Review

Knowledge management performance measurement: A review

Chuen Tse Kuah and Kuan Yew Wong*

Department of Manufacturing and Industrial Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Malaysia.

This paper presents a review on performance measurement of knowledge management (KM). The purpose of this paper is to provide an overall picture of the various types of approaches for KM performance evaluation. Different tools or models published in the literature are described and compared, and research directions are discussed. Future development directions for KM performance evaluation identified from this review include: (1) consideration of external factors, (2) integration of multiple methods, (3) development of external benchmarking tools, and (4) application of data envelopment analysis (DEA) in KM.

Key words: Knowledge management, performance measurement, literature review.

INTRODUCTION

Knowledge has been well recognized as an intangible yet an important asset for gaining continuous competitive advantage (Davenport et al., 1998; Groves, 2002; Bhatt, 2001). There is an abundance of literature demonstrating the importance and benefits of managing knowledge in organizations. A search using keywords "Knowledge and Management" in the Scopus citation database has shown the increase in the number of publications on knowledge management (KM), as illustrated in Figure 1. This has demonstrated the rising interest of researchers and practitioners in the subject.

Reviewing the literature has revealed a number of different definitions and perspectives on KM. Murray (2002) stated that KM is basically the management of the corporate knowledge and intelligent assets that can improve a range of organizational performance characte-ristics and add value by enabling an enterprise to act more intelligently; De Jarnett (1996) defined it as the pro-cesses of knowledge creation, knowledge interpretation, knowledge dissemination and use, and knowledge retention and refinement; Quintas et al. (1997) perceived KM as the process of critically managing knowledge to meet existing needs, to identify and exploit existing and

acquired knowledge assets and to develop new oppor-tunities; and Brooking (1997) defined it as the activity which is concerned with strategies and tactics to manage human centered assets. To generally sum up these definitions, KM can be viewed as the management of knowledge resources and processes (Wong and Aspinwall, 2006; Wong, 2008), with an objective to improve competitive advantage and organizational performance.

Performance measurement is crucial in KM as it serves as the foundation that enables an organization to evaluate, control, and improve its knowledge processes (Pervaiz et al., 1999; Wong, 2005). Improving KM will ultimately lead to organizational improvements. To measure it, however, is not a simple mission due to its characteristics that include subjectivity, transferability, embeddedness, self-reinforcement, spontaneity, and perishability, which are all intangible (Kluge et al., 2001).

There is no standard in categorizing performance measurement models in KM. Chen and Chen (2005) classified KM performance measurement into eight cate-gories, namely qualitative analysis, quantitative analysis, financial indicator analysis, non-financial indicator analy-sis, internal performance analysis, external performance analysis, project-oriented analysis, and organizational-oriented analysis. Robinson et al. (2005) categorized it into two categories - measures for knowledge assets and

---

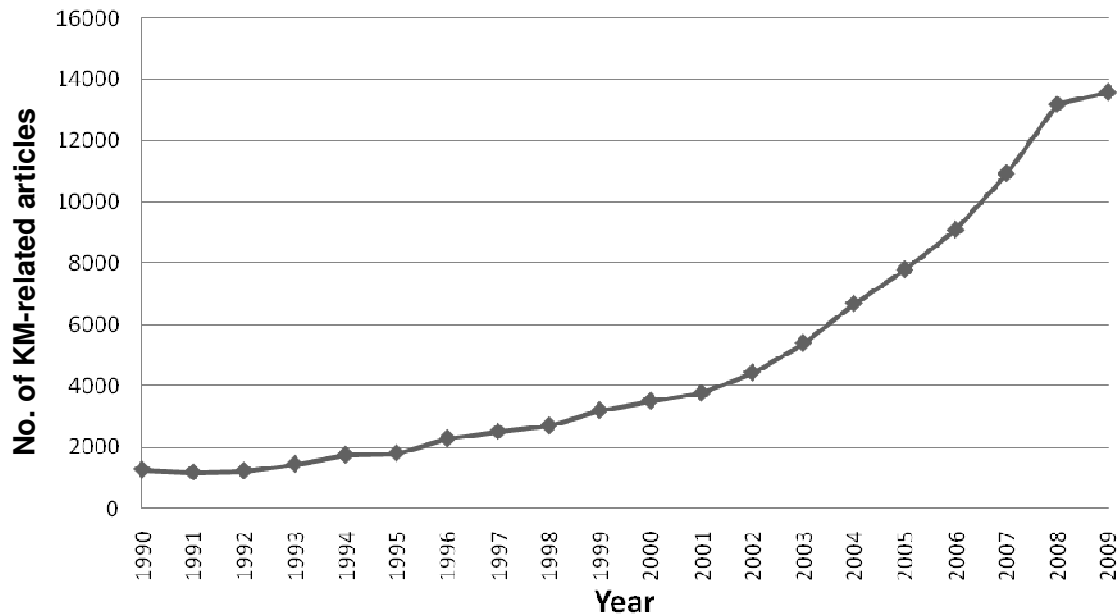*Corresponding author. E-mail: wongky@mail.fkm.utm.my.

