCA approach. *Procedia Economics and Finance*, *20*, 610–622.

Tan, K. H., & Platts, K. W. (2009). Linking operations objectives to actions: A plug and play approach. *International Journal of Production Economics*, *121*(2), 610–619.

Thanassoulis, E., De Witte, K., Johnes, J., Johnes, G., Karagiannis, G., & Portela, M. (2016). *Applications of DEA in education*.

Tseng, M. L. (2010). Implementation and performance evaluation using the fuzzy network balanced scorecard. *Computers and Education*, *55*, 188–201.

Vachon, S., & Klassen, R. D. (2008). Environmental management and manufacturing performance: The role of collaboration in the supply chain. *International Journal of Production Economics*, *111*, 299–3.

Wang, Rong-Tsu, Ho, Chien-Ta Bruce, & Oh, K. (2008). Measuring production and marketing efficiency using grey relation analysis and data envelopment analysis. *International Journal of Production Research*, *48*(1), 183–199.

Weber, C. A., Current, J. R., & Desai, A. (1998). Non-cooperative negotiation strategies for vendor selection. *European Journal of Operational Research*, *108*, 208–223.

Wiersma, E. (2009). For which purposes do managers use balanced scorecard? An empirical study. *Management Accounting Research*, *20*(4), 239–251.

Wu, I. L., & Chang, C. H. (2012). Using the balanced scorecard in assessing the performance of e-SCM diffusion: A multi-stage perspective. *Decision Support Systems*, *52*, 474–485.

Wu, T. H., Chen, M. S., & Yeh, J. H. (2010). Measuring the performance of police forces in Taiwan using data envelopment analysis. *Evaluation and Program Planning*, *33*(3), 246–254.

Yasin, M. M., & Gomes, C. F. (2010). Performance management in service operational settings: A selective literature examination. *Benchmarking: An International Journal*, *17*(2), 214–231.

Yuksel, I., & Dagdeviren, M. (2010). Using the fuzzy analytic network process (ANP) for balanced scorecard (BSC): A case study for a manufacturing firm. *Expert Systems with Applications*, *37*, 1270–1278.

Zervopoulos, P. D., Brisimi, T. S., Emrouznejad, A., & Cheng, G. (2016). Performance measurement with multiple interrelated variables and threshold target levels: Evidence from retail firms in the US. *European Journal of Operational Research*, *250*(1), 262–272.

Zeydan, M., & Çolpan, C. (2009). A new decision support system for performance measurement using combined fuzzy TOPSIS/DEA approach. *International Journal of Production Research*, *47*(15), 4327–4349.

Zhang, W. (2015). The analysis of the agriculture input and output efficiency based on DEA model. *Agricultural Science & Technology*, *16*(2), 414.