

Six Sigma for big companies and SMEs: evidences from literature

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Abstract: - Six Sigma (SS) methodology is nowadays one of the most used approaches in the Quality Management field since its benefits, coming from the improvement of the process outputs quality by identifying and removing the causes of defects and variability in manufacturing and business processes. Thus, literature on the SS topic is exponentially increased during last decades; the vast number of works on the SS field represents a good opportunity for a structured literature review of the articles, in order to understand the evolutions of the concept, the fields of its application and possible evolution for further studies. The literature review has been carried out by using a chronological review of the main SS approaches developed both for large and small companies, in order to highlight particular aspects of the SS literature and some applications of the SS methodology. The evaluation of the papers found in literature is carried out through a Strengths-Weaknesses criterion. Moreover, for those treating the application of the SS methodology into both big companies both Small & Medium Enterprises (SMEs), an assessment has been carried out based on the accordance with some milestones identified as necessary for every SS system. Finally the paper argues the possible further developments of the research field.

Key-Words: - Six Sigma, DMAIC, Literature Review, SMEs

1 Introduction

TQM is an integrated system of continuous quality improvement aimed at meeting external and internal customers [1].

The use of Total Quality Management (TQM) as an overall quality programme is still prevalent in modern industry, but many companies are extending this kind of initiative to incorporate strategic and financial issues [2]. After the TQM hype of the early 1980s, Six Sigma, building on well-proven elements of TQM, can be seen as the current stage of the evolution [3]: although some conceptual differences exist between TQM activities and Six Sigma systems, the shift from the firsts to a Six Sigma program is a key to successfully implement a quality management system [4].

Six Sigma is a business strategy that seeks to identify and eliminate causes of errors or defects, defined as anything which could lead to customer

dissatisfaction [5] or failures in business processes by focusing on outputs that are critical to customers [6]; it uses the normal distribution and a strong relationship between product Non-Conformities (NCs), or defects, and product yield, reliability, cycle time, inventory, schedule, etc. [7]; the activities of Six Sigma are not limited to process or operation levels, but extended to all the levels of an enterprise to reduce cost and produce high quality products/services. Six Sigma has been widely adopted in a variety of industries as a proven management innovation methodology to produce high-quality products/services and reduce the cost at all the levels of an enterprise [8]. General Electric and Motorola are the two most well known success cases of Six Sigma implementation [9]. Moreover, the Six Sigma movement is also gaining acceptance in healthcare, marketing, engineering, financial and legal service organizations, in additions to achieving major benefits in respect to the manufacturing sector [10]. In this sense, it is used

also as performance measurement methodology [11], since it highlights the weaknesses in which companies could improve.

Several studies have been performed regarding the implementation of the methodology in big companies; nevertheless, very few studies have been reported about the successful application of Six Sigma in Small and Medium Enterprises (SMEs), that represent the life-blood of the modern economy [12].

This article tries to furnish a clear overview of the SS topic discussed in literature and gives a first classification of the works based on three different approaches: the implementation of the SS methodology in big companies and in SMEs; a strength-weakness analysis of the articles analyzed for the review; and an evaluation of some milestone respecting, identified by the authors as the fundamental aspects that every SS approach should possess.

2 Research methodology and literature analysis

The literature review analysis started from the collection of the articles on the topic of interest. The methodology used by the authors has been set up by using the ISI Web Of Knowledge databases. The authors were looking for articles with the "Six Sigma" key-word in the main topics (title, abstract, key-words). A total of 4.241 articles have been collected, for a total 156.749 cited works. A citation and co-citation analysis have been carried out for deepening the SS topic, showing that the most cited authors are Becke (131 citations), Sheldrick (116 citations), Reed (77) and Harry (71 citations). The main field of application of the SS methodology are as expected the Chemical sector but with general applications in the physics world. A smaller number of articles have been developed in the other manufacturing businesses, even if the number of works are growing up in different sectors and field of application.

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main field of application of the SS methodology are as expected the Chemical sector but with general applications in the physics world. This is evident by analyzing the main keywords of the most cited articles: the more frequently used terms are in fact chemistry, crystal, spectroscopy and molecules, as depicted in Figure 1.

A smaller number of articles have been developed on the business management and engineering topics. A filtered set of 821 works have been selected refining the criterion only to management, business and engineering (industrial, mechanical, electronic, civil, aerospace, etc.) areas. The increasing interest under the previous research fields is demonstrated by the growth of the literature during the last 10 years in terms of number of articles, as depicted in Figure 2.

The most important authors discussing the SS topic under the management and engineering fields are Antony (2002), Breyfoglefw (1999), Hahn (1999 and 2000), Harry (2000), Hoerl (1998), Linderman (2003) and Pande (2000) (only articles with more than 10 citations have been considered): Figure 3 represents the yearly citation percentage for each of these authors. Before this period, the two most cited works have been Harry (1998) with 32 citations and Feng (1997) with 29 citations.

Figure 4 represents a co-citation analysis network carried out from the managed articles (only articles with more than 10 citations are included), while Figure 5 shows some articles (the circles in the figure) linking the most important references (more than 10, the squares in the figure) in literature. Since the lack of articles discussing Six Sigma implementation in SMEs (only 9 using as searching criterion "Six Sigma" and "SME" in the main topic), the authors deepened the research including different criteria, such as the use of keywords like "Small business" and other different search engines. The 43 total reached articles furnishes the base for the following analysis.

3 Literature review and analysis

The analysis has been restricted by the authors on a smaller number of articles selected by their pertinence on the research. A total of 487 articles have been chosen and carefully analyzed from the 1990 to nowadays: 351 of them have been excluded after the abstract reading due to a non completed appropriateness of the article to the issue of interest; other 93 have been further excluded after a complete article reading, since they didn't meet the inclusion criteria (for example most of them were

related to Six Sigma for particular types of companies, particular sectors and sizes).