Figure 1. Number of KM-related articles published yearly.

measures for KM; and three approaches - metrics approaches, economic approaches, and market value approaches. In this paper, KM performance measurement is grouped into two broad categories, qualitative and quantitative; and eight associated models or tools are discussed.

KM PERFORMANCE MEASUREMENT METHODOLOGIES

Qualitative

Qualitative research usually refines the indications and findings from a pilot study in an organization and from a review by researchers in organizational learning (Chen and Chen, 2005). The advantages of qualitative research include its effectiveness in identifying intangible factors and its capability to produce complex textual descriptions about the "human" side of KM, such as culture, behavior, practice, opinion, and experience. In addition, qualitative approaches are effective in identifying best practices. Since knowledge is recognized as an intangible asset, qualitative methodologies have been widely used in the evaluation of KM. However, they are usually performed subjectively, and hence the accuracy of the results greatly relies on the expertise of the researchers or practitioners involved.

The most common qualitative approaches for internal KM assessment include questionnaire (Changchit et al., 2001), survey (Darroch and McNaughton, 2002; Darroch, 2003), and expert interview (Booker et al., 2008). Changchit et al. (2001) utilized a questionnaire to investigate the effect of an expert system in facilitating the transfer of internal control knowledge to managers whose work experiences are outside of accounting and control systems. Darroch and McNaughton (2002) developed a survey model to evaluate KM based on the Kohli-Jaworski's market-orientation instrument (Jaworski and Kohli, 1993) and Nonaka and Takeuchi's knowledge creation spiral (Nonaka and Takeuchi, 1995). In a follow-up paper, Darroch (2003) expanded her model with behavioral and work practices aspects. Booker et al. (2008) interviewed twelve experts of KM; from the findings, they constructed a framework to investigate the relevance of KM or intellectual capital research towards the academic outputs of business schools.

Quantitative

Quantitative methods, on the other hand, mostly evaluate KM using statistical models, theories, and hypotheses. By using them, numerical results are obtained and causal relationships in KM can be determined. Quantitative approaches can eliminate the drawback of subjective judgment in qualitative methods. In KM, these approaches are used to measure explicit knowledge and the extent of its impact on both decision making and task performance of organizations or individuals with both non-financial and financial indicators (Chen and Chen, 2005).

The most vastly used quantitative approach is metrics. Metrics are input and/or output indicators that are assumed to be correlated with KM performance. Inputs

Table 1. KM metrics categories.

