Accounting method selection using neural networks and multi-criteria decision making

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Abstract

The selection of accounting methods has significant impacts on companies' accounting results and strategic goals. However, this selection problem has not been effectively addressed by existing studies. To fill this important gap, we propose a novel approach for evaluating two accounting method alternatives, namely Full Cost (FC) and Successful Effort (SE) with an empirical case of an oil and gas company. Neural networks (NNs), fuzzy multi-criteria decision making (MCDM) with optimal weighting are applied to evaluate the consequent effects of FC and SE on strategic goals of the case company. The empirical study conducted demonstrates the effectiveness of the proposed approach. Methodologically, this paper provides a structured approach for evaluating accounting method alternatives in a rational and informed manner. Empirically, the evidence obtained from applying the proposed approach can be used to support the case company's decision on accounting method selection.

1. Introduction

The selection of the most suitable accounting method has been a long-standing challenge to companies, accounting professionals and academia. Accounting methods are the rules applied to record business operations in financial information for producing the accounting results. Different accounting methods will produce different accounting results despite the results of business operations. Accounting results, namely the statement of the balance sheet, profit and loss and cash flow, are deemed as a reflection of the company's performance. Accounting results are widely used in performance measurements, credit risk evaluation, bankruptcy prediction, asset pricing and contracting purposes. Thus, accounting results are closely monitored by managers, shareholders, prospective investors and government agencies for making a wide range of decisions.

A company needs multiple types of accounting methods for recording different types of business transactions. Each accounting method type has multiple accounting method alternatives, and only one accounting method in each type must be selected for preparing accounting results. To produce reliable and relevant accounting results, accounting standards and regulations in different countries allow and encourage companies to select the accounting methods that are best suited to the company's situation.

Accounting method selection is a crucial and complex decision problem. The selection has significant effects on a company's accounting results and future growth [1, 2]. For instance, accounting results can substantially influence a company's ability to raise debt or investment for future operation. To support growth and development, the selected accounting method should best assist the company in achieving its business strategy. Under current practice, executives and accountants make such accounting method selection decisions based on experiences as they have in-depth knowledge of the company and accounting systems [3]. The accounting method selection often needs to consider numerous endogenous and exogenous business factors, such as production settings, capital structure, market competition, economic outlook, government incentives and accounting regulations. Some companies may follow similar companies' choices or best practices. However, companies rarely review and adjust the accounting methods in use when the business factors change. The selected accounting methods in many companies with different business models are often indifferent to others [4]. This is due to the lack of decision support for evaluating and selecting the most suitable accounting methods. The complex interactions between the business factors and accounting results have made the evaluation and selection of accounting method alternatives costly and difficult. It is believed that accounting method selection has not been advanced over the past 20 years [2]. Existing studies of accounting methods often make inconsistent suggestions due to a mixed view of the evaluation criteria or selection

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objectives. In addition, estimating accounting results under an unused accounting method has not been studied. The consequences of accounting method alternatives to the overall business performance have not been examined.

To fill this important gap for addressing unresolved issues identified above in the accounting method selection problem, we propose a novel approach using neural networks (NNs) and multi-criteria decision making (MCDM) techniques. To illustrate the approach, we use an empirical case from the oil and gas industry on one of the most crucial accounting method selection problems, namely the exploration costing method selection between Full Cost (FC) and Successful Effort (SE). Eni S.p.A., a multinational integrated oil and gas company, is selected as the case company. This is because Eni's data offers the possibility for accounting results modeling as it changed from FC to SE in January 2016 voluntarily to increase comparability of its accounting results.

Two research questions are to be addressed in order to evaluate the two accounting method alternatives, FC and SE. First, how to estimate accounting results under an unused accounting method alternative? Accounting items and relevant business factors affected by the FC and SE methods are to be identified. The relationship between identified business factors and accounting items need to be modelled. Second, how to evaluate and select the most suitable exploration costing method? Multiple evaluation criteria, criteria weighting, performance ratings of alternatives and criteria aggregation are to be dealt with.