The remaining 43 articles have been selected from the authors as eligible for the research and classified in four groups:

- *GROUP 1* - regarding general Six Sigma methodology: they deal with general Six Sigma definition, including DMAIC/DMADV models and belt systems;
- *GROUP 2* - on general Six Sigma implementation: the “key factors” for a successful implementation of Six Sigma are treated;
- *GROUP 3* - about Six Sigma methodology in SMEs: they explain the main guidelines to adapt the main Six Sigma features to a SME context;
- *GROUP 4* - presenting Six Sigma implementations in SMEs: the main approaches to implement Six Sigma in SMEs, including statistical tools, and the importance of integration with other quality management methods.

The 43 articles selected for the base of the study have been analyzed in depth by the authors, and categorized due to the subjects they relate with. The main classification is between large companies and SMEs, and the second one is between theoretical models and practical implementation in case studies. A strength-weakness analysis has been then conducted by the authors. The main conclusions of this analysis are that in the articles about Six Sigma in large enterprises lots of works have been developed during last decades, nevertheless very few of them present a well structured approach with a discussion of the achieved results. Moreover, a part of them shows the application of Six Sigma approach in real case studies, but on the other hand they don't detailed explain the used methodology. For the articles about the Six Sigma methodology and implementation in SMEs, one of the main weaknesses is the absence of effective theoretical framework or model, whereas there are lots of empirical developed data, such as surveys and interviews. From the analyzed literature, the authors have identified four main milestones for a quality system, as described in the next paragraph. Through this analysis, the authors have been able to draw the conclusion that very few methodologies found in literature contemporarily respect all the four milestones.

3.1 Six Sigma: concepts, applications and key factors (Group 1 and 2)

From the statistical point of view, the term “Six Sigma” is defined as having less than 3.4 defects per million opportunities or a success rate of 99.9997% (these computations assume a 1.5 sigma shift in the process mean, 1.5 to account for long-term variation) where sigma is a term used to represent the variation about the process average [13]; in the same way, in the business world Six Sigma is defined as a business strategy used to improve business profitability, to improve the effectiveness and efficiency of all operations to meet or exceed customer's needs and expectations [13].

At the operational level, Six Sigma builds on a set of well-established traditional methods and tools, as well as new techniques for setting priorities on improvement and for measuring the monetary benefits; these new tools have to ensure that the additional objective of profitability improvement can be achieved [14]. Six Sigma peculiar characteristics are implemented through two simple models: DMAIC (Define-Measure-Analyze-Improve-Control), used when an objective can be reached through the development of products, processes and services (PPSs) that the enterprise already owns, and DMADV (Define-Measure-Analyze-Design-Verify), used when the PPSs are not already realized by the company and it need to be created and implemented. Other phases alternations have been developed in literature (DMADOV, DMEDI, IDOV, DCOV, ecc.), but few studies have tested these new approaches.

According with [13], the main key factors for a successful implementation of SS programs are: managing involvement and commitment, understanding of SS methodology, linking it to a business strategy, linking it to customers, project prioritization and selection, organizational infrastructure, cultural change, project management skills, linking it to suppliers, training and linking it to employees.

One of the Six Sigma key innovations is also the professionalizing of quality management functions; for this reason, Six Sigma methodology identifies several key roles for its successful implementation: executive leadership (CEO and other members of top management); champions (they have the responsibility for Six Sigma development inside the organization); Master Black Belts or MBB (Black Belts and Green Belts' guides with the projects development responsibility); Black Belts or BB (they apply Six Sigma methodology to specific

projects); Green Belts or GB (as black belts, they have a good methodological preparation, although they work part-time to the project development, due to other responsibilities inside the organization); DMAIC, DMADV and belt system represent the core elements of a Six Sigma organisation [15].

3.2 Six Sigma implementation in SMEs vs Big Companies (Group 3 and 4)

SMEs are much more flexible than large ones, and hence changes can be introduced fairly quickly; moreover, in SMEs there is a high visible top management and managers are more likely to be directly involved with customers; in SMEs there is also a better predisposition to the final consumer, that represent one of the fundamental basis of TQM; as [16] affirm, "it is generally easier to introduce radical change to smaller companies because there are fewer organizational layers between the CEO and the front line workers". This close relationship and the high degree of communication with key customers appear to be significant advantageous for SMEs in opposition to large corporations [3]. Nevertheless, SMEs also present particular needs and limits, especially about the lack of financial resources and consequently the impossibility to carry on advanced methods for quality management. The DMAIC procedure is still widely used, although with some differences: as a matter of fact, due to the impossibility to meet high costs and the unavailability of full-time experts, SMEs are often forced to use just simple statistical tools, like process mapping, cause and effect analysis, histograms and FMEA (Failure Modes and Effects Analysis), missing out more complex techniques (run charts, non-parametric tests..) that large companies use instead. In addition, decisions are generally made for short-term profitability and in many cases there are no incentives or reward programs due to budgets and resources constraints [12]. Another typical lack of SMEs is the unavailability of trained experts: for example, the usual criterion for having a full-time Master Black Belt is one per 1.000 employees; the cost for extensive training may be prohibitive, and sparing personnel to become Black Belts is often unrealistic [17]. Actually, basing on the definition of SMEs given by EC, it would not have sense to keep a MBB, since the maximum number of employees for a SME is 250; for this reason the attention for training programs must be focused on BBs (one per 100 employees) and above all GBs, since their costs are sensibly smaller and they are not full-time working on a single projects as they have other

regular jobs inside the organisation. Six Sigma can be also integrated with other quality management models; in fact it is a quite common error considering Six Sigma as a completely replacing model: many companies are apathetic about Six Sigma because they believe their existing culture and system, such as ISO 9000 and continuous improvement, are sufficient to meet their needs [18]. Thus Six Sigma should not replace the already existing quality management methods, but it could improve them by getting into the organisation; final result is a quality approach that includes both traditional features of TQM both Six Sigma quality philosophy.

