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Supply chain performance models: A literature review on approaches, techniques, and criteria

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ABSTRACT: Nowadays supply chain (SC) evaluation is one of the critical problems in most of industries. Various frameworks and systems have been proposed to tackle the problem. In this paper, the literature of approaches, techniques and criteria for SC performance evaluation are reviewed. For this reason, related works appeared in the international journals from 1998 to 2010 are gathered and analyzed. The paper attempts to response the following four questions: (I) Which SC approaches were prevalently applied? (II) Which techniques were used to facilitate the performance measurement? (III) Which evaluation criteria were paid more attention? The result of this review is contributed in recommendation of some possible future work. The other objective of this research is to aid the researchers and practitioners in applying the approaches, techniques and criteria effectively.

Keywords: *Whole supply chain; Performance measurement model; Approach; Performance criteria*

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1. INTRODUCTION

Supply Chain Management (SCM) is an effective business philosophy that has gained a tremendous amount of attention from academics, consultants, practitioners and business managers in the recent years (Wong and Wong, 2007) in order to help enterprises to survive with continuous pressures and achieve the goals. Over the last decade of SCM evolution, a wide steady stream of research papers dealing with SC performance measurement has been published. As an essential management tool and the way to reach success, performance measurement enables supply chain to strategically manage and continuously control achieving objectives. It provides the necessary assistance for performance improvement in pursuit of supply chain excellence.

Although in the recent years, a lot of studies have been done in the area of performance management, but generally the studies can be divided into two groups: 1) those that investigate one or some parts or key processes in supply chains and 2) those that look at the supply chain as a whole. Most of the works which have already been carried out are related to the first group. Current study aims to review the importance of the second group and browse a state-of-the-art review in SC performance measurement.

According to some researchers (Jagdev and Browne, 1998; Jagdev and Thoben, 2001; Tan, 2001) supply chains as extended enterprises are responsible for the whole product life cycle, from material procurement and supply management, to production and manufacturing, further to product distribution and customer service and finally to the recycling and disposal of end-of-life product. In other words, the supply chain is an integrated entity, and all the members should be functionally coordinated as an extended enterprise (Holmberg, 2000; Lambert et al., 1998). The inward-looking view neither promotes excellent management of supply chain, nor results satisfactorily in performance measurement (Chan and Qi, 2003a). Supply chain should be seen as the central unit of competitive analysis (Croom et al., 2000). According to Wong and Wong (2007), effective management of an organization's supply chains is an essential corner stone for the organization to develop a sustainable competitive advantage and to remain at the fore front of excellence in a competitive market. To achieve an efficient supply chain, performance evaluation of the entire supply chain is extremely important.

Consequently, to design SC performance measurement models, considering the supply chain as a whole is really useful. This issue has also been stated by other authors, who agree that an integrated and overall approach needs to be adopted when measuring performance in a supply chain (Lambert and Pohlen, 2001; Drzymalski et al., 2010; Beamon, 1996; Handfield and Nichols, 2002; Gunasekaran and Kobu, 2007, de Leeuw and Beekman, 2008).

There are several studies reviewing the literature regarding SC performance evaluation. Most of them focus on measures as a part of performance measurement system. Some others investigate some parts or key processes in supply chains. Shepherd and Gunter (2006) developed taxonomy of performance measures followed by critical evaluation of supply chain performance measurement systems. Gunasekaran and Kobu (2007) attempted to obtain the key performance measures and metrics in supply chain and logistics operations with the aim of using minimum number of measures that provide reasonable accuracy with minimum cost. Akyuz and Erkan (2010) reviewed the papers which are located at the intersection of supply chain, Information Technology, performance measurement and business process management to provide a broad perspective covering technology, process and people's aspects. It aims at revealing the basic research methodologies followed and problem areas and requirements of the performance management. Cuthbertson and Piotrowicz (2008) analyzed the cases that they classified as the best practices of supply chain and identified common measures used to reflect performance improvements. The research aims to identify, categorize and compare supply chain measures and benefits listed in literature-based case studies.

In completion of the previous works, this paper considers the required components of SC performance measurement systems, beyond just metrics sets and extends the previous works by reviewing the SC-oriented performance measurement frameworks, models and systems (Folan and Browne, 2005) (for simplicity, in this paper, we use the term "model" instead of mentioned words) that developed in some international journal articles from 1998 to 2010 and surveying the applied approaches, techniques and criteria. In this regard, three issues are examined, including: (I) Which SC "approaches" were prevalently applied? (II) Which "techniques" were used to facilitate performance measurement? (III) Which evaluation "criteria"

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were paid more attention? It should be mentioned that in this paper, an "approach" refers to a systematic arrangement of ideas or actions intended to deal with the SC performance measurement. A "technique", on the other hand is a way of doing something or a practical method applied to some particular task (Zowghi and Coulin, 2005). The techniques include the tools used in performance measurement. The performance criteria are the description of the characteristics on which the judgment or decision about performance may be based.

The rest of the paper is organized as follows: The next section describes the literature search procedures and the following section describes the current approaches to SC. Section 4 seeks the techniques used in SC models. Section 5 reviews the criteria used in models. Section 6 analyses the most prevalently used approaches, discusses the most popular evaluating criteria, and finds out the limitations of the approaches and finally section 7 concludes the paper.

2. RESEARCH METHODOLOGY

Many papers on performance measurement in SCM have been published in the past decades. However we consider those papers that regard with SCM as a whole entity in the review. The literature survey has been undertaken using online databases relating to publishers such as Emerald, Elsevier, Taylor & Francis, Springer, Palgrave, Inderscience and Interscience.

In this regard, a three-step procedure was conducted to select qualified papers for review. Since this research topic is relatively new, the review was limited in the time period between 1998 and 2010.

At the first step, some keywords and sentence strings, such as "SC performance measurement", "SC assessment", "SC evaluation", "SC and SCOR (Supply chain operations reference)", and "SC management and BSC (Balanced scorecard based model)" and so on, were queried in the above-mentioned databases to acquire a list of papers fitting into our research objective. Non-referred articles, such as editorial notes, prefaces, industrial reports and book reviews, were excluded from the preliminary search process. To ensure the holistic view to SCM the second step was performed with the further filter the preliminary search results by screening titles and keywords of the identified articles. The third step was accomplished by reviewing the abstract and conclusion if the reminded papers, and even (if necessary) reading the details to removing incompetent ones. At last, 42 journal articles have been selected as the base of this review.

Meanwhile, to ensure that the most of the important SCM paper have been selected and probably find the other possible papers that may be missing, the full bibliography of the papers were checked. Table 1 lists the publishers of all 42 qualified journal articles.

To aid the content analysis, an instrument for collecting the main facts within each of the 42 articles was also designed. These facts included, but were not limited to, author(s), area, approach, methodology, criteria and hierarchical based. This information was then used to identify the responses of research questions, discuss the findings and finally draw the conclusions.