Metrics category	Focus	Example
Customer	Measures related with customers and their perception towards the organization	Number of customers, Customer rating, and Customer retainment rate.
Structural	Measures related with business process and performance.	Processing time, Computers per employee, and Corporate quality performance.
Human	Measures related with employees and their satisfaction level towards their job and the organization	Number of knowledge workers, Number of managers, and Employee turnover rate.
Development	Measures related with the development of employees, products, and businesses.	Training hours per employee, Number of new products, and Number of intellectual properties owned.

are the enablers for KM to be executed, while outputs are its results. By employing various metrics, KM performance could be assessed, monitored and improved. The metrics approach can be used to evaluate both financial and non-financial measures. KM performance measurement tools that have been developed based on this approach are such as Skandia Navigator (Edvinsson, 1997), User-Satisfaction-Based KM Performance Measurement System (USBS) (Chin et al., 2010), and KP^3 Methodology (Ahn and Chang, 2004). There is no standard on what metrics to use for KM performance measurement; however, non-financial metrics can be broadly grouped into four categories - customer, structural, human, and development (Von Krough et al., 1999; Roos et al., 1998; Pervaiz et al., 1999; Robinson et al., 2005). Table 1 shows the explanation of these categories and some examples of metrics. Readers can refer to Ranjit (2004) for a more extensive review on KM metrics.

Despite its usefulness, some problems exist in the metrics approach. Firstly, there is no standard set of metrics and this can be a problem to establish comparison between companies. Secondly, it is difficult to combine various metrics to generate a single efficiency score. Thirdly, this approach mostly does not give enough information to support the organization towards continuous improvement.

Another quantitative method is the financial approach. It evaluates the costs and benefits of KM and whether the benefits exceed the costs. Costs in KM are such as hardware and software costs for KM systems, research and development costs, and training costs; while benefits are the positive outcomes of KM, examples are cost savings and returns on investments (ROI) (Laitamaki and Kordupleski, 1997). An example of KM performance

measurement method that has been developed based on the financial approach is IMPaKT (Improving Management Performance through Knowledge Transformation) assessor, which comprises a cause-and-effect map linking KM initiatives to strategic business objectives, and a road map for selecting the most appropriate evaluation technique to quantify the value of KM (Robinson et al., 2002; Carrillo et al., 2003). The drawbacks of financial approaches include the problem of quantifying the benefits and difficulty of interpreting the results.

KM PERFORMANCE MEASUREMENT TOOLS

This section presents a number of KM performance measurement tools which the authors think are significant in the development of KM performance measurement agendas.

Balanced scorecard (BSC)

BSC is a managerial tool developed by Kaplan and Norton (1996). It measures an organization via four key areas - financial performance, internal business processes, customer, and learning and growth. It has been implemented in KM performance measurement as it links learning components and other intangible assets to organizational performance. Gooijer (2000) expanded BSC into a performance scorecard that is used to map KM objectives across the four BSC key areas. In a recent study, Zhang (2010) has applied BSC to measure the performance of KM; in addition, he evaluated the effectiveness of this approach in KM. From the study, he found that the BSC method does not provide explicit

explanation on how to conduct evaluation on the key areas (Zhang, 2010).

Skandia navigator

Skandia Navigator is an evaluation and management tool for the soft assets of an organization. It focuses on five areas: financial, customer, process, renewal and development, and human aspects, and measures KM via 91 intellectual-based and 73 traditional finance-based metrics (Edvinsson, 1997). By concentrating on each of these metrics individually and collectively, top management will be able to focus on managing the development for the future (Ranjit, 2004). In addition, Skandia Navigator is also capable of measuring the hidden dynamic factors of human, customer and structural capital that underpin the visible aspects of a company's buildings and products, thus reflecting more accurately the value of the company (Robinson et al., 2005). Roos et al. (1998) expanded the tool into another method, intellectual capital index, by combining the measures into a single index and collating the index with changes in the market.

Intangible asset monitor

Intellectual capital is recognized as an important factor in the determination of organizational value and national economic performance (Petty and Guthrie, 2000). Based on three categories of intangible assets: external structure, internal structure, and individual competence; and three sets of measurement indicators: growth and renewal, efficiency, and stability, Sveiby (1997) has developed the intangible asset monitor. It has been used as a new measurement framework with a knowledge perspective to present a more complete measure of organizational success and shareholder value. However, critiques on the non-financial measuring models, such as the intangible asset monitor, are that the models are more concentrated on management objectives and are inadequate for the purpose of quantifying intangible assets (Rodov and Leliaert, 2002).