3.3 Classification and evaluation of the Articles

After the first classification between SS for big companies and SS for SMEs, the 43 articles selected for conducting the research have been evaluated through other two different criteria: a strength-weakness evaluation of the articles and a matching milestone approach. For this second point, the authors identified the milestones that every SS approach should respect, as described in this paragraph.

For the first approach, the 43 articles have shown strengths and weaknesses under different perspectives, as explicated in Tables 1 and 2, the first for the big companies while the second for SMEs. In particular, the most important strengths pointed out from the review is the large use of case studies (51% of the articles) for testing the theories developed by the researchers. The real cases have been used in this way for highlighting the most important emerging successes or issues; a second strength of the 21% of the total articles is the detailed application/illustration of the SS methodology, in particular the implementation of the DMAIC/DMADV phases; moreover the detailed description of particular statistic and non-statistic tools (23%) in supporting the decision making for each of the SS phases; and the proposition of the Critical Success Factors (14%) for a successful SS implementation. On the other side, the most important weaknesses encountered during the review process could be summarized in the absence of case studies presented in the remaining part of the articles (49%), without any practical documentation regarding the theories developed during the researches; a not explicated/deepened description of the concrete utilization of the SS methodology (42%); too high complexity or contrarily incompleteness of the

statistical tool description (19%) presented in the articles; non holistic approach or not complete applicability in different type of companies, sectors and sizes (37%).

For the second evaluation criterion the authors have identified the most important milestones that answer to the specific companies' needs and characteristics for successfully implementing the SS methodology. Four milestones have been identified as follows. They refer to 4 characteristics that a SS system should present:

- *simple*: methodologies and tools used in the SS projects have to be easy to understand and quick to use [3];
- *universal*: the SS approach has not to be referred to a particular type of enterprise, but it must be applicable to every company that intends to implement it;
- *holistic*: if an enterprise already owns a quality management system, the SS approach doesn't have to replace it, but rather it must gradually integrate each in other: generally speaking, the SS project doesn't have to distort enterprise's nature [19];
- *developable*: from adopting the SS approach other solutions and tools should be developed - in fact Six Sigma is a continuously innovative technique [20] and consequently it would be reductive to maintain a static approach to the methodology.

Table 3 furnishes a classification of the articles, especially those related to the SME application of the Six Sigma Methodology, based on the respect of the above milestones. For the authors' point of view there are no articles that respect all the four milestones at the same time. In particular, 56% of the 43 works have discussed a clear application of the first milestone, presenting simple, clear and quick to use approaches and tools; only 7% argued the universality of the discussed theories and practices; 56% adopted an holistic approach for their studies and 60% discussed about their intention in continuing the SS philosophy as an improving circle of quality management activities.

4 Discussion

There are a number of key research gaps in literature, which this paper aims to address:

1. the existing weaknesses in SS implementation both for big companies both for SMEs are still not well understood;

2. the link between SS and small businesses is not well explored in terms of real benefits coming from the implementation of the methodology;
3. there are no clear and detailed description of the used tools and of the methodology adopted for the successful case studies;
4. there is insufficient empirical evidence to verify and further explain the six sigma CSFs identified;
5. the SS systems don't respect simultaneously the milestones required.

All of these issues need to be addressed in further researches. The following key exploratory research questions are derived from the research gaps and issues identified in the literature review, representing a research agenda for further works:

- What are the areas of weakness in six sigma implementations, if any, which could be addressed by research into potential enhancements to the methodology?
- What are the difficulties and issues in the six sigma implementation process and how do they differ between SMEs and big companies?
- What are the CSFs for six sigma implementation? And how do they impact six sigma?

First answers for these questions come from a study conducted by [21], although more research need to be developed.

5 Conclusion

The article presents a literature review on the Six Sigma research topic. The review has been conducted on a sample of 43 articles selected from a more vast base of 4.241 works written in the most important scientific journals.

The analysis conducted by the authors has been developed following three distinct approaches: the aim of the first was to investigate the SS implementation differences between big companies and SMEs; the most important result is the identification of ten main differences in implementing the SS methodology in the two different environments. They represent a sort of key ingredient list for a successful SS implementation, but no article presented quantitative results or concrete impact on the companies' performances.

The second investigated aspect wanted to highlight the incompleteness of the available literature, since almost every article analyzed

presented very important strengths from one side, but contemporarily significant lacks from others. Generally speaking, articles that for instance presented a successful case study, lacked for a clear description of the used statistical tools, or considered the SS approach as a stand alone system, not perfectly integrated in the company's strategy. Other examples are articles presenting a detailed description of several statistic and non-statistic tools, probably with a too high complexity for an applicability to other industrial contexts. Finally, a number of the articles was focused in illustrating the Critical Success Factors for a successful SS implementation, without first quantitative results coming from the testing of the proposed key ingredients in real case studies.

The third analysis is related to the evaluation of the articles under four different milestones identified as essential for a generic SS system; following this criterion a generic SS system should be simple, universal, holistic and developable. The cases presented in literature hardly verify these characteristics at the same time.

From the research questions, further studies need to be conducted addressing the issues highlighted.

