A STRUCTURED REVIEW OF THE SIX SIGMA BELT SYSTEM

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Abstract

The Six Sigma methodology creates many possibilities for a radical improvement of process and product quality. Organizations that are embarking on the implementation of Six Sigma improvement initiatives need to overcome substantial barriers to ensure the effectiveness of the implemented approaches. In many cases, the implementation of improvement initiatives involves a significant investment in the establishment of a supporting infrastructure and training for the improvement initiatives. One of the most critical success factors for the implementation of Six Sigma is a strong organizational infrastructure led by different Six Sigma belts. Thus, the aim of the article is to provide a comprehensive overview of the current state of research regarding the Six Sigma belt system. A total of 62 journal papers about the Six Sigma belt system published during the period from 2000 to 2016 were selected for the analysis. The analysis reveals that the research regarding the Six Sigma belt system has so far been focused primarily on large manufacturing enterprises. The Six Sigma belt system has not been yet adequately studied within the context of smaller companies. Thus, the field on the application of Six Sigma in the small and medium enterprises provides valuable research opportunities. Furthermore, only 15 out of the 62 articles focus exclusively on the examination of the SS belt system rather than exploring general application of the Six Sigma methodology. However, these research papers only focused on Black Belts or Green Belts while neither the Master Black Belt nor Yellow Belt was a high priority in these studies.

Keywords: *Six Sigma, Belt system, Master Black Belt, Black Belt, Green Belt, Yellow Belt*

1 INTRODUCTION

Six Sigma (SS) is a disciplined and data-driven business improvement methodology that was developed to enhance the quality of processes with the objective of establishing an almost zero-defect quality strategy, thereby increasing customer satisfaction as well as improving financial results (Pyzdek, 2003). In recent years, various authors have criticized SS as "nothing but an old wine in a new bottle" since the methods originality seems to be under the Total Quality Management (TQM) umbrella (Kumar et al. 2008). However, there are some key aspects differentiating SS from TQM and other quality initiatives significantly as for example to follow structured methodologies (DMAIC and DFSS) during process improvements with focus on financial results, the use of specific metrics or the hierarchy of improvement specialists (Schroeder et al. 2008; Zu et al. 2008). This article explores the latter aspect of SS implementation, since the hierarchy of improvement specialists is a distinguishing feature of SS as compared to other improvement approaches.

In order to define hierarchy and career paths, SS borrows its terminology from the world of martial arts (Antony et al. 2005). Professionals trained in SS are distinguished by a colour of their belts; thus, belt system is an important ingredient of SS. Within this belt system ranks are determined based on their expertise, similar to karate students (Richardson, 2007). SS recognizes four classifications of trained professionals: Master Black Belt (MBB), Black Belt (BB), Green Belt (GB) and Yellow Belt (YB). For each rank, intensive differentiated training are designed in terms of knowledge and skills in statistical methods, project management,

process design, problem-solving techniques, leadership skills and other managerial skills (Pyzdek, 2003).

The literature is highlighting an extensive and massive organizational infrastructure as well as a strong training approach as one of the most important critical success factors for the implementation of SS in any organization (Timans et al. 2012; Douglas et al. 2015; Laux et al. 2015a and b). For this reason, the purpose of the proposed article is the classification of the literature published on the SS belt system with the goal to provide a comprehensive review of these studies. Based on the analysis, trends as well as future research proposals are presented. To achieve the proposed objectives, this research paper is divided into five chapters. After the introduction part in chapter 1, the theoretical fundamentals of SS (chapter 2), followed by a detailed overview of the research framework (chapter 3) are discussed. Chapter 4 presents the results and findings of the research. Finally, in chapter 5, the conclusion and future research proposals are presented.

