An In-Depth Review and Classification of "Supplier Quality Management" Approaches: Following Trends in Academic, Industrial and Military Literature

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Abstract

"Supply Chain Quality Management" has attained so much focus through the evolution of the product's quality realisation methods. The essence of this methodology is to have a system- based outlook to the product's quality phenomena. Three key components of activities defined in SCQM are "Upstream Quality Management", "Inter-organizational Quality Practices", and "Downstream Quality Practices". While suppliers are considered as the input providers through the supply chain, Supplier Quality Management is considered as the core activity in this methodology. A comprehensive review of papers and industrial and military SQM manuals made it possible to propose a novel classification in this area which is based on defining four interrelated fields of study. This article has been divided into three parts which are: 1.academic, military, and industrial literature review: firstly, by reviewing academically literature, three different fields of studies were reviewed as: (i) supplier selection methods, (ii) supplier performance monitoring, and (iii) supplier relationship management. Next, some of the novel industrial and military supplier quality management approaches have been reviewed. 2. defining selection/assessment criteria and KPIS in seven possible areas of outsourcing, and finally 3. conclusion which proposes a clear and detailed research direction by which the reader can find a good vision of the applicability of subjects analyzed in this study and the reason we have got so far into the SQM concept.

Keywords: Supply Chain Quality Management, Supplier Quality Management, Upstream Quality Management

Introduction

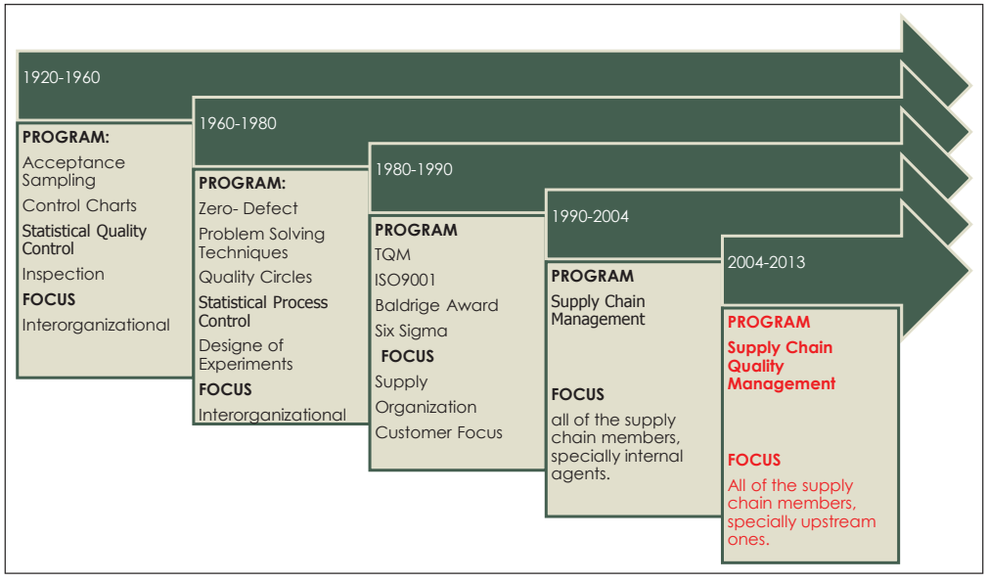
Product quality realization has dramatically changed during decades. In 1920s, Statistical Quality Control (SQC) have gained so much attention as one of the first systematical frameworks which tried to ensure the process owner presenting a certain level of quality. (Robinson & Malhotra, 2005) the evolution of such approaches are shown in Fig 1.

Recently many scholars have studied the concept of Supply Chain Quality Management (SCQM) which is considered to be as the latest systematical approach in the field of product's quality realisation due to incrementally extension of supply chain dimensions and complexity.

In today's economy, it is no longer business versus business, but rather supply chain versus supply chain. To compete, supply chain members must learn to seamlessly integrate, grow, and develop business functions. Traditional quality management practices have been and will continue to be used to address many of these supply chain integration issues. With this in mind, current managerial thinking is advancing the notion of supply chain quality management. Supply chain quality management is a systems-based approach to performance improvement that integrates supply chain partners and leverages opportunities created by upstream and downstream linkages with a focus on creating value and achieving satisfaction of intermediate and final customers.

Although there are several definitions of quality, simply put, quality can be defined as meeting or exceeding customer expectations (Evans & Lindsay, 2002). (J.R. Evans and W.M. Lindsay (2002), Management and control of quality (5th ed.), Thomson Commitment,

Fig 1: Evaluation of Product Quality Realization Programmes



Singapore.) According to the American Society for Quality, the definition of quality is "a subjective term for which each person or sector has its own definition". In technical usage, quality can have two meanings: 1. the characteristics of a product or service that bear on its ability to satisfy stated or implied needs; 2. a product or service free of deficiencies. According to Joseph Juran, quality means "fitness for use;" according to Philip Crosby, it means "conformance to requirements."

Table 1: Key Articles about SCQM

Title	Authors	Year
Defining the concept of Supply Chain Quality Management and its relevance to academic and industrial practice	Carol J. Robinson, Manoj K. Malhotra	2004
Towards an understanding of Supply Chain Quality Management	S. Thomas Foster Jr.	2007
Supply Chain Quality Management	Lynn A. Fish	2011
Supply Chain Quality Management practices and performance: An empirical Study	Jing Zeng, Chi anh	2013

On the other hand, Supply Chain Management is an approach to integrating suppliers, manufacturers, distributors and retailers, such that products are produced and distributed at the right quantities, to the right location, at the right time, with the mutual goals of minimizing system wide costs and satisfying customer service requirements.

A comprehensive definition of Supply Chain Quality Management (SCQM), proposed by Robinson C, et al. is "A systematically approach by means of elevating supply chain's quality performance which is achieved by integration of different layers of the chain". Table 1 contains the main articles which contributed so much in defining different aspects of SCQM Phenomena.