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Appendix

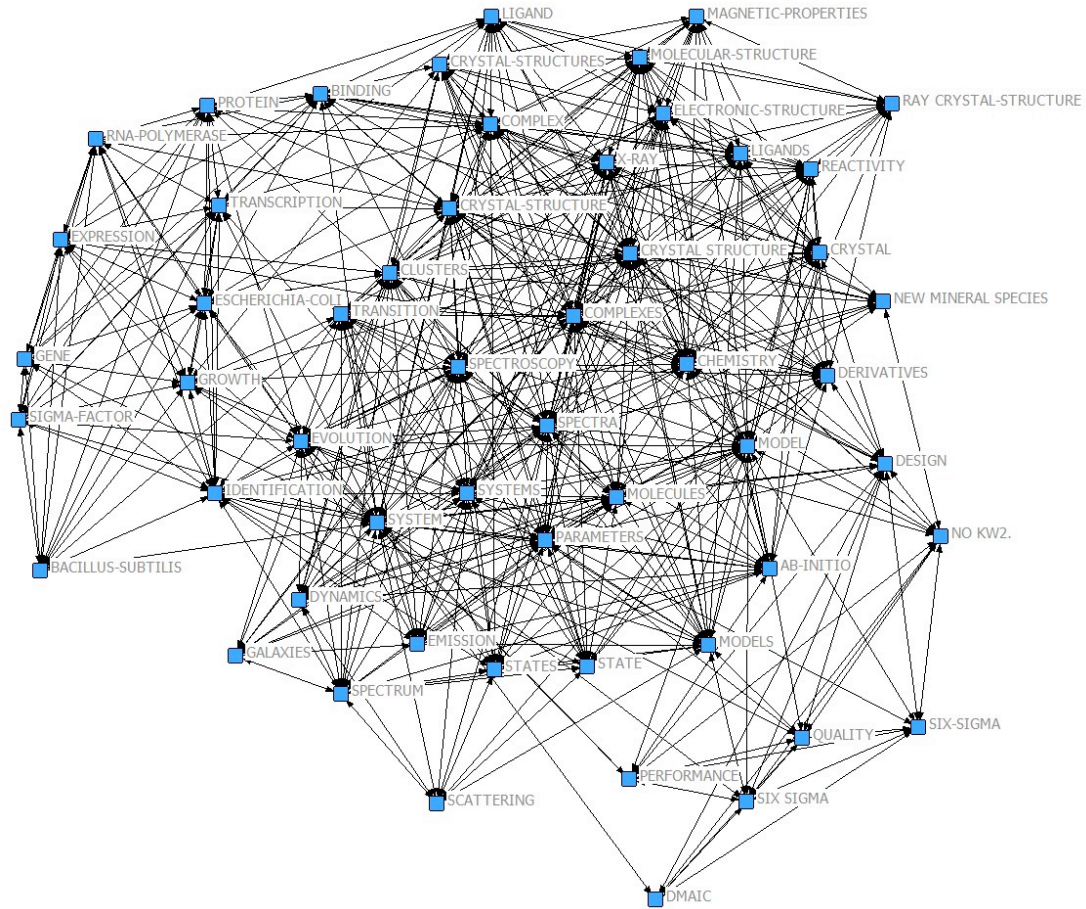


Figure 1: Keyword co-relations among articles

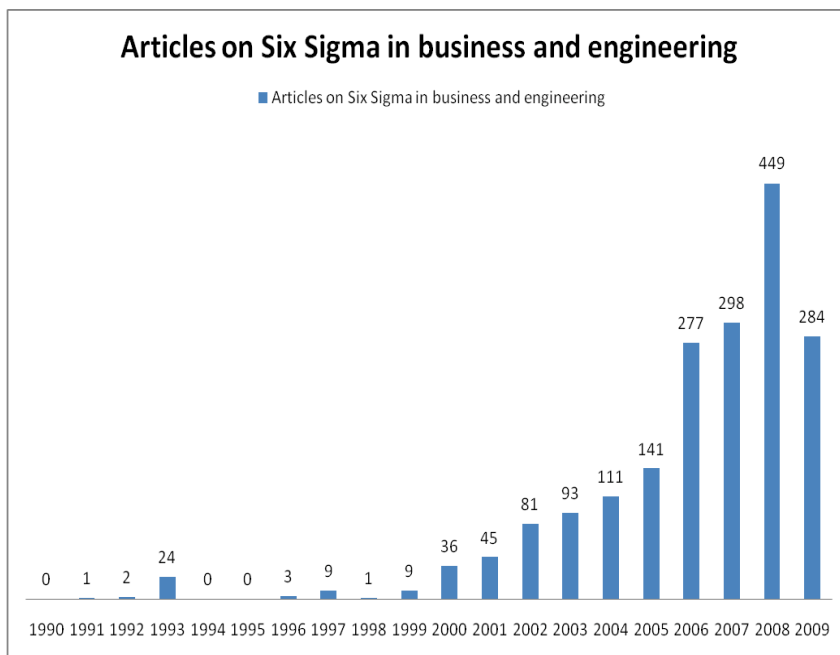


Figure 2: number of articles on Six Sigma (in management and engineering fields) developed during the last decade