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Table 1. Publishers of qualified papers

Publisher	Academic journals	No. of paper
Taylor & Fancis	Production Planning & Control	2
	International Journal of Production Research	2
	Total Quality Management	1
Elsevier	International Journal of Production Economics	3
	Decision Support Systems	2
	European Journal of Operational Research	1
	Computers & Industrial Engineering	1
	Computers in Industry	1
	Transportation Research Part E	1
Springer	International Journal of Advance Manufacturing Technology	2
	Software Quality Journal	1
	Annals of Operation Research	1
Emerald	Benchmarking: An International Journal	3
	Supply Chain Management: An International Journal	2
	International Journal of Operations & Production Management	2
	Integrated Manufacturing Systems	1
	Kybernetes	1
	Facilities	1
	Asia Pacific Journal of Marketing and Logistics	1
	Industrial Management & Data Systems	1
	Supply Chain Management	1
	Journal of Manufacturing Technology Management	1
	International Journal of Productivity and Performance Management	1
Interscience	The Journal of Supply Chain Management	1
InderScience	International Journal of Productivity and Quality Management	1
	International Journal of Business Performance and Supply Chain Modelling	1
	International Journal of Globalisation and Small Business	1
	International Journal of Industrial and Systems Engineering	1
	International Journal of Applied Systemic Studies	1
	International Journal of Business Performance and Supply Chain Modelling	1
	International Journal of Services, Economics and Management	1
	International Journal of Automotive Technology and Management	1

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3. APPROACHES OF ARTICLES

Reviewing the literature of supply chain performance measurement we categorized the models in five groups. As illustrated Fig.1, these groups are Process based approach, Perspective based approach, Hierarchical based approach, Six-Sigma based approach and Uncertainty theory.

3.1. Process based approach

Fourteen out of forty two articles (33.33%) applied this approach in the performance evaluation process.

Some SC models are developed based on their process. Process based refer to those that take SC as a set of processes (such as manufacturing, logistic, inventory management and etc.) and sub processes which are composed of a set of activities. This fact that supply chain management is a set of management processes has been recognized by many other researchers, such as La Londe (1997) and Ross (1998).

Dasgupta (2003) and Lin and Li (2010) constructed their models based on SC processes and sub processes and used six-sigma metrics to evaluates the performance across the entire supply chain. Persson and Olhager (2002) in order to evaluate alternative SC designs, considered the structure of SC as a set of processes. The study is run in a real case of mobile communication industry. Chan and Qi (2003a) proposed a cross boundary process-based model with the idea of managing key processes of supply chains. In other work (Chan and Qi, 2003b) they have studied the feasibility of PMS in supply chain based on process-based approach and measures. The authors proposed a process based approach, with the objective of identifying the participants and analyzing the network structure of supply chain. Theeranuphattana and Tang (2008) applied two process based model SCOR andChan and Qifor demonstrating their model. Thakkar et al. (2009) used SCOR processes at the various levels to report set of performance measures for the supply chain processes in Small and medium scale enterprises (SMEs). Bullinger et al. (2002) applied a process oriented approach and proposed a measurement methodology integrating bottom-up and top-down performance measures as a hybrid balanced measurement approach. Askariazad and Wanous (2009) proposed a hierarchical model for prioritizing SC performance metrics, which decomposed supply chain to processes and sub processes according to the scope and the involved activities. Gunasekaran et al (2001) and Gunasekaran et al (2004) presented a framework for performance measures and metrics, considering the four major supply chain processes (plan, source, make/assemble, and deliver). Parkan and Wang (2007) addressed the process based framework proposed by Gunasekaran et al (2004) for using in measurement of SC performance over a number of time periods. Berrah and Cliville´ (2007) modeled supply chain according to the SCOR model, with its five main processes. Then they had built their PMSs by linking an overall performance expression to elementary ones. Drzymalski et al. (2010) studied SC performance metrics from two aspects of enterprise level and facility level and applied SCOR processes and metrics in the proposed multi-level model.

3.2. Perspective based approach

Perspective based measurement model was developed by Otto and Kotzab (2003). They take all the possible perspectives of a supply chain into account and provide measures to evaluate each perspective. The authors defined a perspective as a unique view of what SCM is about. The authors proposed a goal-oriented approach suggesting six perspectives on SCM each of which follows a particular set of goals, which consequently leads to a particular set of performance metrics. These perspectives are: Systems Dynamics, Operations Research/Information Technology, Logistics, Marketing, Organization and Strategy. Each perspective has its very own notion of a supply chain, its standard problems and solutions, and its performance metrics. Note that there can be a trade-off between measures of one perspective with the measures of other perspectives. Two main perspective based models are SCOR based and BSC based models.

3.2.1. Supply chain operations reference (SCOR) based model

Among 42 journal articles, nine papers (21.43%) employed the SCOR as a single approach in constructing models.

The SCOR model (Supply Chain Council 2006) was introduced in 1996 and includes five basic processes including plan, source, make, deliver, and return. Also, it represents thousands of performance metrics characteristics in reliability, responsiveness, flexibility, cost, and asset attributes. These attributes are characteristics of the supply chain that permits it to be analyzed and evaluated against other supply

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chains with competing strategies. The SCOR model is the only supply chain framework that links performance metrics, best practices and software requirements to a detailed business process model (Ramaa et al. 2009). Some of the performance articles used the perspectives and or attributes and or metrics of SCOR in developing their models.

Cai et al. (2009) proposed a framework using a systematic approach to improve the iterative key performance indicators accomplishment in a supply chain context. The proposed framework quantitatively analyzed the interdependent relationships among a set of key performance indicators. The framework includes a systematic approach that helps to analyze and select the right key performance indicator groups and strategies for their accomplishment, to improve supply chain performance. Considering the complicated characteristics of supply chains, the authors used a process-oriented SCOR model to identify the basic performance measures and the key performance indicators in their methodology.

Berrah and Cliville´ (2007) with the aim of SC performance formalization modeled it according to the SCOR model, with its five main processes (Plan, Source, Make, Deliver and return).

Wong and Wong (2007) and Wong et al. (2007) used SCOR metrics as input and output variables of data envelopment analysis (DEA) model. The authors employed some of the metrics in levels 1-3 of SCOR and then used the DEA as a tool to analyze these variables to evaluate supply chain efficiency.

Wong (2009) and Wong et al. (2008)for discussing an application study on supply chain performance measurement in stochastic environment used input, output and intermediate variables (metrics) that were categorized according to the performance metrics listed in the SCOR.

Drzymalski et al. (2010) proposed a method for aggregating multi-level performance measures with respect to their dependencies. The authors utilized the SCOR model metrics to measure performance of each level and strived to cover the attributes of reliability, responsiveness, flexibility, costs and profitability as designated by SCOR.

Lai et al. (2002) investigated supply chain performance construct in transport logistics and developed a measurement instrument for it. The authors classified metrics in the instrument on the basis of the SCOR model attributes. The authors defined reliability and responsiveness/flexibility attributes and costs and assets attributes as effectiveness and efficiency respectively and constructed the supply chain performance model based on these criteria.