The fundamental elements of SCQM in all of the above articles are nearly alike. Fig 2, 3 and 4 stipulates three different clusters of activities defined in the SCQM approaches.

Fig 2: SCQM Activity Clustering Proposed by Foster et al., 2007 (Foster, 2008)

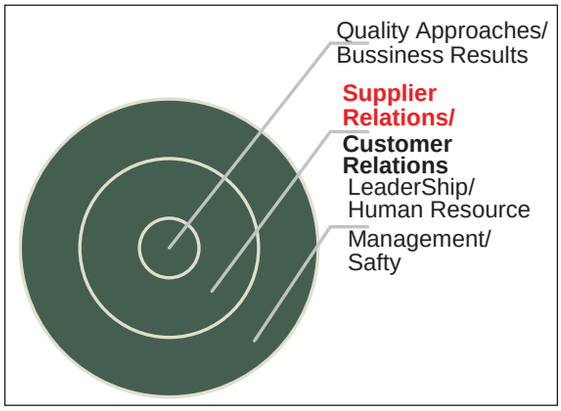


Fig. 3: SCQM Activity Clustering Proposed by Jing Zeng et al., 2013

One major activity which is common in all of the above activity cluster is the "Upstream Quality Management" or what is commonly called "Supplier Quality Management". Confidence in a supplier's ability to deliver a good or service that will satisfy the customer's needs isachievable through interactive relationship between the customer and the supplier. Structures which define such relations arecalled Supplier Quality Management programs. It aims at ensuring the product's 'fit' to the customer's requirements with little or no adjustment or inspection. The US quality guru Joseph Moses Juran (born 1904 in Romania) divides the Supplier Quality Management process into nine steps: (1) definition of the product's quality requirements, (2) evaluation of alternative suppliers, (3) selection of the most appropriate supplier, (4) conduction of joint quality planning, (5) cooperation during relationship period, (6) validation of conformance to requirements, (7) certification of qualified suppliers, (8) conduction of quality improvement plans, (9) creation and use of supplier ratings.

This practice as a part of supply chain quality management approach, is the main focus of this study. The rest of this paper is dedicated to an extensive literature review around the SQM phenomena.

Literature Review

SQM in Academic Papers

Supplier Quality Management (SQM) is defined as "a fundamental phenomenon in leveraging and improving quality of products and services in big organisations by focusing on controlling quality of inputs which means the control of supplier's quality". (Neise, 2009) Patric Nies, in his PhD thesis, after reviewing ten SQM manuals (relating to three aerospace, four automobile maker and three electrical manufacturer companies), proposes a clustering for activities found in these manuals as below:

Fig 4: SCQM Activity Clustering Proposed by Azar et al., 2010

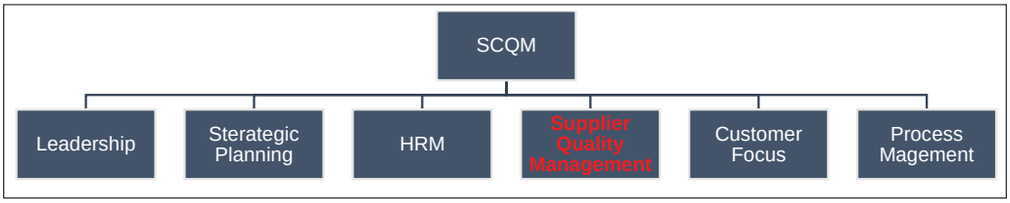


Fig 5: SQM Activities Derived from 10 Industrial SQM Manuals, Patric Nies, 2009

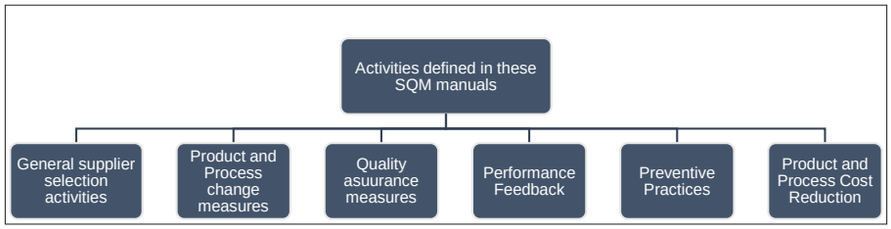


Table 2: General Characteristics of an Appropriate Supplier Selection Criteria

Characteristics	Description
Generality	A criterion which can measure some alike or same characteristics.
Stability	A criterion which can be measure in different situations.
Measurability	A criterion which is easy to measure.
Monotonicity	A constant relation between measures, weights and goals of the organisation.

Table 3: Important Papers Referring to the Supplier Selection Criteria

Title	Author	Year
An analysis of vendor selection systems and decisions	Dickson	1966
A Review for Supplier Selection Criteria and Methods (Deshmukh & Chaudhari, 2011)	J Deshmukh, A., Chaudhari, AA.	2011
A Review of Quality Criteria Supporting Supplier Selection (Abdolshah, 2013)	Abdolshah M.	2013
Comprehensive and configurable metrics for supplier selection (Huang & Keskar, 2007)	Samuel H. Huang, Harshal Keskar	2007
Supplier Selection Criteria and Methods in Supply Chains: A Review (Pal, Gupta, & Garg, 2013)	Om Pal, Amit Kumar Gupta, R. K. Garg	2013

Table 4: Dickson's 23 Supplier Selection Criteria

Rank	Criteria	Rank	Criteria
1	Quality	13	Management and Organization
2	Delivery	14	Operating Control
3	Performance History	15	Repair Service
4	Warranties & Claims Policies	16	Attitude
5	Production Facilities and Capacity	17	Impression
6	Price	18	Packaging Ability
7	Technical Capability	19	Labor Relations Record
8	Financial Position	20	Geographical Location
9	Procedural Compliance	21	Amount of Past Business
10	Communication System	22	Training Aids
11	Reputation and Position in Industry	23	Reciprocal Arrangements
12	Desire for Business		

Another important definition for SQM practices is proposed by LNS Research scholars, which considers five different areas in this field as: 1- Creating a suitable IT network which can handle organisational needs, 2- Processes related to supplier selection with focus on quality criterion, 3- Processes related to supplier performance management, 4- Methods for elevating and developing supplier and manufacturer's quality and 5-Implementing supplier quality management in lower layers of the supply chain. We can divide studies in this area in the recent literature into three categories as: 1-Supplier Selection, 2-Supplier Performance Monitoring and 3-Supplier Relationship Management. Below there is a brief overview of major studies in these areas.