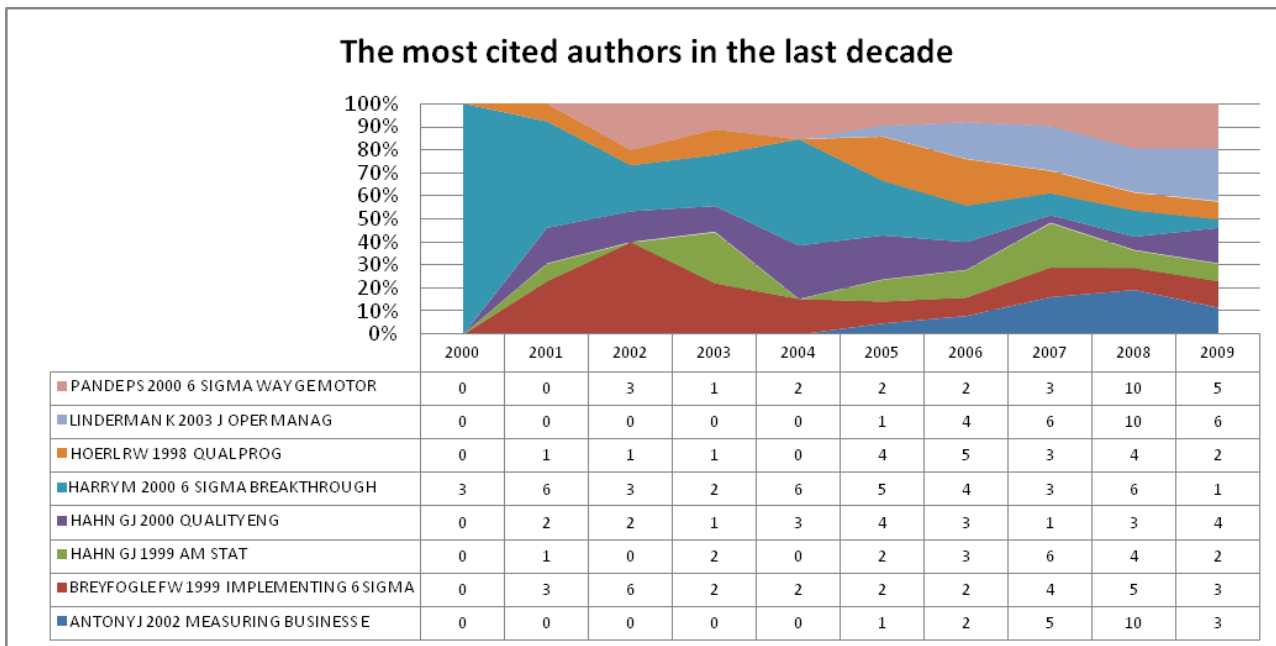


Figure 3: the most cited authors in the last decade

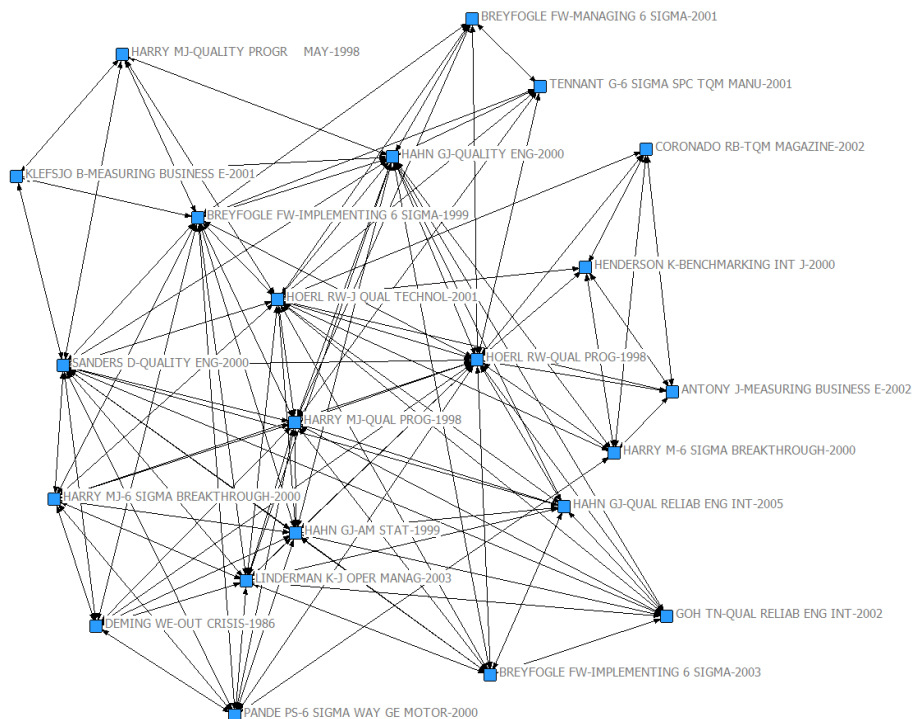


Figure 4: network of the co-citated articles

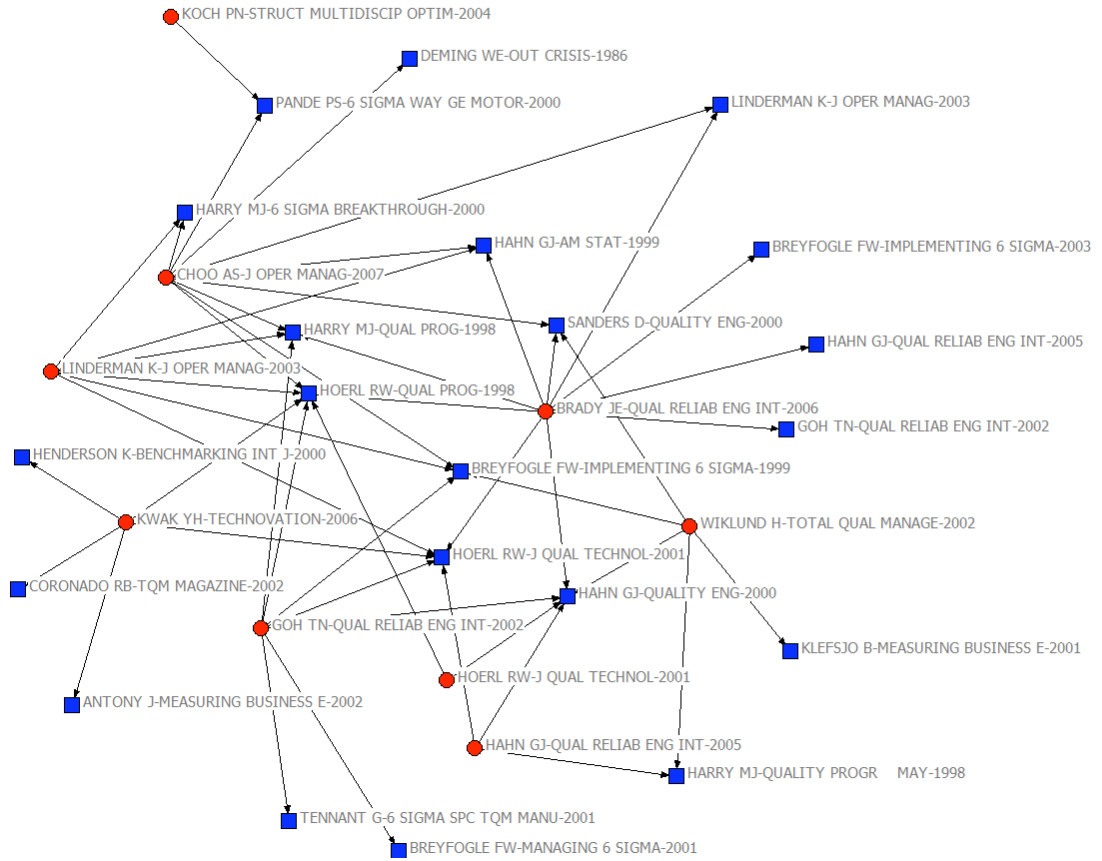


Figure 5: articles to references.

Table 1: Strength-Weakness Evaluation of the Articles regarding SS related to Big Companies

Article	Strengths	Weaknesses
T.N. Goh, L.C. Tang, S.W. Lam, Y.F. Gao, International Journal of Six Sigma and Competitive Advantage, Vol.2 No.3 pp.233-242	- Detailed SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of Six Sigma methodology	- No case studies - DMAIC and DMADV not deepen
C.Doran, Credit Management, Dec.2003 ABI/INFORM Global p.32	- Illustration of Six Sigma utility in finance sector	- Approximative analysis and presentation of methodology - Absence concrete data
P.Cronemyr, International Journal of Six Sigma and Competitive Advantage, Vol.3 No.3 pp.193-209	- Detailed differences between DMAIC and DMADV - New possible methodology obtained by combination of DMAIC and DMADV	- No case studies - No application of new methodology
J.Antony, International Journal of Technology Management, Vol.37 Nos.1/2, pp.8-12	- Differences between Six Sigma methodology and previous quality management initiatives	- Subjective opinions from the author - Future developments are not proved by any empirical data
R.Basu, International Journal of Six Sigma and Competitive Advantage, Vol.1 No.1 pp.44-64	- Roadmap for operational excellence - Possible future Six Sigma model (FIT Sigma) - Detailed description of Quality Total Costs	- DMAIC statistical tools are not associated to single phases - No practical example of FIT Sigma application - New methodology could not be applied to all enterprises
Y.H.Kwak, F.T.Anbari, Technovation 26 (2006) 708-715	- Simple and concise explication of Six Sigma methodology (DMAIC, DMADV) - Widening of Six Sigma to other areas (finance, healthcare, R&D etc.)	- No practical cases analyzed - Approximative explication of key tools and factors for an effective implementation of a Six Sigma program