Tobin's q ratio

Tobin's q is a well-known financial measure that was developed by Nobel Prize winner James Tobin. It is a metric that compares the market value of an asset with its replacement cost (Tobin, 1998). In KM, Tobin's q ratio is applied in intellectual capital measurement. For an asset with a q value less than 1, it is worth less than the replacement cost, thus the company will not buy in more assets of this type. For companies that are intellectual-capital-based, their q value can be around 7; while companies with large physical capital assets such as

construction firms, their q value would be around 1 (Bodie et al., 1993). These indicate that intellectual properties are more important in those intellectual-capital-based organizations like software companies and they are making excellent profits out of their intellectual capital.

A critique on Tobin's q application in KM is it ignores replacement costs for intangible assets (Lev, 2001). Nevertheless, it is important in KM development for laying the groundwork for intellectual capital measurement.

Human resource accounting (HRA)

Human resource management and KM are two closely related fields. Through the integration of these two processes, superior and sustainable performance can be expected (Theriou and Chatzoglou, 2008). Human resource accounting (HRA) is an approach used to quantify the economic value of employees. Based on the principle that human assets are a proxy for capital, salary expenditures can be capitalized and reflected in the balance sheet. Three types of HRA measurement models were developed by Bontis et al. (1999), namely, cost models (replacement or opportunity cost of human assets), human resource value models (non-financial with financial economic value models), and monetary emphasis models (discounted estimates of future earnings or wages).

KP[3] methodology

Ahn and Chang (2004) used a different approach to measure KM. They assessed how much knowledge contributes to business performance; and the relation between knowledge and business performance was established more explicitly. This method, KP[3] (knowledge, product, process, and performance), assesses the contribution of knowledge to business performance by employing product and process as intermediaries. It is particularly useful for the evaluation of productivities of knowledge entities and knowledge workers, and human capital allocation and development. It is worth to mention that Ahn and Chang (2004) also utilized data envelopment analysis (DEA), a multi-criteria decision-making tool, to find the ideal composition of knowledge entities for the most efficient production of business performance.

Knowledge management performance index (KMPI)

Based on an assumption that firms are oriented towards accumulating and applying knowledge to create economic value and competitive advantage, Lee et al. (2005) proposed a new metric, KM performance index (KMPI), for assessing the KM performance of a firm. They introduced a logistic function consisting of five components

that can be used to determine the knowledge circulation process (KCP): knowledge creation, accumulation, sharing, utilization, and internalization. KMPI is able to improve the quality of decision-making in the investment of information system resources, and to establish and evaluate KCP.

User-satisfaction-based system (USBS)

Believing that KM would benefit the organizations when it first benefits the knowledge users, Lo and Chin (2009) have developed the user-satisfaction-based KM performance measurement system (USBS). The applications of USBS include identifying the assessment criteria sourced from user-satisfaction-based (USB) core values, critical success factors and phases of KM process. Organizations could assess the strength and weakness of their own KM system and practice and then identify areas for improvement. To ensure better measurement accuracy, in their follow-up paper, analytic hierarchy process (AHP) and evidential reasoning scoring method were adopted to support multiple-attribute decision making activities that are uncertain (Chin et al., 2010).

A comparison of the various tools described above in terms of their focus, advantages, disadvantages etc is provided in Table 2.

DISCUSSION

Indeed, the reviewed models provide systematic and comprehensive methods to assess KM. However, the limitations of the models should not be overlooked. One of the limitations is the dependence on subjective judgments of the evaluators or assessors, when for example, determining the weights of each metric and the importance of each objective. In addition, there is also a lack of standards in KM performance measurement and this has caused difficulty to compare the various methods (Bontis, 2001).

Some external factors (for example market competition, economic condition, and government policy) have often been neglected in the previous studies.

This has raised arguments that organizational overall performance cannot be considered as a direct impact of KM (Kim, 2006). Future work on KM performance measurement could take these external factors into consideration.