Theeranuphattana and Tang (2008) proposed a model with the aim of more user-friendly SC performance measurement model than the model proposed by Chan and Qi (2003b). For this, the authors employed SCOR model and combined it with Chan and Qi model. They demonstrated that these two methods complement each other when measuring SC performance.

3.2.2 Balanced scorecard based model (BSC)

Among 42 journal articles, seven papers (16.67%) employed the BSC as a single approach in constructing models. Kaplan and Norton (1992) have proposed the BSC approach as a tool for performance evaluation through four perspectives of financial, internal business process, customer, and learning and growth. Some of performance articles used the BSC perspectives in model development.

Bhagwat and Sharma (2009) studied required performance metrics and developed a model for SC performance evaluation. They used BSC approach to analyze their operations from every angle that covers all perspectives of business.

Bhagwat and Sharma (2007b) constructed a hierarchical model and put BSC perspectives in the lowest level as alternatives. They presented a methodology that can help firms to prioritize and formulate viable performance measurement strategies in the volatile and complex global decision environment from different BSC perspectives. In another paper Bhagwat et al. (2008) referred to this model and developed a methodology to optimize the overall performance measurement of SCM for SMEs.

In yet another paper Bhagwat and Sharma (2007a) presented a BSC model for supply chain management in their framework that is structurally similar to the BSC framework proposed by Kaplan and Norton. In this paper, the BSC has applied metrics that was proposed by Gunasekaran et al. (2001) with the intent to evaluate SCM performance comprehensively. Four perspectives of the BSC were applied to these metrics or in another words the different metrics were fitted into four different perspectives of BSC to give a balanced picture of SCM performance evaluation.

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Varma et al. (2008) with the purpose of suggesting a method to evaluate the performance of petroleum industry supply chain, employed BSC perspectives and mapped petroleum supply chain criteria under the four perspectives.

Bigliardi and Bottani (2010) proposed a generic BSC model for supply chain management by focusing on the specific context of the food supply chain. The authors identified key performance indicators in the context of BSC and applied the Delphi technique for obtaining a high degree of consensus on the key indicators in their model. Then the authors offered the final results of Delphi technique as BSC model and tested it on two companies, operating in the food industry for validation.

Yang (2009) for constructing a performance evaluation index system developed BSC by adding society development to BSC perspectives and employed them to emphasize the important role of organization strategy in performance evaluation system.

3.2.3. Hybrid of SCOR and BSC approaches

Two papers (4.76%) utilized SCOR and BSC approaches in the performance evaluation process.

Bullinger et al. (2002) proposed a framework for a supply chain performance analysis that includes identification of business objectives and processes, measurement of process performance, and definition of improvement opportunities and optimization measures. For setting objectives, tolerance limits, allocating resources, assigning responsibilities, measuring performance for feedback and corrective action, the authors developed a methodology that is a hybrid measurement approach integrating SCOR measurement and adapted balanced scorecards. The authors applied the SCOR-model, because the first concept of material and product flow may be defined and controlled by SCOR metrics. For representation of business objectives and requirement a top-down controlling approach to keep the supply chain on track towards realizing business strategy and achieving improvement goals, they employed balanced scorecards to supply network scorecards.

Thakkar et al. (2009) integrated the salient features of BSC and SCOR model to deliver a comprehensive performance measurement framework for SMEs. Their prime intention for proposing an integrated approach of SCOR and BSC was to ensure the greater effectiveness of performance management system on (1) BSC does not provide a mechanism for maintaining the relevance of defined measures, thus SCOR adopts a building block approach and offers complete traceability, (2) SCOR clearly defines the type of process (planning, execution and enabling) and configures them to suit the SC requirements, thus covers the BSC flaw of integrating top level, strategic scorecard, and operational level measures and (3) BSC fails to specify a user-centered development process.

3.3. HIERARCHICAL BASED MEASUREMENT MODEL OR BREAK-DOWN/AGGREGATION MODEL

Among 42 journal articles, sixteen papers (38.1%) proposed hierarchical model to tackle the performance evaluation problem. Hierarchical model can be used in three aspects: metrics, criteria and processes.

Six papers out of forty two articles (14.29%) used hierarchical metrics for constructing the models. Hierarchical metrics were first proposed by Gunasekaran et al. (2001). They presented a framework in which metrics are classified into strategic, tactical and operational levels of management. This is done to assign them where they can be best dealt with by the appropriate management level. Bhagwat and Sharma (2009, 2007b) and Bhagwat et al. (2008) employ strategic, tactical and operational levels of management in their hierarchical PMS of SCM and classified metrics by these three level. Gunasekaran et al. (2004) presented a framework for performance measures and metrics, considering the four major supply chain processes (plan, source, make/assemble, and deliver). Metrics were classified at strategic, tactical and operational to clarify the appropriate level of management authority and responsibility for performance. In this framework measures or metrics are grouped in cells at the intersection of the supply chain activity and planning level. Thakkar et al. (2009) advised users to classify metrics into strategic, tactical and operational level, after extracting metrics in various categories of BSC.

Apart from metrics, a model can be created by a hierarchy of criteria and metrics. Nine articles of forty two articles (21.43%) used hierarchical criteria for constructing models. In these models, objectives or overall performance of supply chain are decomposed into some criteria or sub-entity to investigate the performance based on them. Because of easy usage of multi criteria decision making methods, this

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perspective is attractive for authors and implied by Bhagwat and Sharma (2009, 2007b), Bhagwat et al. (2008), Berrah and Cliville´ (2007),Chan (2003), Theeranuphattana and Tang (2008), Varma et al. (2008),Yang (2009) and Drzymalski et al. (2010).

Five papers out of forty two articles (11.9%) used hierarchical processes for constructing models. Bullinger et al. (2002) used process hierarchy and posed different perspectives to supply chain management activities by considering different supply chain stages: function-based level, process level and supply chain level and used metrics at each level. Chan and Qi (2003a, 2003b) decomposed supply chain to six core business processes including supplier, inbound logistics, manufacturing, outbound logistics, marketing and sales, and end customers. These processes could be decomposed to sub processes or functions. In other word, SC processes that need to be measured can be grouped into these six core processes with the corresponding functions of firms and departments. Thakkar et al. (2009) decomposed SC with SCOR processes at various levels to propose a set of performance measures for the supply chain in SMEs. Askariazad and Wanous (2009)in their hierarchical model, decomposed supply chain to five major processes and defined three or four processes under each function according to the scope and the activities involved in that process.

3.4. Six-Sigma based model

There are two (4.76%) out of 42 journal articles using six-sigma to deal with the performance evaluation problem. Six-sigma approach was developed by Motorola in 1987 and later it was widely adopted by big companies such as GE and Kodak to achieve remarkable benefits (XU, 2008). The six-sigma metrics can be used for performance comparison of different processes. The common six-sigma metrics are dpo (defects per opportunity), dpu (defects per unit), z-value or the sigma value, throughput yield, rolled throughput yield, etc.