A.Y.T.Szeto, A.H.C.Tsang, International Journal of Six Sigma and Competitive Advantage, Vol.1 No.3 pp.307-322	- Detailed analysis of CSF for an effective implementation of Six Sigma program	- No case studies - No deepening of Six Sigma methodology (DMAIC, DMADV)
J.Ferng, A.D.F.Price, International Journal of Six Sigma and Competitive Advantage, Vol.1 No.2 pp.167-187	- Six Sigma integrability with other quality management tools - Simple diagrams and tables illustrating Six Sigma phases	- Potential application of methodology are not verified by any real case.
R.Hoerl, International Journal of Six Sigma and Competitive Advantage, Vol.1 No.1 pp.112-119	- Potential developments of Six Sigma methodology (integration with other QM methods, standardization, globalization)	- Subjective opinions from the author - Methodology not deepen - No case studies
R.G.Schroeder, K.Linderman, C.Liedtke, A.S.Choo, Journal of Operations Management 26 (2008) pp.536-554	- Definition and detailed description of Sei Sigma - Methodology integration with other QM tools	- Methodology is not sufficiently explicated (DMAIC, DMADV)
M.Kumar, J.Antony, C.N.Madu, D.C.Montgomery, S.H.Park, International Journal of Quality & Reliability Management, Vol.25 No.8 pp.878-895	- Demistification of "myths" about Six Sigma methodology - Integrazione con altri sistemi di QM - Applicabilità ad ogni tipo di aziende	- Methodology is not sufficiently explicated - Subjective opinions from the authors - No case studies
D.Näslund, Business Process Management Journal, Vol.14 No.3 pp.269-287	- Complete and detailed analysis of Lean and Six Sigma methodologies with strengths and weaknesses	- No case studies - Six Sigma methodology is not deeply explicated - Absence of new models
R.Banuelas, J.Antony, The TQM Magazine, Vol.14 No.2 pp.92-99.	- Literature review about main success factors of Six Sigma methodology	- Approximative explication of methodology - Lack of a case study to verify the applicability of identified CSF
S.Ingle, W.Roe, The TQM Magazine,	- Analysis of different approaches that	- Explication of methodology not