2 THEORETICAL FUNDAMENTALS

Bill Smith from Motorola/USA developed SS during the mid-1980s. Based on the ideas of statistical process control, Motorola defined "Six Sigma" as 3.4 defects per million opportunities in a given production process. Sigma (σ) is used to represent the variation (standard deviation) of a process mean. "Six" means that the distance between the mean and the critical tolerance limits shall be 6 standard deviations constantly (Arnheiter and Maleyeff, 2005; Pyzdek, 2003). Furthermore, SS is also being widely recognized as an effective leadership development tool. After 1995, SS was enhanced by General Electric as a business strategy used to improve business profitability. It was initially applied in the manufacturing sector but has then spanned over service, financial, healthcare and public sectors (Coronado and Antony, 2002). In 2003, LSS was established as part of the evolution of SS. It is the combination of Lean Management and SS which are the most popular business strategies for enabling continuous improvement and improved bottom-line results (Albliwi et al. 2015). This combination is achieved by merging tools and principles to overcome the weaknesses while bringing out the advantages of both programs. Lean focuses on removing all types of waste from the process (the efficiency issue) while SS concentrates on controlling the process statistically and reducing variation from the process (the effectiveness issue). The phrase "Lean Six Sigma" is therefore used to describe the integration of both these approaches into a comprehensive management system (Arnheiter and Maleyeff, 2005).

To produce the expected results, organizational roles and responsibilities that lead, deploy and implement SS must be clearly defined and aligned. As already mentioned, SS creates a hierarchy of process specialists which is also known as the belt system or the belt hierarchy. It consists of four main levels. Table 1 presents the minimum competencies of the SS belt roles according to the International Standard for SS, BS ISO 13053-1 (BSI, 2011).

Tab. 1 – Competencies for Six Sigma personnel. Source: British Standards Institute 2011

Competency/Skills	Master Black Belt	Black Belt	Green Belt	Yellow Belt
Practical problem solving skills	Highest level of availability	Highest level of availability	Highest level of availability	Basic competence
Six Sigma tools knowledge	Highest level of availability	Highest level of availability	Proficient user	Proficient user
Statistical skills	Highest level of availability	Proficient user	Basic competence	Skill not needed

Individuals at the highest level of expertise in the SS methodology carry the title of "Master Black Belt" (MBB). They are certified experts who lead the SS methodology implementation, develop training materials and teach, coach and mentor the lower-level BBs and GBs. MBBs undergo BB training, approximately four weeks of SS training over a four-month period, plus two weeks of additional training on mentoring SS projects (Montgomery and Woodall, 2008). BBs typically work on implementing and leading strategic, large, high-impact process improvement projects with the DMAIC methodology that might take 4-6 months to complete (Montgomery and Woodall, 2008; Coronado and Antony, 2002). They fall in the middle of the "Belt Hierarchy" and are the linkage between GBs and MBBs. Consequently, they are the driving force and play a critical role in the organization (Black and McGlashan, 2006). The importance of the BB level has been highlighted in many published articles and textbooks. Training to become a BB includes intensive rigorous training in analytical tools and their application for four weeks and is in most cases combined with a project or exam (Montgomery and Woodall, 2008). It is generally recognized that it is more effective to have full-time MBB and BB positions, meaning that 100% of their time and energy is dedicated to SS endeavours within the company. GBs are experts who integrate SS into their daily job duties and have been trained often 1 or 2 weeks within a two-month period in the SS DMAIC (Define – Measure – Analyse – Improve – Control) problem-solving methodology as well as in basic statistical tools. Additionally, GBs should complete their education with a project (Montgomery and Woodall, 2008). Since the projects are running along their other job responsibilities, GBs typically work part-time for SS projects (Coronado and Antony, 2002; Montgomery and Woodall, 2008) or shall spend at least 30 percent of their time working toward SS initiative projects (Aboelmaged, 2010). The specialized training and education on statistical methods and other quality tools equip BBs and GBs to function as team leaders and technical problem solvers (Montgomery and Woodall, 2008). Due to the growth of SS application coupled with the proliferation of consultancy and training companies, it was found that it is equally important to have a large group of employees trained in basic SS tools in addition to trained mentors. The SS specialists that acquired this basic training level are named "Yellow Belts" (YB). In the industry, they are often used to point out employees that take up roles in SS projects along their other job responsibilities. YBs should understand and work within the SS culture but are not integral to its success (Chakrabarty and Chuan, 2009). In addition to the improvement specialists, SS roles at the higher management level are also required. They must have basic SS knowledge and support the SS program. Sponsors should be responsible for the overall initiative while Champions create the organization´s strategic improvement plans, identify the right projects and ensure the availability of resources for training and projects (Pyzdek, 2003).