Dasgupta (2003) applied the six-sigma metrics to help organizations in performance measuring of various processes and entities on a common scale and benchmarked against world-class standards. Their motivation behind the integration of the two concepts comes from: (1) both have been strongly recognized as 'process approaches', (2) the versatility of the six-sigma metrics in performance measurement and demand for common metrics.

Lin and Li (2010) presented a framework which measures the overall performance of supply chain system processes and cascades down to the lowest level, where those activities of a sub process within an individual organization process take place. The authors used six-sigma metrics to evaluate the performance across the entire supply chain. Also they pointed out that through the implementation of their framework, an organization will be able to monitor its progress at a given point of time at each level within a supply chain.

3.5. Uncertainty theory based model

Four papers (9.52%) utilized uncertainty theories in the SC performance evaluation process.

Chan and Qi (2003a) developed a fuzzy set theory model to address the real situation on judgment and evaluation. With disputing efficacy of analytic hierarchy process (AHP), the authors favor fuzzy ratios for selecting measures.

Parkan and Wang (2007) in their paper with the aim of measuring the performance of a supply chain over a number of time periods, used approach proposed by them in Wang and Parkan (2005) for determination of the relative importance weights for the supply chain metrics. With respect to this problem that decision makers have usually difficulty in revealing explicitly their perceptions as to the relative importance distribution for a set of metrics, the authors applied fuzzy preference matrix to derive decision makers' subjective ranking of the metrics.

Chen and Larbani (2005) focused on the SC performance with respect to various alliances among partners and applied a fuzzy resolution approach to find the appropriate SC solution.

Yang (2009) in order to built implemented model of SC performance evaluation system by considering fuzzy environment, proposed logarithm triangular fuzzy number-analytic hierarchy process method for using in evaluation of integrative performance evaluation index system.

An overview of the approaches is shown in Fig.1.

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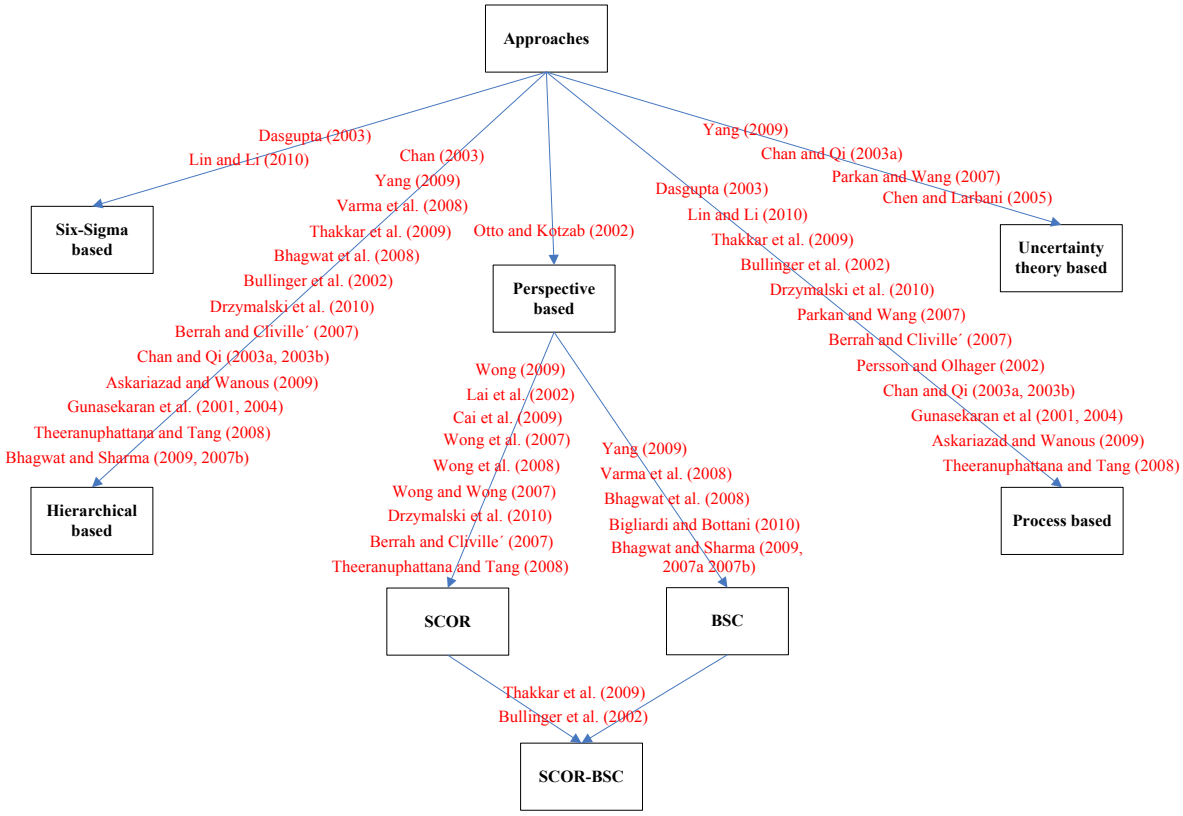

Fig. 1 An overview of approaches used by researchers

4. TECHNIQUES

The models are also categorized based on techniques used for analyzing, solving, and integrating models (see Fig.2). These categories are as follow:

4.1. Analytic hierarchy process (AHP)

Eight papers (19.05%) applied AHP technique to evaluate the performance of SC.

Bhagwat and Sharma (2007b) prioritized SCM metrics and different performance metric levels with the help of the analytical hierarchy process. In their paper, AHP is also used to prioritize the different BSC perspectives for SCM evaluation. For pair-wise comparison in AHP, the authors used a survey methodology.

Chan (2003) used AHP to make decisions based on the priority of performance measures. The author outlines the application and particularly the pair-wise comparison which helps to identify easily the importance of different performance measurements and then applied AHP to choose the optimum supply chain.

Askariazad and Wanous (2009) in order to propose a consistent framework for measuring the overall performance of supply chains applied AHP technique for pair-wise comparisons of main supply chain functions, processes and criteria. This was done to identify and prioritize the key performance metrics according to their importance in the evaluation of value-added activities in the entire supply chain.

Varma et al. (2008) used the AHP in combination with BSC, to align BSC to petroleum industry supply chain strategy. The AHP technique was applied to determine the relative weights of the four perspectives as also weights of the criteria under each perspective.

Yang (2009) in order to build implement model of SC performance evaluation system, proposed logarithm triangular fuzzy number-AHP method expanding from fuzzy environment and developing from traditional AHP method for using in evaluation of integrative performance evaluation index system.

Bhagwat and Sharma (2009) explained how an integrated AHP-PGP (pre-emptive goal programming)

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model can be used in performance measurement while optimizing the overall performance. The authors used AHP and PGP techniques to determine the required performance measures and provide the values of the performance metrics to optimize the overall performance, respectively. These optimized values of the performance metrics will help the decision maker to identify and focus on performance metrics, which are crucial for overall PM of the system.