Supplier Selection

Supplier selection is among the most popular topics in ORMS literature. Supplier selection is way more than just selecting the lower price supplier from a price list. Many factors like time value of money, quality, reliability, service and many other criteria are affecting supplier selection decisions. One of the main ideas in the qualitative approaches of supplier selection is the long term supplier- manufacturer relationship. There are two major categories in the field of supplier selection studies which are classified as below.

Supplier Selection "Criteria"

As Xia, L. has mentioned in his novel article, management must consider four characteristics while creating supplier selection criteria which are described in table 2.

We can refer to the five important recent papers relating to the supplier selection criteria which is as below:

One of the most important studies about supplier selection criteria is proposed by Dickson in 1966, which are highlighted in almost every literature review in this field. He describes 23 supplier selection criteriaas table 4.

Studies about supplier selection criteria have developed during last years. Abdolshah M., in his late article, proposes a novel classification of supplier selection criteria as shown in table 5.

Table 5: A Novel Classification of Supplier Selection Criteria by Abdolshah M (2013)

Selection Criteria[1]	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
Price	■	■	■	■	■	■	■		■	■	■	■	■		■	■			■	■	■
Quality	■	■	■	■		■	■	■	■		■	■	■		■	■	■	■	■	■	■
Delivery	■	■	■	■		■	■	■	■		■	■	■	■	■	■	■	■	■	■	■
Warranties and claims	■		■																		
After Sales Services	■		■		■		■					■			■				■		
Technical support			■		■		■			■						■			■		■
Training aids	■		■					■													
Attitude	■						■									■			■		■
Performance history	■						■														
Financial position	■		■				■														
Geographical location	■	■		■			■	■													
Management and organisation	■			■			■				■										■
Labor relations	■						■														
Communication system														■							
Response to customer request			■				■	■			■					■			■		■
e- commerce capability																					
JIT												■									
Technical capability	■	■														■		■			
Production facilities and capacity	■							■				■									
Packing ability	■																				
Operational controls	■						■											■			
Ease of use			■								■			■		■				■	
Maintainability			■				■					■									
Amount of past business		■	■							■											
Reputation and position in industry		■	■								■		■						■		
Reciprocal arrangement		■					■										■		■		■
Impression		■	■				■										■		■		
Environmentally friendly products							■			■	■						■				■
Product appearance							■						■								
Catalog technology																					
Dependability										■			■								
Flexibility																■					
Payment terms																					
Productivity							■	■									■		■		
Applicable of conceptual manufacturing								■		■		■			■						
Manufacturing challenges																	■				
Driving power							■					■		■							
To match the lead times																		■	■		
Personnel capability							■							■							
To be solution oriented				■			■		■							■					
Global factors										■		■						■			
Environmental risks				■								■				■					■

(Footnotes)

1 A: Dickson; B:Wind et al. ; C: Lehmann and haughnessy ; D: Perreault and Russ ; E: Abratt ; F: Billesbach et al. ; G:Weber et al.; I: Min and Galle ; J: Stavropolous ; K: Pi and Low ; L: Pi and Low , M: Teeravaraprug ; N: Sanayei et al. ; O: Parthiban et al.; P: Peng ; Q: Bilis¸ik et al. ; R: Tektas and Aytekin ; S: Li ; T: Bet¨ ul et al. ; U:Mehralian et al.

Table 6: Different Approaches in Supplier Selection Method

Selection Approach			CONS	PROS
Elimination			Final selection will be based on the overall performance considering all of the criteria.	On- time Accessibility Considering experts opinion
Optimization	Without constrain	Multiple criteria	Based on human interpretation Unconstraint model	Ease of use Considering all information
		Based on cost	A based method.	Using un-base information
	Constraint	Single objective	Lack of transparency in results for the manager.	Having exactly one optimal solution. Ability to define many constraints.
		Multiple criteria	Lack of transparency in results for the manager.	Having more than one optimal solution. Ability to define many constraints.
Probabilistic Methods			None. Optimal solutions Difficulty in analysing the results. Difficulty in managing constraints.	Analysing probabilistic behaviour of the supplier.

Although, there are more major studies addressing supplier selection criteria. For example, Weber et al., have reviewed 74 articles in the field of supplier selection and derived a bunch of criteria for selecting the supplier.(Weber, Current, & Benton, 1991) (Deshmukh & Chaudhari, 2011) elrama et al., Choose a three categories for criteria while selecting the supplier which are: 1- Financial measures, 2- Cultural and strategic structure of the supplier's company and 3- technological capabilities. (Ellram, 1990) (Zeng et al., 2013)Yazgac and barbarosoglu, try to differentiate suppliers with three categories of measures which are: 1- supplier's performance, 2- technological and financial capabilities and 3- supplier's quality management system, where each of them contain many sub-criteria. The criteria proposed by council of supply chain management (SCOR) can be considered as the most comprehensive reference in this area.In the proceeding section we will present a brief review in the literature of "supplier selection methods".

Supplier selection "Methods"

The second field of study which has gained so much attention by ORMS researchers is the supplier selection methods. Table 6 is dedicated to show the different approaches in supplier selection based on the *military industrial engineering handbook, 2010*.