Another trend that can be seen from the literature is that researchers and practitioners are combining both qualitative and quantitative methods, and integrating and synthesizing the tools in order to compensate their respective shortcomings. For instances, Wen (2009) used focus groups, AHP, and questionnaires to develop a model to measure the effectiveness of KM in Taiwanese high-tech enterprises; while Chen et al. (2009) integrated

analytic network process (ANP) with BSC to propose a method that can be used as a KM measurement tool for the entire organization.

Limited benchmarking tools have been proposed to evaluate the relative KM performances of competing companies.

Benchmarking can be achieved through comparison with other organizations recognized as the best within the area (Bhutta and Huq, 1999). The central essence of benchmarking is learning how to improve activities, processes and management (Ahmed and Rafiq, 1998). Benchmarking KM performance with other organizations in the same sector would give useful indications for companies to improve their own knowledge initiatives. Hence, more emphasis could be given on the external evaluation of KM.

Lastly, a widely researched multi-criteria decision-making methodology, DEA, is thought to be potentially applicable in KM. DEA is a linear programming formulation introduced by Charnes et al. (1978). It has been used to measure the relative efficiencies among entities with multiple-input and multiple-output. The renowned feature of DEA is that it does not need prior assumptions for the weights and relationships between the inputs and outputs (Wong and Wong, 2007; Kuah and Wong, 2011). Viewing KM as a multi-input-output system, DEA can be applied in various ways.

To name a few, it can be used to evaluate KM performance among knowledge workers, KM projects, departments within an organization, and KM performance among organizations in a similar context. For further reading on DEA, readers can refer to Cooper et al. (2007) and Kuah et al. (2010).

CONCLUSIONS

Due to the vast amount of literature, a complete review cannot be achieved. Nevertheless, this paper is believed to be a comprehensive study that has covered most of the important KM performance measurement approaches. Particularly, different types of tools or models which are useful for evaluating and monitoring KM have been reviewed and compared. In addition, some future research opportunities have been discussed, hoping that tools which are more holistic and easy to implement will be developed in the near future.

Lastly, KM performance measurement should consider sufficient input data to provide a thorough assessment of KM and the results should not be over-complicated and confusing. A good KM performance measurement tool should at least include the following characteristics:

1. Consider both qualitative and quantitative measures
2. Easy to be implemented
3. Empirically tested
4. Results should be clear, meaningful and not confusing

Table 2. Comparison of KM performance measurement tools.

Tool	Focus	Measurement approach	Advantage / Drawback
BSC	1. Financial performance 2. Internal business processes 3. Customer 4. Learning and growth	Qualitative, Quantitative (financial)	No explicit explanation on how to conduct evaluation on the key areas
Skandia Navigator	1. Financial 2. Customer 3. Process 4. Renewal and development 5. Human aspects	Qualitative, Quantitative (metrics, financial)	Capable of measuring the hidden dynamic factors, easy to implement, but too many measures might cause confusing interpretations
Intangible Asset Monitor	A. Intangible assets: 1. External structure 2. Internal structure 3. Individual competence B. Measurement indicators: 1. Growth and renewal 2. Efficiency 3. Stability	Quantitative (metrics, non-financial)	Too many measures might cause confusing interpretations
Tobin's q	1. Market value of asset 2. Replacement cost of asset	Quantitative (financial)	Ignores replacement costs for intangible assets
HRA	Economic value of employees	Quantitative (financial and non-financial)	Helps to convert employees' knowledge and experience into monetary value
KP^3	1. Knowledge 2. Product 3. Process 4. Performance	Qualitative, Quantitative (metrics, financial and non-financial)	Relation between knowledge and business performance is shown more explicitly
KMPI	1. Knowledge creation 2. Knowledge accumulation 3. Knowledge sharing 4. Knowledge utilization 5. Knowledge internalization	Qualitative, Quantitative (metrics, financial and non-financial)	Explicitly establishes and evaluates KCP
USBS	1. USB core values 2. Critical success factors 3. KM process	Qualitative	Provides an alternative way to evaluate KM solely based on knowledge users.

5. Able to indicate opportunities for improvement provide future directions and predict the results after improvement.

REFERENCES

Ahmed PK, Rafiq M (1998). Integrated benchmarking: a holistic examination of select techniques for benchmarking analysis. Benchmarking Qual. Manage. Technol., 5(3): 225-242.