Bhagwat et al. (2008) applied AHP and linear programming techniques to optimize the overall performance measurement of SCM for SMEs. By considering the hierarchy proposed in Bhagwat and Sharma (2007b), the authors used AHP to prioritize SCM parameters in the model. Then based on the prioritization of the performance measures and performance at different decision levels, they developed a linear programming model to optimize the overall performance measurement of SCM for SMEs.

Drzymalski et al. (2010) with the aim of aggregating performance measures of a multi-echelon SC, developed a new method which utilizes both the AHP and the Analytic Network Process (ANP) techniques to quantify the SCM's performance based upon two types of dependencies existing in a multi-echelon SC: intra- and inter-organizational. The former type accounts for the relationship between various parts or departments of a firm, while the latter accounts for the influence of one organization upon another.

4.2. Simulation

One paper (2.38%) proposed simulation technique to deal with the SC performance evaluation.

Persson and Olhager (2002) presented a supply chain simulation study to evaluate alternative supply chain designs with respect to quality, lead-times and costs as the key performance parameters. The main objective of using the simulation technique for SC modeling by them was learning about the interrelations among parameters in the SC.

4.3. Data envelopment analysis (DEA)

Nine out of forty two articles (21.43%) applied DEA in the performance evaluation process.

Wong and Wong (2007) and Wong et al. (2007) with the aim of measuring internal supply chain performance used data envelopment analysis and developed two DEA models to measure SC efficiency based on inputs and outputs variables. These two models were technical efficiency and cost efficiency. The authors addressed that technical efficiency reflects the ability of a firm to obtain maximum output from a given set of input, and cost efficiency is equivalent to the opportunity cost.

In another paper, Wong and Wong (2008) gave motivation of using DEA in addressing supply chain benchmarking. The authors first reviewed problems in supply chain benchmarking, existing tools used in benchmarking, problems in existing tools and then justified that DEA can be used as a benchmarking tool for supply chain performance measurement.

Abu Bakar et al. (2010) investigated the efficiency levels of the decision-making units within the public hospital laboratories in using their supply chain towards meeting the satisfaction of doctors. For this purpose DEA method was applied to monitor the performance of decision-making units with respect to doctors' satisfaction and determining areas and ways that warrant improvement.

Yang et al. (2009) considered that the performance of a supply chain is attributed to two main factors: the performances of all supply chain members, and the cooperation and harmony of its members. The authors defined two types of supply chain production possibility sets and based upon those, proposed a supply chain constant return to scale DEA model to appraise the overall technical efficiency of supply chains.

Xu et al. (2009) created rough DEA by integrating classical DEA and rough set theory for SC performance evaluation under uncertainty situations. In their paper, DEA is employed to evaluate the performance of supply chain. The authors addressed that the main virtue of DEA is that it can be used to measure efficiency when there are multiple inputs and outputs. To depict rough uncertain environment, the authors employed rough set theory proposed by Pawlak and rough variable proposed by Liu (2004) to deal with the rough uncertainty phenomena in real world.

Parkan and Wang (2007) applied two non-parametric performance measurement methods, DEA and operational competitiveness rating analysis (OCRA), on the basis of the framework of Gunasekaran et al. (2004), to measure the performance of a supply chain over a number of time periods. These two performance measurement methods, DEA and OCRA, were used to aggregate the metric scores of a

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supply chain in a number of periods so as to obtain overall ratings that gauge the supply chain's relative overall performance during those periods.

Wong et al. (2008) proposed a framework employing Monte Carlo simulation and DEA to measure supply chain efficiency in a stochastic environment. The authors introduced a DEA model to measure the supply chain efficiency by considering the entire value chain. Since the DEA supply chain model can only be used to measure supply chain efficiency in a deterministic environment (because it requires all data to be known) and it is not able to operate in a stochastic environment (where the data are uncertain), the authors utilized Monte Carlo simulation to handle stochasticity in the data and addressed its simplicity as their motivation of selecting this technique.

In another paper, Wong (2009) supplements the proposed framework in Wong et al. (2008)by adding genetic algorithm technique to it. He presented a genetic algorithm-based heuristic technique to improve the prediction of the SC performance measurement.

4.4. Delphi

Same as simulation technique, one paper (2.38%) utilized Delphi technique to tackle the performance evaluation problem. The Delphi technique is a systematic, interactive forecasting method, which allows obtaining forecasts from an independent panel of experts, over two or more rounds.

Bigliardi and Bottani (2010) with the aim of developing a model for supply chain management by focusing on the specific context of the food supply chain identified key performance indicators with literature review, concerning SCM, performance measurement and food supply chain. The authors adopted the Delphi technique with the aim of obtaining a high degree of consensus on the key performance indicators to be included in their model.

4.5. Heuristic techniques based model

Two papers (4.76%) used heuristic techniques to evaluate SC performance.

Angerhofer and Angelides (2006) modeled the constituents of a collaborative supply chain, key parameters they influence and performance indicators. Their model encompasses six constituents as a "Weltanschauung" which were topology, levels of collaboration of the stakeholders, processes, supporting technology, and the business strategy employed. With spot of Beamon (1999) that identified resources, output, and flexibility as necessary components for supply chain performance measurement, the authors integrated the model with multiplication and division of output, flexibility and resource measures.

HO (2007) measured performance of ERP-based supply chain systems in terms of the total related cost. An equation was proposed that calculates total related cost by summation of rescheduling cost as well as carrying and ordering costs.

4.6. Hybrid techniques based model

Among 42 journal articles, three papers (7.14%) utilized hybrid techniques in performance evaluation process.

Berrah and Cliville´ (2007) by considering the SCOR model break-down, proposed to extend Choquet integral operator and MACBETH techniques for expressing the overall performance of a SC. The authors adapted an aggregation methodology, based on the Choquet integral operator and MACBETH techniques. The MACBETH methodology has been applied to the performance expression of the four main processes of a SC (Plan, Source, Make and Deliver) according to literature to give a structured framework, which links the elementary performance expression to the overall one, based on human expertise.

Chen and Larbani (2005) focused on the SC performance with respect to various alliances among partners and employed game theory and multi-objective programming techniques for this purpose. The authors explored the game theory for describing various alliances among partners in a SC, where each partner has its own objectives and constraints. They compared the SC performance under various alliances, e.g., union, extreme competition, and Stackelberg competition among partners. The authors employed fuzzy multi-objective programming technique for capturing appropriate SC design so as to make all partners satisfied with respect to various alliances.

Soni and Kodali (2010) investigated internal benchmarking as a tool for performance improvement and leveling the performance of member supply chains of a global supply chain. Then, the authors proposed

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a methodology that the internal benchmarking of supply chain drivers is done by measuring performance by using performance value analysis (PVA) and SWOT analysis. The authors used PVA, because its analysis works on best values hence is highly suitable to benchmarking process, and used SWOT analysis in order to point out the relative performance of various drivers of each supply chain with respect to each other and suggested improvements.

An overview of the above mentioned techniques is shown in Fig.2.