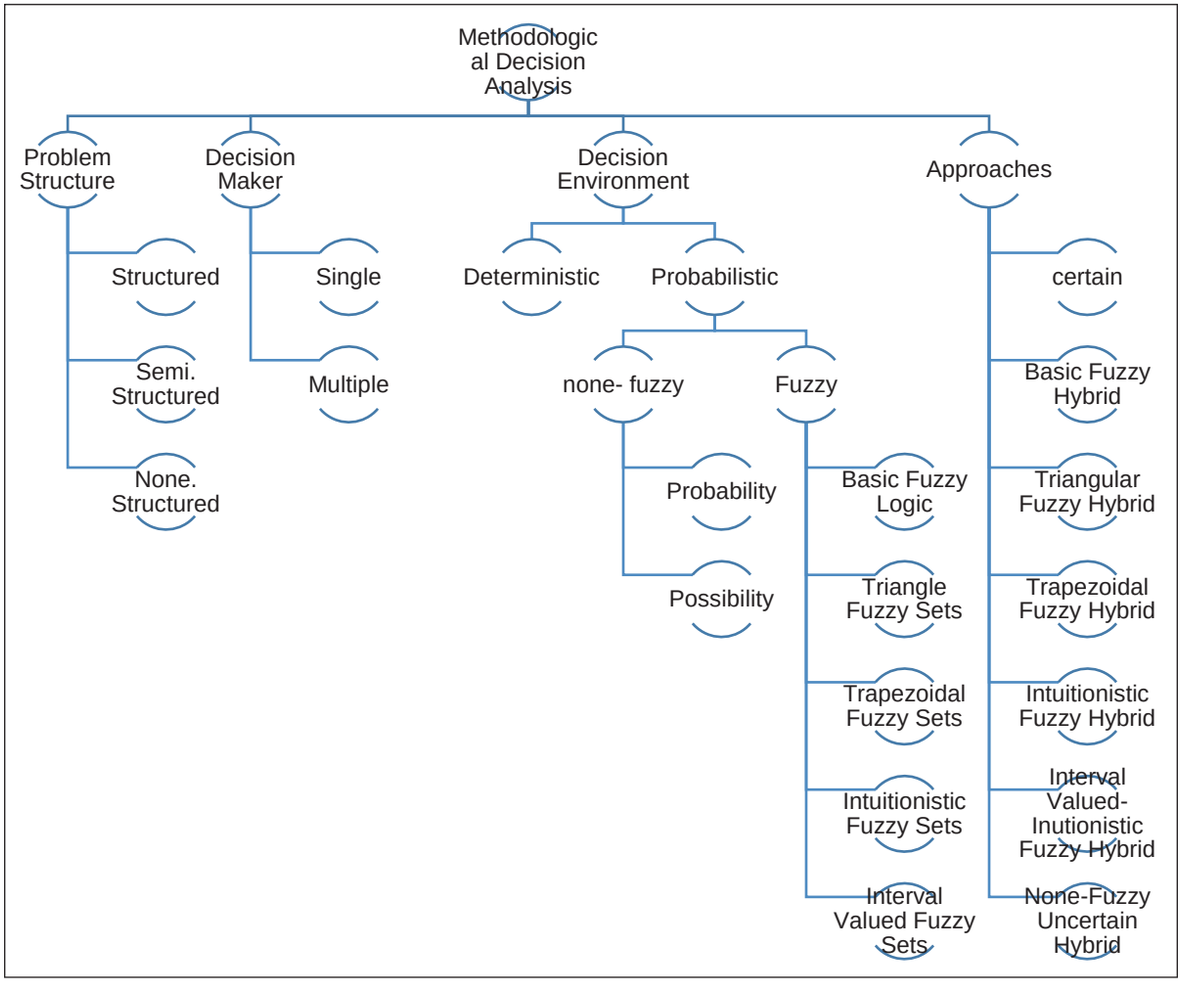
There are so many article dedicated to the mathematical and analytical methods (like optimization) in the field of supplier selection. Below are some of the latest review articles published in this area.

The second article in the above table proposes an outstanding classification of the mathematical models in this area, which divides them into four categories based on the methodological approach which are: 1- Problem structure (Structured/semi-structured/non structured), 2- Decision maker (single/multiple), 3-

Table 7: Mathematical Review Papers Considering Supplier Selection Methods

Title	Author	Year
Supplier Evaluation and selection: a review of literature from 2007-2014.	Moliné JI, Coves AM	2014
Application of decision making techniques in supplier selection: a systematic review of literature.	Chai, Liu & Ngai	2012
Select Supplier related issues in modeling a dynamic supply chain: Potential, Challenges and Direction for future research.	Jain, Wadhwa & Deshmukh	2009
Multi Criteria Decision making approaches for supplier evaluation and selection: A literature Review.	Ho, Xu & Dey	2008
Supplier Selection Problem: Criteria and methods.	LBHDX Xie	2003
A review of methods supporting supplier selection.	de Boer, Labro & Morlacchi	2000

Fig 6: Methodological Decision Analysis in Supplier Selection Problems



Decision Environment (Deterministic/Probabilistic) and 4- Decision making approaches. Fig 6 presents the "Methodological Decision Analysis" tree.