Vol.13 No.4 pp.273-280	could be utilised to implement a Six Sigma program for Black Belts - Comparison between implementation strategies utilised by Motorola and General Electric	deepen - Implementation for Black Belts is only relative to large enterprises
J.Antony, The TQM Magazine, Vol.16 No.4 pp.303-306	- List of main strengths and weaknesses of Six Sigma methodology	- Subjective opinions from the author - Lack of a real case
I.D.Rajamanoharan, P.Collier International Journal of Six Sigma and Competitive Advantage, Vol.2 No.1 pp.48-68	- Case study	- Methodology could not be applied to alle enterprises
J.L.Cheng, International Journal of Six Sigma and Competitive Advantage, Vol.3 No.1 pp.1-12	- Case study - Integration of Six Sigma methodology with other business strategies	- DMADV not mentioned - Enterprises size is not specified
K.C.Kapur, Q.Feng, International Journal of Six Sigma and Competitive Advantage, Vol.1 No.2 pp.210-228	- Suggest of new integrated models for optimization - Case study	- Case study not applicated to a real case - High statistical complexity of tools
U.D. Kumar, D. Nowicki, J.E. Ramírez-Márquez, D. Verma, International Journal of Production Economics 111 (2008) pp.456-467	- Benefit-cost analysis for a correct realization of a Six Sigma project - Two models for cost-benefit analysis	- Methodology could not be applied to all enterprises - Methodology description not detailed
R.D. Snee, International Journal of Six Sigma and Competitive Advantage, Vol.1 No.1 pp.4-20	- Case study - Simple methods - DMAIC illustrated in detail	- DMADV not mentioned - Methodology not applied in manufacturing area
J.Antony, R.Banuelas, Measuring Business Excellence, 2002, 6, 4; ABI/INFORM Global, pp.20-27.	- Key-ingredients for success of Six Sigma methodology - Empirical data (surveys)	- Survey limited to UK enterprises - Methodology description not detailed
M.Soković, D.Pavletić, S.Fakin, Journal of Materials Processing Technology, 162-163 (2005) pp.777-783	- Case study - Modified diagrams after methodology application	- No references to Six Sigma methodology (DMAIC, DMADV) - The application takes place only in process phase
C.T.Su, C.J.Chou, Expert Systems with Applications 34 (2008) pp.2693-2703	- Case study - FMEA tools explication and algorithm for Risk Priority Number (RPN) calculation - Adaptable to several processes	- Tools are not associated to single phases of Six Sigma methodology - DMAIC and DMADV not mentioned
C.Han, Y.H.Lee, Annual Reviews in Control 26 (2002) pp.27-43	- Case study - Six sigma application through MSPC (Multivariate Statistical Process Control)	- Advanced mathematic tools - Define phase is not discussed (MAIC only) - Case study is only relative to plant engineers
K.Linderman, R.G.Schroeder, A.S.Choo, Journal of Operations Management 24 (2006) pp.779-790	- Case study	- Some statistical tools could not be appliable to all enterprises - No reference to methodology
K.Linderman, R.G.Schroeder, S.Zaheer, A.S.Choo, Journal of Operations Management 21 (2003), pp.193-203	- Case study	- No reference to methodology
Y.C.Ho, O.C.Chang, W.B.Wang, Journal of Air Transport Management 14 (2008) pp.263-269	- Empirical data (surveys and questionnaires) - Analysis of Six Sigma main success factors	- Analysis made just for one type of enterprise - DMAIC and DMADV not widen
X.Zu, L.D.Fredendall, T.J.Douglas, Journal of Operations Management 26 (2008) pp.630-650	- Real data (surveys) - Analogies and differences between Six Sigma and Quality Management	- DMAIC e DMADV not widen - Final model could be applied with difficulty to some enterprises

L.O.Jenicke, A.Kumar, M.C.Holmes, The TQM Journal, Vol.20 No.5 pp.453-462	<ul style="list-style-type: none"> - Case study - Every DMAIC phase is illustrated in detail 	<ul style="list-style-type: none"> - Limited application to the academic environment - Not integrable with other QM methods - No applicability to enterprises
A.Thomas, R.Barton, P.Byard, Journal of Quality in Maintenance Engineering, Vol.14 No.3 pp.262-271	<ul style="list-style-type: none"> - Case study - Creation of a new integrated model - Every DMAIC phase is illustrated in detail 	<ul style="list-style-type: none"> - Enterprise size is not specified
J.L.Cheng, The TQM Journal, Vol.20 No.3 pp.182-195	<ul style="list-style-type: none"> - TQM tools are utilized for Six Sigma implementation - Case study 	<ul style="list-style-type: none"> - Methodology is just applied to one enterprise - Asian context could be different from the European, in which the model could not be applied
Q.Feng, C.M.Manuel, International Journal of Health Care Quality Assurance, Vol.21 No.6	<ul style="list-style-type: none"> - Empirical data (surveys) - Six Sigma applicability to healthcare sector 	<ul style="list-style-type: none"> - DMAIC not widen - US health system is different from systems of other countries - Impossibility of applying the model in other enterprises
R.Banuelas, C.Tennant, I.Tuersley, S.Tang, The TQM Magazine, Vol.18 No.5 pp.514-527	<ul style="list-style-type: none"> - Empirical data (pilot study) - Detailed list of a Black Belt essential characteristics 	<ul style="list-style-type: none"> - Description of Six Sigma methodology is not widen - Few attention to other roles (GB, MBB, Champions) - Study is focused only to some UK enterprises
J.Antony, A.Douglas, F.J.Antony, The TQM Magazine, Vol.19 No.3 pp.274-281	<ul style="list-style-type: none"> - Empirical data (surveys) - Description of main criteria for Six Sigma project selection 	<ul style="list-style-type: none"> - Few attention to Six Sigma methodology - Survey is only referred to UK enterprises

Table 2: Strength-Weakness Evaluation of the Articles regarding SS related to SMEs