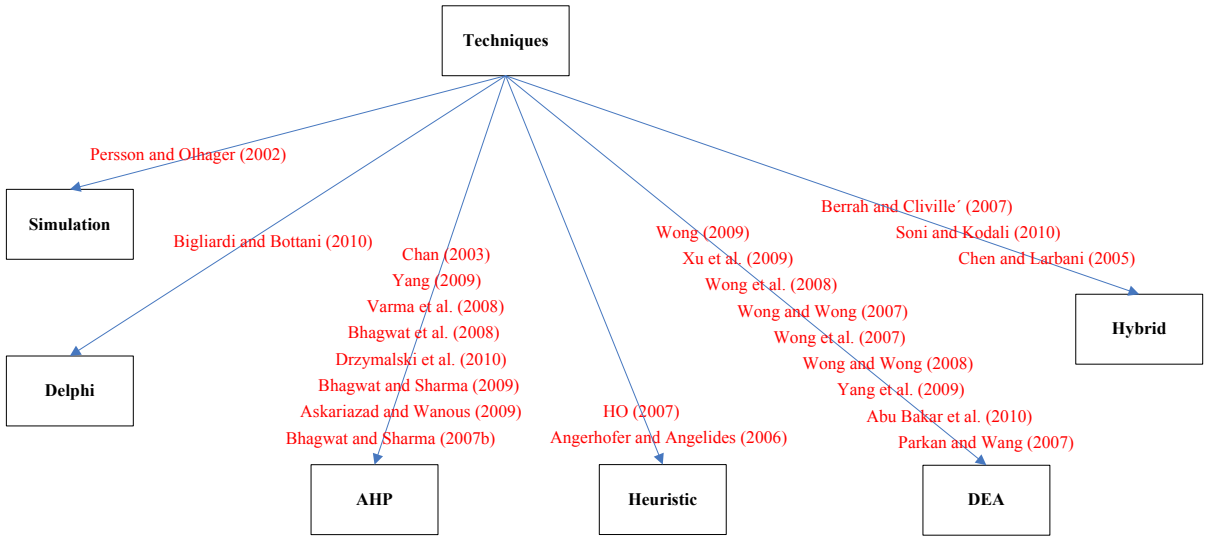

Fig. 2 An overview of techniques used by researchers

5. OVERVIEW OF CRITERIA

In some performance models, some criteria are defined and used to assess supply chain based on achieving them. Based on this, if the supply chain performance was appropriate based on the criteria, it can be concluded that the performance is good. In other words, a performance criterion is information delivered to the management function, evaluating efficiency and effectiveness of a process, resource or an outcome (Papakiriakopoulos and Pramatari 2010). For example, flexibility criterion defines and supplies chain assessment with regard to its level of achievement. According to literature review, it was observed that authors used criteria to group or select metrics based on them. In this section, a review of performance criteria used in the studied models is carried out. A list of these measurement criteria is given in Table 1.Among 42 journal articles, thirty seven papers (88.1%) applied some criteria for SC performance evaluation. Note that criterion (e.g. flexibility, reliability) is different from process (e.g. plan, source).

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Table 2. Criteria list of SC models

Cost	**Bhagwat and Sharma (2009, 2007a, 2007b), Bullinger et al. (2002), Persson and Olhager (2002), Xu et al. (2009), Chan (2003), Chen and Larbani (2005), Theeranuphattana and Tang (2008), Varma et al. (2008), Chan and Qi (2003a, 2003b), Yang (2009), Bigliardi and Bottani (2010), Gunasekaran et al (2001), Thakkar et al. (2009), van Hoek (1998), Shah and Singh (2001), Wong and Wong (2007), Soni and Kodali (2010), HO (2007), Lai et al. (2002), Drzymalski et al. (2010), Wong et al. (2007, 2008), Bhagwat et al. (2008), Wong (2009)**
Customer	Bhagwat and Sharma (2009, 2007a, 2007b), Bullinger et al. (2002), Varma et al. (2008), Yang (2009), Bigliardi and Bottani (2010), Thakkar et al. (2009), van Hoek (1998), Xu et al. (2009), Abu Bakar et al. (2010), Bhagwat et al. (2008)
Internal process	Bhagwat and Sharma (2009, 2007a, 2007b), Bullinger et al. (2002), , Varma et al. (2008), Yang (2009), Bigliardi and Bottani (2010), Thakkar et al. (2009), Bhagwat et al. (2008)
Learning and development (Innovativeness)	Bhagwat and Sharma (2009, 2007a, 2007b), Bullinger et al. (2002), Varma et al. (2008), Yang (2009), Bigliardi and Bottani (2010), Thakkar et al. (2009), Cai et al. (2009), Chan (2003), Bhagwat et al. (2008)
Flexibility	Cai et al. (2009), Xu et al. (2009), Chan (2003), Theeranuphattana and Tang (2008), Chan and Qi (2003a, 2003b), Beamon (1999), Angerhofer and Angelides (2006), Aramyan et al. (2007), Lai et al. (2002), Drzymalski et al. (2010)
Reliability	Theeranuphattana and Tang (2008), Chan and Qi (2003b), Lai et al. (2002), Drzymalski et al. (2010), Chan and Qi (2003a)
Responsiveness	Theeranuphattana and Tang (2008), Aramyan et al. (2007), Lai et al. (2002), Drzymalski et al. (2010), Chan and Qi (2003a)
Quality	Persson and Olhager (2002), Chan (2003), Aramyan et al. (2007)
Asset management	Theeranuphattana and Tang (2008), Lai et al. (2002), Drzymalski et al. (2010)
Six-sigma metrics	Dasgupta (2003), Lin and Li (2010)
Resource	Cai et al. (2009), Soni and Kodali (2010), Beamon (1999), Chan (2003), Angerhofer and Angelides (2006)
Output	Cai et al. (2009), Chan and Qi (2003b), Beamon (1999), Xu et al. (2009), Angerhofer and Angelides (2006),
Information	Cai et al. (2009), Soni and Kodali (2010)
time	Persson and Olhager (2002), Xu et al. (2009), Chan and Qi (2003a, 2003b)
HR	Xu et al. (2009)
Trust	Chan (2003)
Visibility	Chan (2003)
Capacity	Chan and Qi (2003b)
Effectiveness	Chan and Qi (2003b)
Availability	Chan and Qi (2003b)
Productivity	Chan and Qi (2003a, 2003b)
Utilization	Chan and Qi (2003a, 2003b)
Society	Yang (2009)
Facilities	Soni and Kodali (2010)
Inventory	Soni and Kodali (2010)
Efficiency	Wong and Wong (2007), Aramyan et al. (2007), Yang et al. (2009), Wong et al. (2007), Chan and Qi (2003a)
Integration	van Hoek (1998)
Operational	Wong et al. (2008), Wong (2009)

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6. OBSERVATIONS AND RECOMMENDATIONS

In this paper the trend of studies in supply chain measurement were reviewed along with 42 journal papers. Fig. 3 illustrates yearly distribution of the papers. It is observed that there is a growth in the study of the whole SC performance evaluation from the first 9 years (1998–2006) to the recent 4 years (2007–2010), 15 vs. 27. This means that in recent years researchers have paid more attention to holistic view of SC performance measurement than previous. Since the dependencies between organizations in a SC and their effects on the performance of the entire supply chain is increasing day by day, the need for a holistic approach to supply chain will feel more. It is expected that this trend continues in the future.