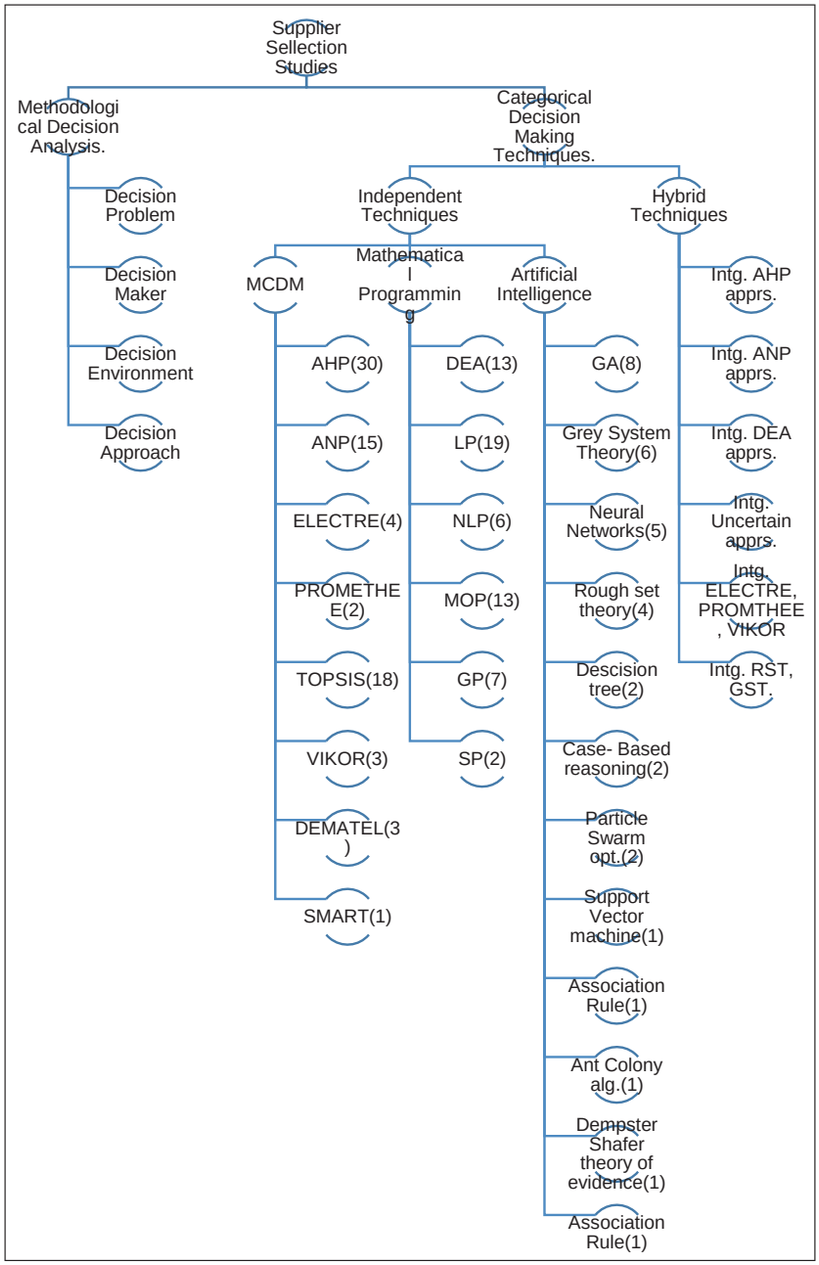
Although, the authors of the above mentioned article proposes a categorical decision making technique diagram which tries to classify related papers published during 2000-2012 which can be seen in Fig 7. (Digits in parenthesis are the number of related papers in this area).

The rest of section 2 is dedicated to studies related to analysing the interaction of supplier- manufacturer after finishing the selection process.

General Supplier Performance Monitoring

A comprehensive definition for supplier performance monitoring is proposed by "Metric Stream" which is:"supplier performance monitoring is referred to the measurement, analyse and assessment of conformation of the supplier with contractual enforcements and a reliable supply's requirements." Supplier performance monitoring has gained lots of attentions as a methodology which must and needed to be implemented based on an information technology network with an appropriate software base vision. Integrated software systems like Enterprise Quality Management Systems (EQMS), Product Lifecycle Management (PLM) and Manufacturing Operations Management (MOM) are among these systems. Rate of reject, continuous improvement programmes, quality of after sale services, certificates, on time delivery, rate of acceptance, process capability, defective parts per million, number of corrective actions in the last three months, number of complaints received during the last period and rate of customer's satisfaction are considered to be as the most important criteria while assessing the supplier performance in the literatures. (Wu & Choi, 2005) (Ittner, Larcker, Nagar, & Rajan, 1999)

Fig 7: Categorical Decision Making Tree in Supplier Selection Problems



Supplier Relationship Management

Supplier relationship management (SRM) is the systematic, enterprise-wide assessment of suppliers' assets and capabilities with respect to overall business strategy, determination of what activities to engage in with different suppliers, and planning and execution of all interactions with suppliers, in a coordinated fashion across the relationship life cycle, to maximise the value realized through those interactions. (Bensaou, 1999) The starting point for defining SRM is a recognition that these various interactions with suppliers are not discrete and independent-instead they are accurately and usefully thought of as comprising a relationship, one which can and should be managed in a coordinated fashion across functional and business unit touch-points, and throughout the relationship lifecycle. (Choi & Kim, 2008) SRM necessitates a consistency of approach and a defined set of behaviours that foster trust over time. Effective SRM requires not only institutionalising new ways of collaborating with key suppliers, but also actively dismantling existing policies and practices that can impede collaboration and limit the potential value

that can be derived from key supplier relationships. Two practical (and also commercial) methodologies widely used in the field of SRM are: 1- Purchasing Chessboard and 2- True SRM models. Below, we provide a brief review and definition for these methodologies. (Gadde & Snehota, 2000)

Purchasing Chessboard

Purchasing Chessboard SRM model is proposed by a renowned German company which has been working in the field of quality assurance for a long time. The main idea of this model is based on analysing "supply power" of a certain supplier with respect to "demand power" for the respective good or service. By using a two axis graph, different strategies is proposed, based on the simultaneously status of the two mentioned. The model has three versions called 4, 16 and 64 strategy houses. Supply power can be assessed by answering to the following questions: 1- how many appropriate suppliers are available in this area? 2- What is the market share structure? 3- Is it easy for other suppliers enter to this market area? 4- How much easily we can replace a supplier in this market area? 6- Are there enough and accessible suppliers in this market area? 7- What about the generality of product's accessibility? We also need to answer to the following questions to find out about the "demand power" of a certain supplier: 1- How much market share has dedicated to the supplier? 2- Is company going to leverage its market share? 3- How much the supplier is investing in its R&D department? Detailed description for this strategy can be found on www.purchasingchessboard.com.