The two research questions can be addressed by the proposed NN-MCDM approach. NNs are used to predict accounting results under the unused accounting method alternative. MCDM is used to evaluate the performance of the two accounting method alternatives with respect to Eni's strategic goals. By quantifying the impacts of accounting method alternatives on accounting results and strategic goals, the most suitable accounting method for achieving the highest overall performance value can be identified. NNs have been proven effective in modeling many complex business and finance problems [5]. Applying NNs has three advantages. First, NN models do not require assumptions of the underlying model form. Second, NN models handle nonlinearity well. Third, NN models perform well in a wide range of complex prediction problems [6]. MCDM can address rationality, effectiveness, consistency and complexity of decisions involving multiple evaluation criteria [7]. To deal with the subjectivity and impreciseness involved in assessing the relative weights of evaluation criteria, we apply pairwise comparisons with linguistic terms characterized by fuzzy numbers [8]. To reflect the case company's best possible operational condition for evaluating the performance of the two accounting method alternatives, we apply the notion of optimal weighting for the evaluation criteria used.

In subsequent sections, we first review related studies in accounting methods and identify the gap to be addressed. Next, we present the proposed NN-MCDM approach and demonstrate how the approach works in Eni's empirical case. Finally, we discuss the results and suggest future studies.

2. A review of accounting method selection

Accounting is a systematic and comprehensive approach for measuring, processing, recording and communication companies' operations in financial form. Accounting results are essential information used for supporting internal and external decision making. Accounting results are a crucial element for supporting research in accounting, management and finance, such as accounting information quality, accounting standard adoption, contracting, performance measure, bankruptcy, credit risk and asset pricing [2, 9]. As a subfield of accounting research, accounting choice research investigates a wide range of accounting-related decisions that are purposefully made to affect accounting results [2]. Accounting method selection is one subset of accounting choice that is visible, non-specific to and generally exercised by companies.

One type of accounting methods consists of two or more accounting method alternatives. Different types of accounting methods affect different items of the accounting results. In addition to exploration costing, there are other types of accounting methods, for example, inventory accounting methods, revenue recognition, depreciation and research and development (R&D) methods. Public trade companies are required to disclose their accounting results and accounting methods applied in preparing the accounting results. Significant impacts can be observed by the release of accounting results in companies' credit ranking and share prices, but the role played by accounting methods is overlooked by investors [2, 3, 11].

2.1. Influential factors in accounting method selection

The influential factors in accounting choice are well studied. Under the influence of the positive accounting theory, the determinators of accounting choice have been examined from four main perspectives include (a) agent theory, (b) the true reflection hypotheses, (c) income management, and (d) comprehensive framework. Numerous studies have found that

accounting method selection is heavily influenced by CEOs' personal motives, such as personal economic benefits, CEO tenure and reputation [12, 13]. However, other studies believe that accounting method selection is made by CEOs of the companies under investigation to properly reflect the companies' true performance and financial situation [1, 10, 14, 15]. Moreover, another view of emphasizing the accounting method selection is driven by financial demands to manage the company's earnings for meeting or beating benchmarks and financial analysts' expectations [16-18]. In evolving research progress, many conflicting conclusions and suggestions are reached [1, 15, 19].

In recent studies, comprehensive frameworks are developed [3, 20, 21]. One of the frameworks identifies five groups of factors that influence accounting choice, including company internal factors, political factors, economic factors, financial factors and people factors. For instance, in practice, the accounting method selection would be made with an iterative review process in alignment with the application of different accounting methods and various objectives, such as financial objectives, operation objectives, valuation objectives and overall company objectives. Then, based on whether the outcome of current data is appropriate to internal and external entities, the adjustment can be made. The goal of the process is to record, measure, monitor and communicate the company's financial information in the way best suited to the situation of the company [3].

2.2. Accounting method selection as a decision problem

As accounting choice research have adopted positive research approach since the early 1980s, fewer studies take the normative approach to develop deterministic models for accounting method selection problem [2]. Inventory accounting method selection between last-in-first-out (LIFO) and first-in-first-out (FIFO) is one of the most studied accounting method selection problem using models in early studies. This is because the accounting results under alternative inventory accounting method can be obtained by the modelling techniques at its time. Various mathematical models are proposed with objectives, such as maximizing the economic benefits of asset value, minimizing tax cost and investors' negative expectation [22-24]. The rest of the accounting methods are left unexamined.