Ahn JH, Chang SG (2004). Assessing the contribution of knowledge to business performance: the KP^3 methodology. Decis. Support Syst., 36: 403-416.

Bhatt GD (2001). Knowledge management in organizations: examining the interaction between technologies, techniques, and people. J. Knowl. Manage., 5(1): 68-75.

Bhutta KS, Huq F (1999). Benchmarking - best practices: an integrated approach. Benchmarking: Int. J., 6(3): 254-268.

Bodie Z, Kane A, Marcus AJ (1993). Investments. Irwin: New York.

Bontis N (2001). Assessing knowledge assets: a review of the models used to measure intellectual capital. Int. J. Manage. Rev., 3(1): 41-60.

Bontis N, Dragonetti NC, Jacobson K, Roos G (1999). The knowledge toolbox: a review of the tools available to measure and manage intangible resources. Eur. Manage. J., 17(4): 391-404.

Booker LD, Bontis N, Serenko A (2008). The relevance of knowledge management and intellectual capital research. Knowledge Process Manage., 15: 235-246.

Brooking A (1997). The management of intellectual capital. J. Long Range Plann., 30(3): 364-365.

Carrillo PM, Robinson HS, Anumba CJ, Al-Ghassani AM (2003). IMPaKT: a framework for linking knowledge management to business performance. Electron. J. Knowl. Manage., 1(1): 1-12.

Changchit C, Holsapple CW, Viator RE (2001). Transferring auditors' internal control evaluation knowledge to management. Expert Syst. Appl., 20: 275-291.

Charnes A, Cooper WW, Rhodes E (1978). Measuring the efficiency of decision making units. Eur. J. Oper. Res., 2: 429-444.

Chen AP, Chen MY (2005). A review of survey research in knowledge management performance measurement: 1995-2004. J. Universal Knowl. Manage., 1: 4-12.

Chen MY, Huang MJ, Cheng YC (2009). Measuring knowledge management performance using a competitive perspective: an empirical study. Expert Syst. Appl., 36(4): 8449-8459.

Chin KS, Lo KC, Leung JPF (2010). Development of user-satisfaction-based knowledge management performance measurement system with evidential reasoning approach. Expert Syst. Appl., 37: 366-382.

Cooper WW, Seiford LM, Tone K (2007). Data envelopment analysis: a comprehensive text with models, applications, references and DEA-Solver software, 2nd Ed., Springer Science & Business Media: New York.

Darroch J (2003). Developing a measure of knowledge management behaviors and practices. J. Knowl. Manage., 7: 41-54.

Darroch J, McNaughton R (2002). Developing a measure of knowledge management. In World Congress on Intellectual Capital Readings, Bontis N (Ed). Butterworth-Heinemann: Boston, pp. 226-243.

Davenport TH, De Long DW, Beers MC (1998). Successful knowledge management projects. Sloan Manage. Rev., 39(2): 43-57.

De Jarnett L (1996). Knowledge the latest thing. Inf. Strategy: Exec. J., 12(2): 3-5.

Edvinsson L (1997). Developing intellectual capital at Skandia. J. Long Range Plann., 30(3): 366-373.

Gooijer JD (2000). Designing a knowledge management performance framework. J. Knowl. Manage., 4(4): 303-310.

Groves S (2002). Knowledge wins in the new economy. Inf. Manage. J., 36(2): 6.

Jaworski BJ, Kohli AK (1993). Market orientation: antecedents and consequences. J. Mark., 57: 53-70.

Kaplan RS, Norton DP (1996). Using the balanced scorecard as a strategic management system. Harvard Bus. Rev., January-February, pp. 75-85.

Kim JA (2006). Measuring the impact of knowledge management. J. Int. Fed. Library Assoc. Inst., 32(4): 362-367.

Kluge J, Stein W, Licht T (2001). Knowledge unplugged: the McKinsey & Company global survey on knowledge management. Palgrave: New York.