True SRM

True SRM is another famous model which tries to formulate the optimal interaction between the customer and supplier by means of proving an appropriate atmosphere for a long term relationship between the two parties and leveraging the level of quality. This model is based on analysing the status of the supplier based on two criteria: 1-Recent Performance and 2- Strategic Importance (which means the effect that each of suppliers can have on the organisational performance.) True SRM Matrix proposes nine strategies (or solutions) for dealing with suppliers with that certain performance and strategic importance as: 1- integrate, 2- influence, 3- invest, 4- harvest, 5- sustain, 6- improve, 7- mitigate, 8-develop and 9- bail out. Detailed information about this strategy can also be found on a website *www.atkearney.de.*

The next section of literature review is dedicated to analysing Military and Industrial SQM manual by means of understanding their framework and structure, which is a somehow different from academic studies in this area of study.

SQM in Military Manuals

Supplier quality management has gained lots of attention in military industries because Supplier's quality can have a vital effect on the performance of the army. In this section, we have an overall review on SQM manuals related to the US Department of Defense (DoD), Lockheed Martin and UK Ministry of Defense (MOD).

SQM in DoD

As we know, the first step in every supplier quality management approach is the "Supply Base Management"which is referred to a set of activities which formulates the routings in which suppliers can get in or out of vendor list. DoD uses a novel approach for accepting suppliers in its supply base and supplier selection which based on assessing industrial maturity level in three different categories called Manufacturing/ Technology/Company Readiness Level (MRL/TRL/ CRL). Manufacturing Readiness Level (MRL) is a measure developed by the United States Department of Defense (DOD) to assess the maturity of manufacturing readiness, similar to how Technology Readiness Level (TRL) are used for technology readiness. They can be used in general industry assessments, or for more specific application in assessing capabilities of possible suppliers. The Government Accountability Office has described it as best practices for improving acquisition outcomes. The United States Department of Defense adopted the usage of MRLs in 2005, but the GAO continued to note inconsistent application across DOD components. In 2011, consideration of manufacturing readiness and related processes of potential contractors and subcontractors was made mandatory as part of the source selection process in major acquisition programmes. (Sauser, Verma, Ramirez-Marquez, & Gove, 2006) (Choi, 2007) (Wagner, 2009)

MRLs are quantitative measures used to assess the maturity of a given technology, component or system from a manufacturing perspective. They are used to provide decision makers at all levels with a common understanding of the relative maturity and attendant risks associated with manufacturing technologies, products, and processes being considered. Manufacturing

risk identification and management must begin at the earliest stages of technology development, and continue vigorously throughout each stage of a programme's life-cycles.

Manufacturing Readiness Level definitions were developed by a joint DOD/industry working group under the sponsorship of the Joint Defense Manufacturing Technology Panel (JDMTP). The intent was to create a measurement scale that would serve the same purpose for manufacturing readiness as Technology Readiness Levels serve for technology readiness – to provide a common metric and vocabulary for assessing and discussing manufacturing maturity, risk and readiness. MRLs were designed with a numbering system to be roughly congruent with comparable levels of TRLs for synergy and ease of understanding and use. A novel scoring method is used for the final supplier selection. (DeGroot, Jargon, & Marks, 2002; Postel, 1980; Williams, Wang, & Arz, 2003) an evolved, automated implementation of the Multiline TRL (Thru-Reflect-Line).

SQM in Lockheed Martin

Lockheed Martin Company is one of the world's largest military manufacturers in recent years. Due to the grate volume of it's production, this company has engaged in so many outsourcing contracts, which mean a huge number of suppliers in it's supply base. LM is also known as one of the pioneers implementing SQM methodology in Military industries. SQM activities in LM can be divided into six separated clusters of activities. Each of these clusters have their own pre-defined activities, which means a total number of 16 activities is the basic structure of LM's SQM programme. Implementation of this SQM methodology is strictly depended on online infrastructure which is prepared among all supplier around the globe by consideration of security standards due to the nature of informations transferred via this network. Sqm.lmaeronautics.com is one of these portal related to aerospace industries of LM suppliers. Below we provide a qualitative picture of LM SQM approach:(Marketline, 2012)

A: Manuals, Technical Requirements and certifications: 1- Calibration Standards, 2- Supplier Production Capability Analysis, 3- Quality Certification Requirements, 4- Initial Inspection Manuals, 5- Production Verification Procedures, 6- Maintenance Procedures, 7- Quality Assurance procedures, / B: Specifications Control: 1- Component Acceptance, 2- QM verification, 3- Guaranty Requirements, / C: Corrective Actions: Corrective actions requirements, / D: Quality Attachments: Supplier quality requirements, E: Online Supplier Quality Management System, / F: Continual Improvement:Quality Monitoring Using "Oregon Productivity Matrix".

SQM in MOD

SQM has also played a major role in the Ministry of Defense of United Kingdom (MOD) in recent years. In 2010, CDM organisation proposed MOD as the responsible authority for the SQM in military section of UK. It has to be mentioned that in UK, a military standard named DEF-STAN 05-21 is dedicated to provide a supplier quality management framework. As one can guess, identification of suppliers is done based on an online portal in which supplier can enroll their company and their respective activities. The MOD's SQM manual is divided into four chapters: 1- introduction and definitions, 2- defining responsibilities, 3- Quality Assurance, 4- Quality Management. As you see, quality assurance (QA) and quality management (QM) are known as two distinct activities in this structure. The difference between QA and QM is that in QA directions, one can find detailed instruction by which the quality of product or service is realized. But a QM manual is bound with the Managerial framework for implementing such activities. Common QA activities are defined in the MOD's QA cluster. But the part of the manual which we need to be focused on more, due to the subject of our study (SQM) is QM which consists of these activities as: 1- Documents and records control, 2-Managerial Review, 3- Supplier Source Management, 4- Transferring Quality related information, 5-Audit Management, 6- Assessing Goal Achievements, 7- Practical Quality Improvement Plans. (Quayle, 2000) (UK MoD, 2008)

Specific Supplier Selection/ Assessment Criteria

Previous section was all the structure of supplier quality management in literatures. The Rest of literature review section is dedicated to studying the Key Performance Indicators used for selecting and performance assessment of the suppliers.