Although existing studies on accounting choice research have provided insights into understanding why practitioners prefer one particular accounting method over the alternatives, how to make a good selection is unaddressed [4]. It is believed that accounting choice research has not led to a better understanding of the accounting method selection problem and has disconnected with the practice [2]. As the complexity and volatility of the business environment increases, the current practice for accounting method selection is becoming less effective, and the existing decision support for the problem is inadequate. For instance, based on the current understanding of accounting theories, companies should adopt different accounting methods that best align with their business models and strategies. However, the selection of accounting methods made by companies with significantly different business models is indistinguishable [4].

Accounting methods have impacts on a company's business performance, strategic performance and future growth [1, 15, 25]. Existing studies have overlooked such perspectives. It is thus believed that further research on accounting method selection for supporting business objectives are needed [2, 4, 10]. As such, the following limitations in existing studies need to be addressed [2]:

a) Multiple and conflicting business objectives are neglected by research design. Existing studies recognize multiple business objectives in accounting method selection research but ignore them in the assumption.
b) Research questions are ineffective to support better accounting method selection. Questions are often designed to explain what drives the accounting method selection in current practice. However, how to make a better selection by what criteria has not been addressed.
c) Traditional methodologies are insufficient. Accounting method selection is a nonlinear, interactive and complex problem. However, existing studies often use traditional statistical techniques only.

3. An NN-MCDM approach for accounting method selection

The proposed NN-MCDM approach is applied to help the case company Eni to justify their selection of the most suitable exploration costing method (FC or SE), as shown in Figure 1. The approach consists of two main modules: an NN module and an MCDM module. The NN module is used to predict consequent accounting results under the two accounting method alternatives, FC and SE. The MCDM module is used to evaluate the performance of the two accounting method alternatives in terms of Eni's strategic goals. Two modules work jointly to help Eni identify the most suitable exploration costing method for best achieving its strategic goals. In the rest of this section, we first

describe Eni's background for this empirical study. Then, we explain the modeling processes for the NN module and the MCDM module, respectively, illustrated with Eni's empirical data. Lastly, we present the results.