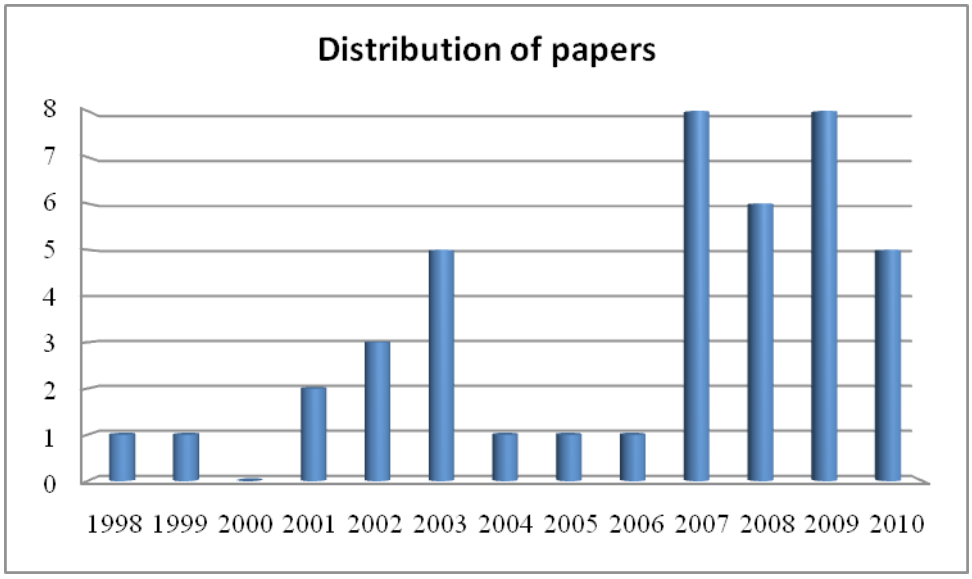

Fig. 3. Yearly distribution of the papers

The first objective of this paper is to find out the most popular approach adopted in SC performance evaluation literature. The most popular approach is perspective based followed by hierarchical based, process based, uncertainty theory based and six-sigma based. From perspective based approaches, SCOR based has attracted more attention compared with BSC based. The SCOR model has gained growing use and increased visibility, contributing to the development and evolution of supply chain performance measurement systems and maturity models by:

- Providing a standardized way of viewing the supply chain (cross-industry standard).
- Offering a consistent 'scorecard' framework for development of performance.
- Emphasizing process orientation and deemphasizing functional orientation.
- Enabling cross-industry benchmarks.

Both Hwang et al. (2008) and McCormack et al. (2008) clearly support the importance of the SCOR model as a base in current SC performance measurement.

Also from hierarchical approaches, hierarchical criteria have attracted more attention with respect to hierarchical metrics and hierarchical processes.

The second objective of this paper is to find out the most popular technique adopted in SC performance evaluation literature. As shown in section 3, there are various techniques for performance evaluation. The most popular techniques are DEA and AHP.

The third objective of this paper is to discover the most popular criterion considered by the authors for evaluating whole SC. Many criteria were proposed and summarized in Table 2. The most popular criterion is cost/finance, followed by customer, flexibility, innovativeness, internal processes, reliability, responsiveness, efficiency, resource, output, time,

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quality, asset management. By considering Table 2, it can be observed that most of authors focused on criteria included in SCOR and BSC models. Since the performance criteria differ field by field and the SCOR and BSC related criteria are most compatible with SCs context, these criteria are more prevalent.

In addition to the previous questions, the following questions will be answered. How many articles include integrating method? How many models developed based on achieving strategies? How many articles applied benchmarking in SC performance evaluation?

According to (Wong (2009), Berrahand Cliville´ (2007)), it can be very useful for top managers to have a general view of SC. For this, some articles have used integrating method. The purpose of integrating method is that the paper in addition to viewing supply chain as an entity, can present a value for SC performance. From 42 journal articles, 22 papers proposed an integrating method (Bhagwat and Sharma (2009, 2007b), HO (2007), Angerhofer and Angelides (2006), Berrah and Cliville´ (2007), Berrah and Cliville´ (2007), Chan (2003), Chen and Larbani (2005), Yang et al. (2009), Theeranuphattana and Tang (2008), Chan and Qi (2003a), Varma et al. (2008), Yang (2009), Wong and Wong (2007, 2008), Abu Bakar et al. (2010), Parkan and Wang (2007), Wong (2009), Bhagwat et al. (2008), Wong et al. (2007, 2008), Askariazad and Wanous (2009), Drzymalski et al., (2010)).

Are developed models based on achieving strategies? Investigating this question can explain a great problem in measuring performance. We have found 21 papers which take into account the strategies of SC in their performance model. The papers can be categorized in two groups: BSC-based and non BSC-based. The former group contains 8 (Bhagwat and Sharma (2009, 2007a, 2007b), Varma et al. (2008), Yang (2009), Bigliardi and Bottani (2010), Thakkar et al. (2009), Bhagwat et al. (2008)), while the latter contains 13 papers (Bullinger et al. (2002), Otto and Kotzab (2003), Cai et al. (2009), Chan (2003), Chen and Larbani (2005), Theeranuphattana and Tang (2008), Chan and Qi (2003a, 2003b), Beamon (1999), van Hoek (1998), Shah and Singh (2001),Dasgupta (2003),Lin and Li (2010)). It means that many measurement models lacked strategy alignment ((Cai et al. 2009), Shepherd and Gunter (2006)). They neither employ BSC criteria nor strategic level measures in defining the models. Of course, Najmi and Makui (2012) illustrates some components necessary for a SC performance measurement model especially strategic alignment.

The aim of supply chain management is to gain an advantage over competitors. Moreover benchmarking is a valuable tool that provides an opportunity to learn from other organizations (Meybodi, 2009) to improve organizations' performance and competitiveness in business life (Wong and Wong, 2008). Therefore it is desirable to assess the company's performance by benchmarking. The manager has to make judgments as to the firm's performance relative to the competition (Chan 2003). Twelve papers, which are reviewed, have used benchmarking approach in their models (Bullinger et al. (2002), Dasgupta (2003), Soni and Kodali (2010),Wong and Wong (2007, 2008),Shah and Singh (2001),Wong (2009),Wong et al. (2008),Wong et al. (2007),Abu Bakar et al. (2010),Yang et al. (2009),HO (2007)).

As a result of this review, we try to build ontology of the subject areas in SC measurement. The ontology constructed on hierarchical structure begins by strategic level and continues by approaches, criteria and metrics to reach the applied techniques in this topic. Fig. 4 illustrates the ontology. Since our study is focused on trilogy of approaches, criteria and techniques, the metrics have not been discussed in this ontology. The ontology demonstrates the elements at each level similar to periodic table of elements in chemistry. Also in similar way, some used **works are brought by ticked sign and** some others are offered for future studies.