Kuah CT, Wong KY, Behrouzi F (2010). A review on data envelopment analysis (DEA). In Proceedings of the Asia Modelling Symposium 2010 - 4th International Conference on Mathematical Modelling and Computer Simulation, Kota Kinabalu, Malaysia, pp. 168-173.

Kuah CT, Wong KY (2011). Efficiency assessment of universities through data envelopment analysis. Procedia Computer Science. In Press, 3: 499-506.

Laitamaki J, Kordupleski R (1997). Building and deploying profitable growth strategies based on the waterfall of customer value added. Eur. Manage. J., 15(2): 158-166.

Lee KC, Lee S, Kang IW (2005). KMPI: measuring knowledge management performance. Inform. Manage. 42(3): 469-482.

Lev B (2001). Intangibles: management, measurement, and reporting. Brookings Institution Press: Washington.

Lo KC, Chin KS (2009). User-satisfaction-based knowledge management performance measurement. Int. J. Qual. Reliab. Manage., 26(5): 449-468.

Murray P (2002). Knowledge management as a sustained competitive advantage. Ivey Bus. J., 66(4): 71-76.

Nonaka I, Takeuchi H (1995). The knowledge-creating company. Oxford University Press: New York.

Pervaiz KA, Kwang KL, Mohamed Z (1999). Measurement practice for knowledge management. J. Workplace Learning, 11: 304-311.

Petty R, Guthrie J (2000). Intellectual capital literature review: measurement, reporting and management. J. Intellect. Capital., 1(2): 155-176.

Quintas P, Lefrere P, Jones G (1997). Knowledge management: a strategic agenda. J. Long Range Planning, 30(3): 385-391.

Ranjit B (2004). Knowledge management metrics. Ind. Manage. Data Syst., 104(6): 457-468.

Robinson HS, Carrillo PM, Anumba CJ, Al-Ghassani AM (2002). Evaluating knowledge management strategies: an IMPaKT assessment. In Proceedings of the 3rd European Conference on Knowledge Management, Ireland, pp. 586-598.

Robinson HS, Carrillo PM, Anumba CJ, Al-Ghassani AM (2005). Performance measurement in knowledge management. In Knowledge Management in Construction, Anumba CJ, Egbu CO, Carrillo PM (Eds). Wiley-Blackwell, pp. 132-150.

Rodov I, Leliaert P (2002). FiMIAM: financial method of intangible assets measurement. J. Intellect. Capital., 3(3): 323-336.

Roos J, Roos G, Dragonetti N, Edvinsson L (1998). Intellectual capital: navigating in the new business landscape. New York University Press: New York.

Sveiby KE (1997). The intangible assets monitor. J. Hum. Resour. Cost. Account, 2(1): 25-36.

Theriou GN, Chatzoglou PD (2008). Enhancing performance through best HRM practices, organizational learning and knowledge management: a conceptual framework. Eur. Bus. Rev., 20(3): 185-207.

Tobin DR (1998). The knowledge-enabled organization: moving from "training" to "learning" to meet business goals. AMACON Books: New York.

Von Krough G, Roos J, Kleine D (1999). Knowing in firms: understanding, managing, and measuring knowledge. Sage Publications: California.

Wen YF (2009). An effectiveness measurement model for knowledge management. Knowledge-Based Syst., 22(5): 363-367.

Wong KY (2005). Critical success factors for implementing knowledge management in small and medium enterprises. Ind. Manage. Data Syst., 105(3): 261-279.

Wong KY (2008). An exploratory study on knowledge management adoption in the Malaysian industry. Int. J. Bus. Inform. Syst., 3(3): 272-283.

Wong KY, Aspinwall E (2006). Development of a knowledge management initiative and system: a case study. Expert Syst. Appl., 30(4): 633-641.

Wong WP, Wong KY (2007). Supply chain performance measurement system using DEA modeling. Ind. Manage. Data Syst., 107(3): 361-381.

Zhang R (2010). The application of the balanced scorecard in performance assessment of knowledge management. In Proceedings of the 2nd IEEE International Conference on Information Management and Engineering, Chengdu, pp. 443-447.