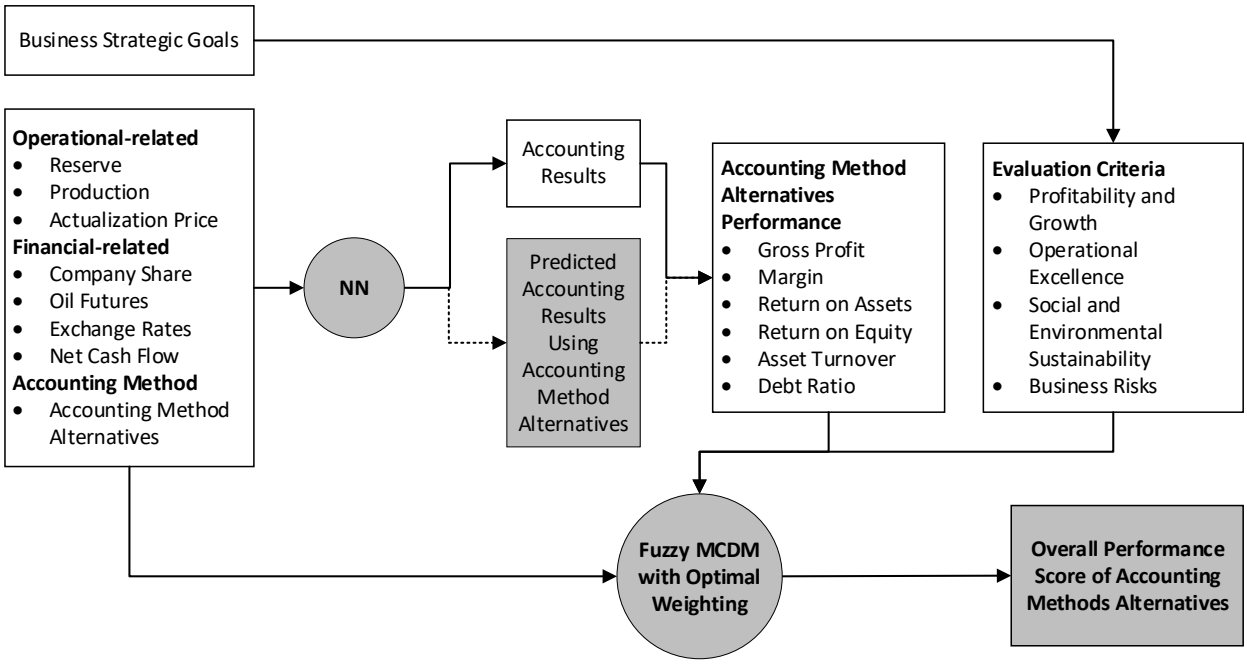

Figure 1. An NN-MCDM approach for accounting method selection

3.1. Exploration costing method at the case company Eni

Eni operates across upstream and mid-downstream. With a market capitalization of 56 billion USD as in 2019, Eni has a complex capital structure including debt, corporate bond and shares. Their upstream activities include oil reserve exploration and field development. The downstream activities include production, supplying, trading and shipping products of natural gas, liquid natural gas (LNG), electricity, fuels and chemicals. Eni's business strategy and business models are set by the board of directors, who directs the company operations and growth through establishing values, strategy, structure, delegation to management and exercising accountability.

Eni discloses its accounting results in compliance with International Financial Reporting Standard (IFRS). Based on their internal analysis, Eni's accounting results are under the influences of several endogenous and exogenous factors. Endogenous factors include operating results, sales, capital structures and management preference. Exogenous factors are economy, financial market performance, oil future price, currency exchange rates and interest rates. For instance, capital expense can fluctuate as interest rates and exchange rates changes. Furthermore, operation revenue and profit can be affected by the change of oil future prices, as the futures market and the spot market for crude oil and refined products are highly integrated. Hence, oil future and interest rates are identified as risks by Eni's analysis.

Full Cost (FC) and Successful Effort (SE) are different methods in recording the cost that is related to searching for, acquiring and developing oil reserves. Oil reserves set a large proportion of assets for oil and gas companies. SE records unsuccessfully exploration costs as expenses immediately on a field-by-field basis, whereas, FC capitalizes the cost and charge it as cost to the company as an entity in future time. Compared with SE, FC reports more net income and profit in the early stage of new exploration projects. The effect will reverse in later stages of the exploration projects given other factors remain the same. The selection of FC and SE is one of the most crucial decisions and the most debated among industry practitioners. To increase financial information comparability, Eni has changed from FC to SE since January 2016. IFRS encourages companies to choose the most suited accounting method for producing relevant and reliable accounting results [25]. However, existing studies lack in the evaluation and selection for FC and SE in a comprehensive and company-specific setting.

3.2. NN module for accounting results prediction

3.2.1. NN inputs and outputs. To obtain accounting results under a different accounting method for the same reporting period, we need to model the relationships between relevant business factors and accounting items that are to be affected by the accounting method under examination. We review and analyze relevant accounting literature, oil and gas industry reports and Eni's annual reports. A number of key performance indicators (KPIs) that are commonly used by the industry and by Eni are identified as the basis for measuring Eni's performance on its strategical goals. The accounting items that contribute to the identified KPIs are selected as NN outputs, given as follows:

a) Total asset (O_1): the resources owned or controlled that can provide future economic benefits.
b) Total liability (O_2): the financial obligations that the company owes to external entities.
c) Total equity (O_3): the resources brought by the ownership of the company.
d) Revenue (O_4): the full amount of total sales by providing goods and services.
e) Gross profit (O_5): the profit made after deducting the costs associated with production and sales.
f) Operating income (O_6): the profit made through the business normal and repeating operations after operating expenses including wage, depreciation and cost of goods sold.

Then, the business factors that affect the selected accounting items are to be identified. Based on the relationships between Eni's operations and accounting items, we categorize relevant business factors into three groups: operation-related factors, financial factors, and accounting factor.

First, operation-related factors are reserves (I_1), production (I_2) and actualization price (I_3). Oil and gas reserves are the most important assets for generating future economic benefits. We aggregate three types of resources, liquids (B_{11}), natural gas (B_{12}) and hydrocarbons (B_{13}) as one NN input (I_1). Production (I_2) is the products for sale and generate revenues. We include the production volumes of liquids (B_{21}), natural gas (B_{22}) and hydrocarbons (B_{23}). The sale price of any product fluctuates during a period of time. Hence, actualization price (I_3) is the aggerated weighted average of the actual selling price of liquids (B_{31}), natural gas (B_{32}) and hydrocarbons (B_{33}) in the reporting period.