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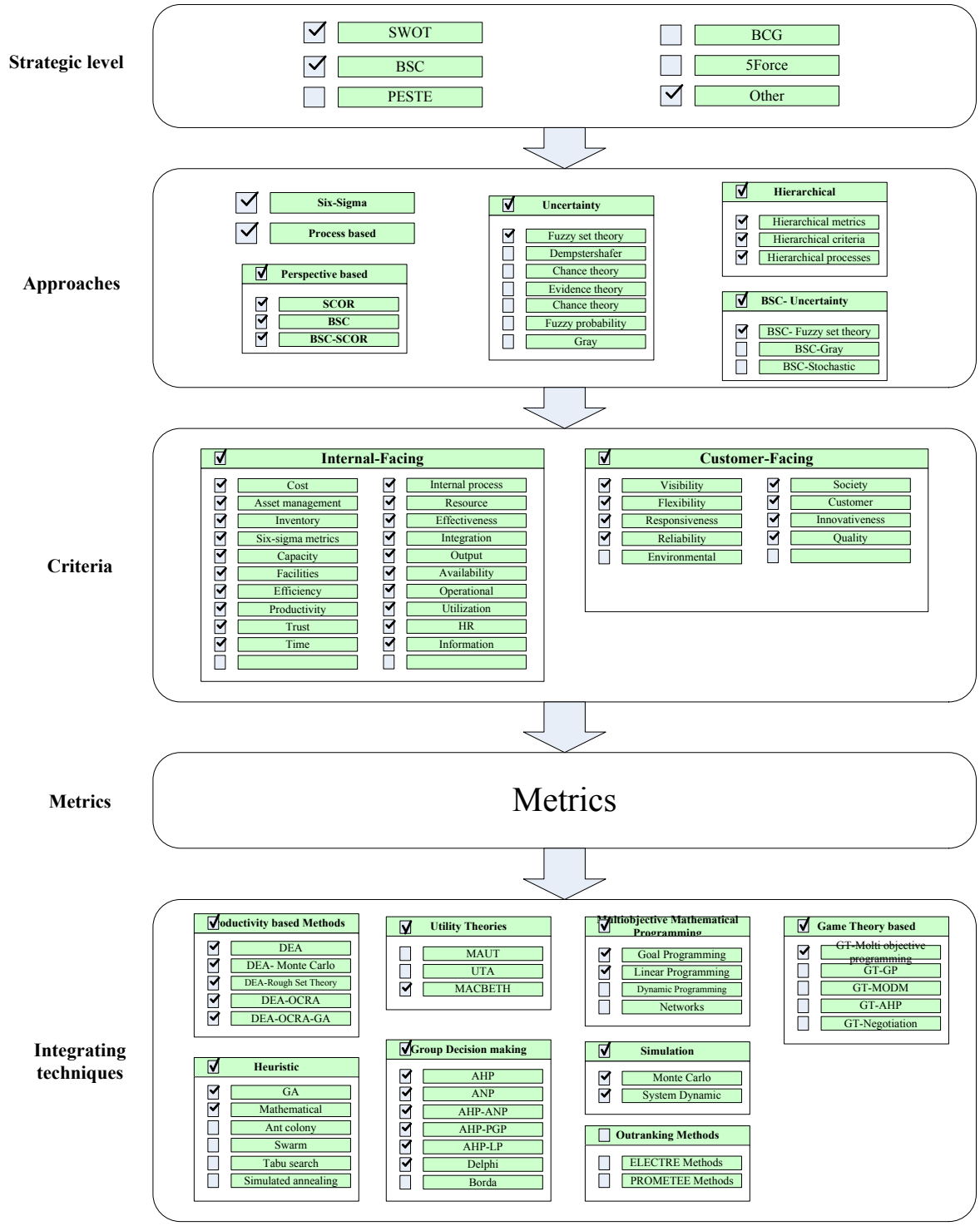

Fig. 4. The ontology of subject areas in SC measurement

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As mentioned in previous sections, in strategic level the studies are more centralized on BSC and SWOT analysis. However, some other methods such as BCG and PESTE analysis can be used in future studies. In approach level, three subparts can be identified. Hierarchical approaches are mostly used in previous studies. However, a few works are performed in uncertainty. In addition to fuzzy applications to cover uncertainties, some other approaches such as evidence theory, chance theory and gray systems can be used in similar way. Also in BSC-uncertainty subpart other uncertainty approaches can be used. Apart from these subparts some independent approaches have been used by researches in previous studies that have been brought separately.

In criteria level, two subparts are identified. As shown in Table 2, there are many criteria introduced by researches. However, if one wants to categorize them, the criteria may be divided into two subparts of internal facing and customer facing. But yet, some new criteria can be offered. For example environmental criterion can be added into customer facing criteria. Considering the extent of the supply chain locations and their environmental impacts and pressure of governments to consider environmental parameters, the lack of this criterion is felt in the assessments.

In techniques level, 8 subparts are identified. There are many studies in DEA based and AHP based methods. The studies can be extended to other hybrid methods (in productivity based methods) or some supplementary methods such as Borda (in group decision making methods). Against, some subparts are not attended in previous studies. Various outranking methods such as the variations of ELECTRE and PROMETHEE can be used instead of AHP or in hybrid applications. The Meta-heuristics can be used in conjunction with mathematical programming tools in measuring SCs performance and efficiency. The only example in this area is the study conducted by Wong (2009). In Meta-heuristics, only GA or mathematical heuristics are used and there are many future areas for using other ones such as ant colony, swarm intelligence and so on which may be even more powerful than GA applications. Game theory is a novel area for future works. Although game theory is the most applied important mathematical method applied in supply chain management, it is neglected in SC performance measurement. Considering the competition in a supply chain, each player seeks to maximize its profit. With this regard, the game theory can be used in SC measurement successfully by composition with decision making techniques such as goal programming and MODM. Unlike previous studies, the future studies can be moved into the vision of utility measurement instead of value measurement by means of some techniques such as MAUT and UTA. There are some applications of simulation techniques such as Mont Carlo or system dynamics to encounter with stochastic environment. However, some other discrete event or continuous ones can be used in future studies. Finally, some researchers used mathematical programming but the usages are restricted in goal programming or at last linear programming. The studies can be improved into other programming methods such as dynamic programming, mixed integer programming and even networks. Specially, dynamic programming is more absorbing for future studies in dynamic area.

7. CONCLUSION

This paper is based on a literature review on the SC performance evaluation models that investigate the SC as a whole entity to extract more prevalent approaches, techniques and criteria used in the models. It is observed that this view to supply chains was attractive for many researchers. The constituents of SC performance measurement models were extracted and it was concluded that an SC model can be made of various approaches, techniques, criteria and metrics according to SC strategy. Except the metrics, these components were reviewed and based on them, some recommendations on new ideas for future researches were proposed. The new ideas are categorized in an ontology framework to demonstrate the gaps of studies and also opportunities of future developments.

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