In our study, we have proposed a novel categorical division for different kinds of suppliers based on their activities which are: 1- Production Suppliers, 2- General Services Suppliers (as Catering, Gardening, Cleaning and so on), 3- Trading Suppliers, 4- Engineering Services Suppliers, 5- Research and development service suppliers,

6- Consulting and learning Suppliers, 7- Knowledge Based Suppliers. As mentioned, KPIs can be divided into Selection and assessment (during the contractual period) ones. Bellow we describe these criteria for each of the major seven categories of the suppliers.

Production Suppliers

According to the KPI Library[1] web site which is a honorable reference in this area, one can consider these criteria while selecting suppliers in the field of production: 1- the average quality inspections in the last period, 2- percentages of defects during the last quality control period, 3- percentage of improvements made during the last period, 4- percentage of Cost of Quality (COQ) over annual income, 5- percentage of defects based on customer's claim, 6- number of corrective actions defined by the supplier during the last audit, 7- number of complaints received, 8- number of rejected products by QC department, 9- effectiveness of the audit process, 10- number of rejected batches, 11- total time of machine availability, 12- quality of the machines, 13- first run quality pass, 14- first pass yield, 15- average income of workers, 16- MTBF for equipment, 17- percentage if deviation in the production planning, Work in process, 18- OPME, 19- production leadtime, 20- unit price. (Cai, Liu, Xiao, & Liu, 2009)

General Services Supplier

There are some papers which had contributed so much in defining the criteria and aspects of supplier selection criteria for a general service supplier as below: (Buckley, 2003; White, 2000)

1- From the perspective of conformance with the norms, rules, standards and common procedures.

2- From the perspective of "effectiveness"

3- From the perspective of "end user's satisfaction"

In many other articles as the one published by Zeithmal, Parasuraman & Berry we can see that all of them are referring to the presence of common problems while selecting these suppliers which are as bellow: (Parasuraman, Berry, & Zeithaml, 1993)

1- The nature of these services are not well defined, thus proposing overall KPIs which can cover a vast range of suppliers in this area are not possible.

2- The nature of some of these services are non-homogenous and thus it cannot be categorised in one seed.

3- In many of the case, "the production phase" and "the usage phase" of services are not detachable.

Another paper is dedicated to assessing the "quality dimensions of outsourcing in a "general supplier" relationship" which describes them as: 1- measurable and tangible dimensions, 2- Reliability, 3- Technical Response level, 4- Completion Capability, 5- Personnel behaviour, 6- Security, 7- Availability, 8- Appropriate Communications, 9- End user responsiveness. (Parasuraman, 2010)

The last article in this field is the one proposed by Muhammad rais bin abdulkarim, in which some of the supplier selection of a "general supplier" is proposed as: 1- supplier must have an integrated maintenance management system, 2- human resource management of supplier must work properly, 3- complaints handling system must be efficient.

Trading Supplier

Trading suppliers refer to all of the suppliers which provide goods or services through a professional buying process. UPS supply chain Solution Company proposes the following criteria which must be assessed as the most important KPIs while selecting a Trading Supplier: 1- Experts (does it have professionals and educated employees in that certain field we want to outsource our goods), 2- Service (is supplier ready to set a certain SLA for the service he provides), 3- Supply Base (Does contracting with this supplier leads to reduction in supply base), 4- Economics (Does proposed solutions by supplier leads us to a cost saving), 5- Resources and References (Does the candidate supplier have enough references, resources and connections to procure our needs). (Hui, Othman, Omar, Rahman, & Haron, 2011)

Another white paper concerning "indirect procurement" is proposed by Charles Dominick in which he stipulates 5 criteria to assess a supplier's capability in this field: 1- Cost Reduction, 2- Managed Spends/ Annual Spends ratio, 3-Cost Savings as a ratio of Managed Spends, 4- Outsourcing operational costs as a ratio of Managed Spends, 5- Return on Investment (ROI).

In another white paper by Daniel Ridman, one of the experts of Proqur Consultant Company in 2013, some of the major criteria which is important to be assessed while selecting a "procurement Supplier" is defined as:

1 KPI-library.com

1- Defect Rate (DPM), 2- Procurement Cycle Time, 3- Delivery, 4- Contractual Conformance, Cost Savings (which is assessed through controlling the previous performance of the supplier).

Although we can refer to a recent research made by Hurber B, 2013 which is a novel paper in this field that addresses the requirements for an appropriate Procurement supplier which is similar to the previous study made by Ridman. (Huber, Sweeney, & Smyth, 2004) there has been little empirical research investigation on purchasing consortium issues focusing on a detailed analysis of ICT-based procurement strategies. Based on the exploration of academic literature and two surveys among purchasing organizations as well as e-marketplaces/procurement service providers (PSPs).

Engineering Services Supplier

Engineering services outsourcing consist of a vast range of technical, analytical, maintenance, design and high- tech services. (Willcocks, Oshri, Kotlarsky, & Rottman, 2011) There are many articles considering selection criteria for an engineering service supplier. Some articles have considered R&D investment rate of an engineering service supplier as a key proxy for understanding it's competency to deliver required service with the best quality possible. They refer to these benefits as the reasons for outsourcing engineering services in organisations: 1- Cost Reduction, 2- Increasing the Flexibility, 3- Achieving Goals.