Second, financial factors include company share effect (I_4), future effect (I_5), interest rates (I_6), exchange rate (I_7) and net cash flow (I_8). Share price (B_{41}) and traded share volume (B_{42}) compose B_4. The oil futures price (B_{51}) and traded volume (B_{52}) in the two major oil future markets, the West Texas Intermediate (WTI) market and the Brent Crude market, are used for generating I_5. USD and EURO are both used currencies by Eni; hence, the interest rates of USD (B_{61}) and EURO (B_{62}) and exchange rate of USD/EURO (B_{71}) are chosen for B_6 and B_7, respectively. Net cash flow (B_{81}) is used directly for I_8, which is the amount of cash available. It funds future operations directly and helps distinguish non-cash resources for supporting the operations.

Third, the accounting factor is the exploration costing accounting method (I_9), including FC and SE. The voluntary change from FC to SE substantially changes how to record the cost that is related to searching for, acquiring and developing the reserves. The FC method records the cost associated with unsuccessful exploration and development as an entity in the future time. The SE method assesses exploration and development on a field-by-field basis, and expense unsuccessful effort immediately. Assuming identical exploration operation, accounting results would be different in the short term, but the amount to be recorded as expenses will be the same in the long term. More net income and profit will be reported in the early stage using FC. The effect reverses in the later stage from the accounting perspective without considering other factors. As a result, nine NN inputs generated from 20 business factors are summarized as follows:

a) Reserve (I_1): Reserves volume of liquids (B_{11}), natural gas (B_{12}) and hydrocarbons (B_{13})
b) Production (I_2): Production volume of liquids (B_{21}), natural gas (B_{22}) and hydrocarbons (B_{23})
c) Actualization price (I_3): Average sold price of liquids (B_{31}), natural gas (B_{32}) and hydrocarbons (B_{33})
d) Company share effect (I_4): Share price (B_{41}), traded volume (B_{42})
e) Futures effect (I_5): Future price and traded volume in WTI (B_{51}, B_{52}) and Brent (B_{53}, B_{54})
f) Interest rates (I_6): Interest rate for USD (B_{61}) and EURO (B_{62})
g) Exchange rate (I_7): Exchange rate for USD/EURO (B_{71})
h) Net cash flow (I_8): Net cash flow (B_{81})
i) Accounting method (I_9): Exploration costing accounting method (FC or SE)

3.2.2. Data collection and pre-processing. Data are collected from Eni's annual reports, Eni's Factbook, U.S. Securities and Exchange Commission (SEC) 20-F filings, Yahoo finance and the economic research data repository of Federal Reserve Bank of St. Louis (FRED). After data pre-processing, 55 sets of 15

quarterly data points from the 2nd quarter of 2005 to the 4th quarter of 2018 are used for training NN models. 2018 data are reserved as test data for model testing only. All accounting data are in millions of USD, and business factors are in their natural units of measurements. For the data normalization, we test and select the decimal scaling method as it outperforms the standard score normalization and feature scaling normalization methods.

3.2.3. NN model architectures and performance evaluation. We select multiple-inputs-multiple-outputs (MIMO) for NN modeling as it outperforms NN models with a single output and better captures the relationships among multiple accounting items. Then, we test four NN architectures, including single-layer perceptron (SLP), multilayer perceptron (MLP), recurrent neural network (RNN) and long short-term memory (LSTM). Each architecture has 30 trained models using a random initialization and 10-fold cross-validation procedure. Additionally, we use four model training techniques to improve the model performance, including 20% random data for validation (N), 20% neural dropout layer (D), specified more current data for validation (V), and both dropout layers and specified validation data (D & V). The best performing model in each training setting is saved with a tolerance of 3,000 epochs. The model performances are measured by the mean of the absolute percentage error (MAPE) and mean absolute error (MAE) using test data. Finally, the performance of each architecture and training technique is reported using an averaged performance of 30 trained models. Table 1 shows the results.