Article	Strengths	Weaknesses
G.Wessel, P.Burcher, The TQM Magazine, Vol.16 No.4 (2004) pp.264-272	<ul style="list-style-type: none"> - SMEs strengths and weaknesses - Guidelines for SMEs to implement Six Sigma methodology 	<ul style="list-style-type: none"> - No case studies - No effective verify of guidelines
J.Antony, International Journal of Productivity and Performance Management, Vol.57 No.5 pp.420-423	<ul style="list-style-type: none"> - Six Sigma applicability both for large enterprises and SMEs. 	<ul style="list-style-type: none"> - Subjective opinions from the interviewed people. - No case studies
F.B. Green, J. Barbee, S. Cox, C. Rowlett, International Journal of Six Sigma and Competitive Advantage, Vol.2 No.2 pp.179-189	<ul style="list-style-type: none"> - Example of training program for Green Belts - Comparison between SMEs and large enterprises for implementation 	<ul style="list-style-type: none"> - Few attention to other roles - Methodology is not explained
A.Thomas, G.Lewis, International Journal of Six Sigma and Competitive Advantage, Vol.3 No.3 pp-228-247	<ul style="list-style-type: none"> - Integrated approach (case study) - Detailed application of DMAIC 	<ul style="list-style-type: none"> - Six sigma needs to lean on other methods in order to work correctly - Methodology could result complex if applied to other SMEs
A.Thomas, R.Barton, Journal of Manufacturing Technology Management, Vol.17 No.4 pp. 417-434	<ul style="list-style-type: none"> - Detailed illustration of DMAIC phases - Case study 	<ul style="list-style-type: none"> - Some methods could be too complex for other SMEs
M.Kumar, International Journal of Six Sigma and Competitive Advantage, Vol.3 No.4 pp.333-351	<ul style="list-style-type: none"> - Empirical data (surveys) - CSF (Critical Success Factors) illustration for Six Sigma methodology 	<ul style="list-style-type: none"> - No result about application utility - Methodology (DMAIC, DMADV) is not explicated - Case study relative to one enterprise only - Not applicable to services
J.Antony, M.Kumar, C.N.Madu, International Journal of Quality & Reliability Management, Vol.22 No.8 pp.860-874	<ul style="list-style-type: none"> - Empirical data (surveys) - SMEs strengths and weaknesses - CSF for Six Sigma application in SMEs 	<ul style="list-style-type: none"> - No effective applications in SMEs - Survey limited to UK
D.A.Desai, International Journal of Six Sigma and Competitive Advantage, Vol.2 No.1 pp.23-47	<ul style="list-style-type: none"> - Case study - Detailed illustration of DMAIC phases 	<ul style="list-style-type: none"> - DMADV is not mentioned - Methodology is applied only to one sector of considered enterprise
T.Fouweather, S.Coleman, A.Thomas, Proceedings 2nd International Conference on Intelligent Production Machines and Systems, I*PROMS , Cardiff University, July 2006	<ul style="list-style-type: none"> - Case study with study of Six Sigma single phases 	<ul style="list-style-type: none"> - Need of european funds to implement Six Sigma in SMEs - Case study is relative to two enterprises and it could be not applicable in other sectors

Table 3: Milestone Evaluation of the Articles regarding SS related to SMEs

Article	Simplicity	Applicability	Integrability	Developability
T.N. Goh, L.C. Tang, S.W. Lam, Y.F. Gao, 2006			√	
C.Doran, 2003	√			
P.Cronemyr, 2007	√			√
J.Antony, 2007			√	√
R.Basu, 2004	√		√	√
Y.H.Kwak, F.T.Anbari, 2006	√	√		
A.Y.T.Szeto, A.H.C.Tsang, 2005	√			
J.Ferng, A.D.F.Price, 2005	√		√	
R.Hoerl, 2004			√	√
R.G.Schroeder, K.Linderman, C.Liedtke, A.S.Choo, 2008			√	√
M.Kumar, J.Antony, C.N.Madu, D.C.Montgomery, S.H.Park, 2008		√	√	√
D.Näslund, 2008			√	
R.Banuelas, J.Antony, 2002	√			
S.Ingle, W.Roe, 2001	√			
J.Antony, 2004	√			√
I.D.Rajamanoharan, P.Collier, 2006	√		√	
J.L.Cheng, 2007			√	√
K.C.Kapur, Q.Feng, 2005			√	√
U.D. Kumar, D. Nowicki, J.E. Ramírez-Márquez, D. Verma, 2008			√	√
R.D. Snee, 2004	√			
J.Antony, R.Banuelas, 2002	√			√
M.Soković, D.Pavletić, S.Fakin, 2005				√
C.T.Su, C.J.Chou, 2008		√		√
C.Han, Y.H.Lee, 2002				√
K.Linderman, R.G.Schroeder, A.S.Choo, 2006				√
K.Linderman, R.G.Schroeder, S.Zaheer, A.S.Choo, 2003				√
Y.C.Ho, O.C.Chang, W.B.Wang, 2008			√	
X.Zu, L.D.Fredendall, T.J.Douglas, 2008			√	

L.O.Jenicke, A.Kumar, M.C.Holmes, 2008	√			√
A.Thomas, R.Barton, P.Byard, 2008	√		√	√
J.L.Cheng, 2008			√	√
Q.Feng, C.M.Manuel, 2008				√
R.Banuelas, C.Tennant, I.Tuersley, S.Tang, 2006	√			√
J.Antony, A.Douglas, F.J.Antony, 2007	√			√
G.Wessel, P.Burcher, 2004	√	√		
J.Antony, 2008		√		
F.B. Green, J. Barbee, S. Cox, C. Rowlett, 2006	√			√
A.Thomas, G.Lewis, 2007	√		√	√
A.Thomas, R.Barton, 2006	√		√	√
M.Kumar, 2007	√			
J.Antony, M.Kumar, C.N.Madu, 2005	√			
D.A.Desai, 2006	√			
T.Fouweather, S.Coleman, A.Thomas, 2006	√			√