Although there are some negative aspects in outsourcing engineering services which are: 1- not letting your engineering team to achieve the technological knowledge according to that project, 2- costs related to alignment of your engineering team with the methods of outsourced engineering team, 3- direct costs related to outsourcing, 4- usual opposition of middle- level manager for outsourcing engineering services. Another article proposed by Routzong 2012, considers so many benefits for outsourcing engineering services as: 1- cost reductions, 2- using professional experts, 3- cost reduction in internal R&D section, 4- Lifecycle time reduction, 5- knowledge transfer, 6- optimal monetary resource usage.

Another recent paper in this field, proposed in 2013, is dedicated to analyse engineering service outsourcing in aerospace industries, in which same criteria are defined for selecting appropriate engineering service supplier in this section.

Research and Development Supplier

R&D supplier is referred to those suppliers which responsibility is to propose aimed researches by means of growing a knowledge in a certain direction achieving desired results in a certain problem defined by an industry or an organisation.

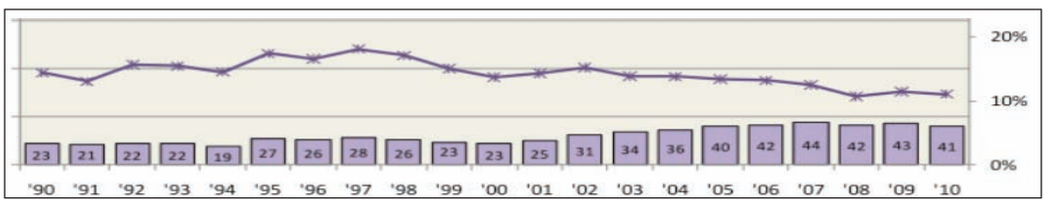
In one important article in the field of R&D outsourcing, the author stipulates that four major clusters of criteria must be considered while selecting such a supplier as: 1- Performance criteria with respect to end user's vision, 2- Performance criteria with respect to internal trading stream, 3- Organisational learning and innovation, 4- Economical performance.

Although, researchers of Stellenbasch University have mentioned four groups of criteria that must be considered while selecting an R&D service supplier as: 1- Risk (information security risks), 2- Costs, 3- Human Resource, 4- Time.

Some related researches have stipulated that outsourcing R&D services is the worst option that an organisation can take into account because in this way the opportunity for knowledge transfer will be lost

The DOD's published statistics about the rate of expenditures for R&D outsourcing, shows a downward slop trend between 1990- 2010 due to the same reason (Fig 8)

Fig 8: R&D Outsourcing Expenditures/Over Expenditures Due to all Other Kinds of Outsourcing



Consultant and Learning Services Suppliers

Another class of supplier are those who are active in the field of consultant and learning services. As Doug Haward, a researcher of Training Industry Company stipulates, there are six groups of criteria which must be assessed while selecting such suppliers which are: 1- Cost reduction, 2- Human resource competency, 3- Geographical situation and availability, 4- Role in increasing the sale rate and productivity of the organisation, 5- Flexibility (vast range of consulting fields), 6- Decreasing risks. Proposed criteria in this context are so much alike to the ones mentioned in R&D section.

Knowledge Base Services Suppliers

Knowledge base organisations are the ones in which the seed of a basic knowledge are grown beside the production capabilities are considerations are taken into account so that the company is responsible for creating the product and finally gaining the required added value. This phenomena in the literature is called Knowledge Process Outsourcing (KPO). As scholars of KPOEXPERTS company stipulates, there are five groups of criteria which must be considered while selecting the KPO supplier as: 1- Reasonable turn over, 2- Educated Human Resources, 3- appropriate facilities and machines, 4- reasonable ROI, 5- reasonable price.

Discussion

Supplier quality management is shown to be an important phenomenon in product's quality realisation in the recent years. One of the key elements of every Supply Chain Quality Management model is the Supplier Quality Management approach. Many researchers have focused their study in the area of SQM. In this study, we proposed an in-depth review on the academic studies have been made on this area. We also have considered some of the military SQM manuals to conceive the common structure available for this phenomenon. In the next section, by dividing suppliers into seven categories based on the essence of their activities, we proposed a novel list of criteria while assessing and selecting such suppliers, which is an important part of every SQM structure.

This study can be used as a road map for multidimensional organizations which have a vast range of suppliers, to increase their awareness about the concepts of SCQM and specially SQM. Although this study can be considered as a reasonable resource for constructing appropriate SQM framework based on the nature of every company's activities. The last part addressing the novel supplier classification and supplier selection and assessment criteria would give insightful ideas for organizations and industries.

Conclusion

This paper was devoted to conduct an overall overview on papers published in the field of "supplier quality management". In this paper, we tried to propose a semi-structures problem and investigate the ways in which we can clearly define the dimensions of SQM problem in real world by using qualitative classification techniques. By the end of this paper, reader can prepare an overall picture in her mind that what SQM phenomenon is, why it is so much important in today's economy, what its dimensions and structures are, where it is most applicable.

Further studies and research directions would be about proposing a Comprehensive Supplier Quality Management Model (CSQM). This model can consist of four interrelated parts as: 1- Supply Base Management (SBM) which focuses on optimal management of supply base by means of proposing appropriate routines for entering or even exiling supplier to/ from vendor lists, supply base reduction or expanding strategy decisions, supplier ranking structure. 2- Supplier Selection Management (SSM) which consists of the optimal supplier selection strategies, managerial considerations, and optimal contractual frameworks which guaranty the quality of delivered product from the supplier, optimal pricing structure and cost of poor quality (COPQ) approach which assures the quality of the supplier, 3- Supplier Performance Management (SPM) which is referred to as post- contractual assignment activities and during the contract period for monitoring the supplier performance, conventional techniques like auditing, preparing appropriate checklists based on the nature of outsourcing. 4- Supplier Relationship Management (SRM) which is referred as a bunch of activities in which the long term relationship between supplier and manufacturer are guaranteed. Novel strategically methods like True SRM and Purchasing Chessboard can be helpful in order to construct such structure.

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