Table 1. Performance of NN models

NN	Training Setting	N		D		V		D & V	
		MAPE	MAE	MAPE	MAE	MAPE	MAE	MAPE	MAE
SLP	N	6.1%	0.597	8.4%	0.632	6.1%	0.474	8.0%	0.653
MLP	D	12.5%	0.963	4.1%	0.415	4.5%	0.418	10.2%	0.613
RNN	V	26.3%	5.020	12.8%	0.605	38.2%	1.625	16.1%	0.817
LSTM	D & V	30.9%	1.682	14.1%	0.686	28.1%	1.452	24.2%	1.435

Table 2. Predicted accounting results using FC for 2018

	Quarter	Accounting results (USD in millions)					
		O_1	O_2	O_3	O_4	O_5	O_6
FC	1	152,737.5	89,764.5	62,464.7	17,460.1	1,924.3	1,223.5
	2	158,016.6	92,167.3	64,666.7	20,242.6	2,930.6	1,833.6
	3	154,556.1	89,915.5	63,443.9	20,524.8	3,360.2	1,920.5
	4	150,676.2	88,086.3	61,780.2	18,556.7	2,642.3	1,598.7

Table 3. Actual accounting results using SE for 2018

	Quarter	Accounting results (USD in millions)					
		O_1	O_2	O_3	O_4	O_5	O_6
SE	1	140,527.0	81,240.3	59,286.8	22,208.0	6,434.9	2,948.9
	2	141,112.0	80,920.3	60,191.7	22,471.0	6,232.5	3,147.3
	3	143,231.0	84,086.5	59,144.2	23,147.0	7,046.0	4,010.2
	4	139,798.0	79,481.3	60,317.2	23,037.8	5,460.9	1,683.7

The results suggest that feedforward neural networks, SLP and MLP, outperforms recurrent neural networks in terms of prediction accuracy for the given problem formulation and model training settings. The prediction MAPE is satisfactory for the purpose of accounting method evaluation. MLP architecture with dropout layers performs the best. Using the best performing MLP model among a total of 480 trained models, Table 2 shows the predicted accounting results for 2018 using FC. Table 3 shows the actual accounting results for 2018 produced under SE. As the prediction results show, the relative value between different accounting items are well kept. The impacts of FC and SE on the accounting results are consistent with the current understanding.

3.3. MCDM module for evaluating the performance of accounting method alternatives

To best achieve its strategic goals, it is desirable for Eni to select the most suitable exploration costing method. To understand the elements of Eni's business strategy and performance measures, we review and analyze Eni's integrated annual reports for 2014 to 2018 to gain preliminary views. Eni has a comprehensive structure in defining its strategic goals and associated strategic KPIs. To support its long-term corporate value, Eni has four strategic goals as four fundamental pillars, including profitability and growth, operational excellence, prevention of business risks, and social and environmental sustainability. For each strategic goal, strategic KPIs can be used to evaluate the overall performance value of accounting method alternatives, including the following:

a) Profitability and growth: gross profit, R&D expenditure, exploration capital expenditure (CAPX), margin, return on assets (ROA), return on equity (ROE), asset turnover.
b) Operational excellence: total production and proved reserve.
c) Social and environmental sustainability: employment and emissions.
d) Business risks: future price impact, interest rates impact, book-to-market ratio, sharp ratio and debt ratio.

In the context of this study, the selection of FC and SE will impact six KPIs under profitability and growth, and business risks. The performance ratings of the two accounting method alternatives are indifferent with respect to other KPIs. Hence, as shown in Figure 2, the evaluation criteria used in this empirical study are gross profit (C_1), margin (C_2), return on assets (ROA) (C_3), return on equity (ROE) (C_4), asset turnover (C_5) and debt ratio (C_6). Figure 2 also shows the two accounting method alternatives considered and the business factors and accounting results used. Table 4 shows the descriptions of the evaluation criteria and measurements

Table 4. Evaluation criteria description and measurement

Evaluation criteria	Description	Measurement
Gross profit (C_1)	An accounting measure of revenue minus the cost of goods sold. The cost only considers the variable costs associated with operations. It can be used to assess a company's efficiency in using operating resources.	O_5
Margin (C_2)	A ratio reflecting the company's ability in generating profit from each dollar of revenue. The higher the margin is, the more efficient the company can generate profit. It is an important indicator for managers and investors in monitoring the operation efficiency financially.	O_6/O_5
Return on assets (ROA) (C_3)	A ratio indicating the profitability relative to the total asset. This study slightly modifies the ratio by using gross profit divided by total assets. This modified ROA approximates the overall business profitability relative to its total assets. The ratio includes both investors and debtors.	O_5/O_1
Return on equity (ROE) (C_4)	A ratio indicating how profitable a company is, relative to its total equity. This study slightly modifies the ratio by using gross profit divided by total equity. This modified ROE approximates the overall business profitability relative to its total equity. ROE provides information on generating profits with its investors' resource.	O_5/O_3
Asset turnover (C_5)	A ratio measuring the revenue relative to its assets. It can be used as an indicator of the efficiency using the asset to generate revenue.	O_4/O_1
Debt ratio (C_6)	An important measure of the proportion of debt in total capital, which reflects the level of financial obligation a company is bearing. It is calculated by total liability divided by total asset. It is commonly used for indicating the level of flexibility or the financial stress of a company's financing structure.	O_2/O_1

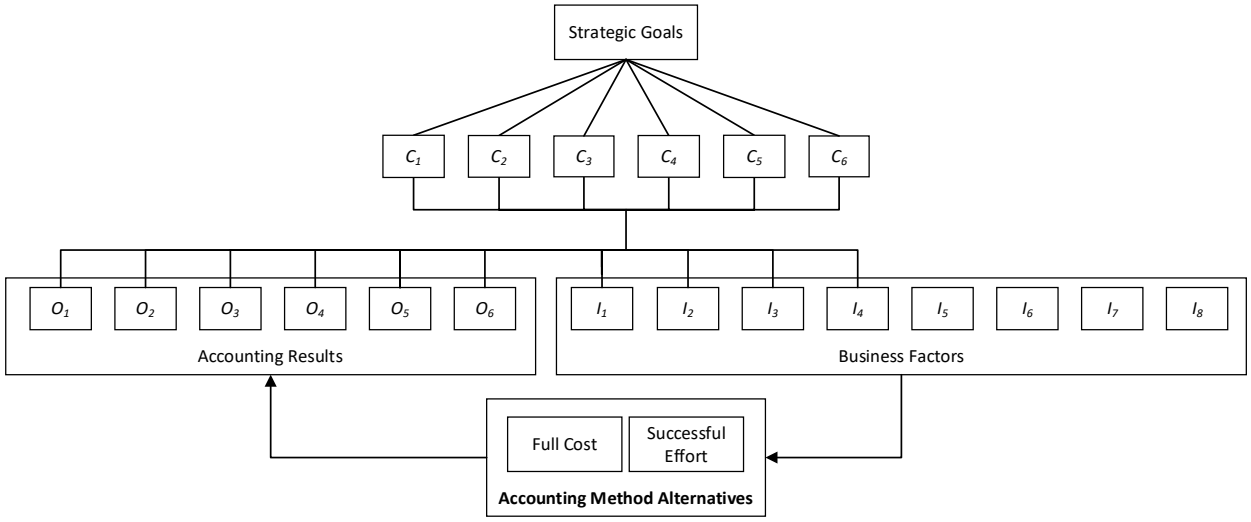

Figure 2. The problem structure for accounting method evaluation and selection

With MCDM, the overall performance value for using the FC or SE method on the company's strategic goals can be obtained by aggregating its performance ratings on the six criteria and the criteria weights. To deal with the impreciseness inherently involved in the process of weighting the six criteria for evaluation, linguistic terms characterized by a triangular fuzzy number are used to assess the relative importance of the six criteria using pairwise comparisons [8]. The triangular fuzzy number is denoted as (a, b, c), where b is the most possible value of a linguistic term, and a and c are the lower bound and upper bound for reflecting the fuzziness of the term. As shown in Table 5, a 1-9 scale is used with a set of five linguistic terms to provide nine possible fuzzy numbers. This scaling method has been proved effective in measuring qualitative information and offering approximation [27]. For instance, if a strongly more important is given in a pairwise comparison, then the fuzzy representation of the weighting is (3, 5, 7). After applying pairwise comparisons to weight the six criteria, fuzzy geometric mean and normalization are used to obtain relative weights [8]. Column 2 of Table 6 shows the fuzzy weights for the six evaluation criteria.

Table 5. Linguistic terms and value fuzzification for pairwise comparison of criteria importance

Equally important	Moderately more important		Strongly more important		Very strongly more important		Extremely more important	
1	2	3	4	5	6	7	8	9
		a		b		c		

Table 6. Fuzzy weights of the six criteria using pairwise comparisons

Evaluation criteria C_i	Fuzzy weight	l_i	u_i
C_1	(0.224, 0.367, 0.575)	0.2955	0.471
C_2	(0.048, 0.084, 0.162)	0.066	0.123
C_3	(0.09, 0.186, 0.361)	0.138	0.2735
C_4	(0.066, 0.122, 0.254)	0.094	0.188
C_5	(0.068, 0.135, 0.25)	0.1015	0.1925
C_6	(0.05, 0.106, 0.23)	0.078	0.168

The fuzzy criteria weights shown in Table 6 represent the case company's preferences in weighting the six criteria, but they may not necessarily reflect its best possible operational condition. To reflect the case company's best possible operational condition for evaluating the two accounting method alternatives (FC and SE), we develop an optimal weighting model for obtaining the optimal weights for the six criteria. The optimal weighting model maximizes the overall performance of FC and SE as a whole. As such, the optimal weights enable FC and SE to be evaluated under the best possible operational condition.

To be in line with the case company's criteria weighting preferences for ensuring its acceptance, the optimal weighting model considers the fuzzy criteria weights as its constraints. To achieve this, we use the concept of α-cut to derive the lower and upper bounds of the case company's preferred criteria weights. To reflect that the case company has no particular confidence degree on the fuzzy criteria weights, we use the mean value of all α-cuts, i.e. the average of value intervals of all α-cuts on the fuzzy number [28]. Columns 3 and 4 of Table 6 show the crisp lower bounds (l_i) and upper bounds (u_i) of the six criteria respectively.

The optimal weights for the six criteria when considering the two accounting method alternatives can be obtained by the following optimal weighting model:

Objective

$$Maximize\ P = \sum_{j}^{2} \sum_{i}^{6} w_i x_{ij} \quad (1)$$

Subject to:

$$l_i \leq w_i \leq u_i \quad (2)$$

$$\sum_{i}^{6} w_i = 1 \quad (3)$$

where

Decision variable:

w_i = optimal weights for criteria C_i

Parameters:

x_{ij} = the performance rating for accounting method alternative j for criteria C_i

l_i = the lower bound of the criteria weights for criteria C_i

u_i = the upper bound of the criteria weights for criteria C_i

The objective function (1) is to maximize the overall performance value of the two accounting method alternatives. Constraints (2) impose that the optimal criteria weights generated must lie within the criteria weight ranges specified by the case company using fuzzy pairwise comparisons. Constraint (3) states that the optimal weights generated are to be normalized to sum to 1.

To obtain the performance rating x_{ij} of FC and SE, the accounting results for using FC and SE shown in Tables 2 and 3 are used. To make the performance ratings (x_{i1}) and (x_{i2}) comparable, their corresponding accounting results measured in different scales are normalized, as shown in Columns 2 and 3 of Table 7 respectively.

Column 4 of Table 7 shows the optimal criteria weights obtained by solving the optimal weighting model, with the overall performance value of FC and SE shown in the last row of Table 7. The result suggests that SE achieves a much higher overall performance value, thus providing a clear and new evidence to support Eni's change from FC to SE in 2016. The change can help Eni to better achieve its strategic goals.

Table 7. SE and FC performance ratings and optimal weights for 2018

Criteria (C_i)	SE performance rating (x_{i1})	FC performance rating (x_{i2})	Optimal weights (w_i)
C_1	0.699	0.301	0.471
C_2	0.768	0.232	0.1175
C_3	0.717	0.283	0.138
C_4	0.710	0.290	0.094
C_5	0.563	0.437	0.1015
C_6	0.497	0.503	0.078
Overall performance value	0.6809	0.3191	

4. Conclusion

Accounting method selection has a great impact on companies' accounting results and strategic goals. However, this critical selection problem has not been well addressed by existing studies. To address this problem, we have proposed a new approach using NNs and MCDM, illustrated with a case company's selection problem of exploration costing methods, FC and SE. The proposed NN-MCDM approach provides a new perspective for practitioners to evaluate and select accounting methods in a rational and informed manner. It can be applied to other companies and industries by adjusting relevant business factors, accounting items and evaluation criteria based on their business settings. For future research, we will examine the sensitivity of FC and SE to business factors. We will also examine other accounting method types and the selection problem of multiple types as different types of accounting methods may have interactive effects on a company's accounting results and subsequently strategic goals.

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