3 RESEARCH FRAMEWORK

The paper focuses on research findings concerning the SS belt system structure and provides an overview of the actual state of research and makes future research proposals. The research applies a systematic literature review to respond to the research objectives. According to Okoli and Schabram (2010), a systematic literature review is "a systematic, explicit, comprehensive and reproducible method for identifying, evaluating, and synthesizing the existing body of completed and recorded work produced by researchers, scholars, and practitioners". For the proposed systematic literature review, peer-reviewed journal papers from academic databases have been taken into consideration since academics mainly use articles of the highest level of research findings to obtain information and to disseminate their own research findings. Therefore, information from editorials, news reports, textbooks and conference papers were not included in this study. Multiple high-quality online journal databases from the academic publishers, including ProQuest, Scopus, EmeraldInsight, Inderscience, and Taylor & Francis

were selected and searched to provide a comprehensive bibliography. These databases provide online access to complete research texts and abstracts of multiple peer-reviewed articles. The following search strings were used to identify the research articles of interest: [(Lean Six Sigma) or (Six Sigma) AND (Belt system) OR (Belt hierarchy) AND (Black Belt) OR (Green Belt) OR (Yellow Belt)]. The end of 2016 was selected as the cut-off date and it starts with articles from the year 2000. These criteria ensure a comprehensive set of high-quality, peer-reviewed articles. The selected articles were carefully reviewed and comprehensive data was collected in order to produce the following classification framework: (a) number of articles per year with respective researcher names, (b) application sector and organization size, (c) authors country and research country, (d) journal types with released number of articles, and (e) articles with the term „Belt" in the title, their research focus as well as research methods.

4 RESULTS AND DISCUSSION

After reviewing the current literature, 62 journal papers published between the years 2000 until 2016 were selected for this analysis. These papers focused on findings regarding the SS belt system (see table 2). Half of the articles were published between 2006 and 2010. The year 2006 marks the highest number of publications with a total of 13 released articles, followed by 8 publications in 2008. Hahn et al. (2000) and Henderson and Evans (2000) were the first to include observations about SS belts in an article while Antony and Karaminas (2016) and Marzagão and Carvalho (2016) were the last researchers to do so.

Tab. 2 – Overview of publications per year and author. Source: own research

Year	No. of articles	Authors
2000	2	Hahn et al.; Henderson and Evans
2001	3	Hoerl et al.; Ingle and Roe; Klefsjo et al.
2002	3	Coronado and Antony; Rasis et al. (a) and (b)
2003	2	Byrne; Linderman et al.
2004	4	Antony, J.; Haikonen et al.; Motwani et al.; Wessel and Burcher
2005	2	Antony et al.; Gowen and Tallon
2006	13	Andersson et al.; Bendell; Black and McGlashan; Black and Revere; Buch and Tolentino (a); Buch and Tolentino (b); Green; Green et al.; Johnson et al. (a) and (b); Lee-Mortimer; Linderman et al.; Kwak and Anbari
2007	4	Antony et al. (a) and (b); Pandey; Savolainen and Haikonen
2008	8	Antony et al.; Antony; Feng and Manuel; Ho et al.; Kumar et al.; Montgomery and Woodall; Schroeder et al.; Zu et al.
2009	1	Cauchick and Marcos
2010	5	Aboelmaged; Hagen; Moosa and Sajid; Pulakanam and Voges; Snee
2011	3	Kumar et al.; Leyendecker et al.
2012	4	Antony; Hilton and Sohal; Timans et al.; Zhang et al.; Laureani and Antony;
2014	2	Monteiro de Carvalho et al; Krueger et al;
2015	5	Douglas et al.; de Jesus et al.; Laux et al. (a) and (b)
2016	2	Antony and Karaminas; Marzagão and Carvalho

Overall, 38 of the 62 articles placed their focused on an application sector. Out of these 38 articles, 34 papers concentrated on the manufacturing industry whereas the service industry was looked at in four papers. Organization sizes were considered in 46 papers, however, most articles related their findings to large industries. This is the case for a total of 36 research papers while only 10 articles studied small and medium-sized enterprises. Figure 1 shows the respective journals that published at least two or more articles about this research field. The highest number of articles was released in the TQM journal, followed by the Journal of Quality Engineering and Journal of Quality & Reliability Management both of which published five articles each. The Journal of Operations Management published four articles.

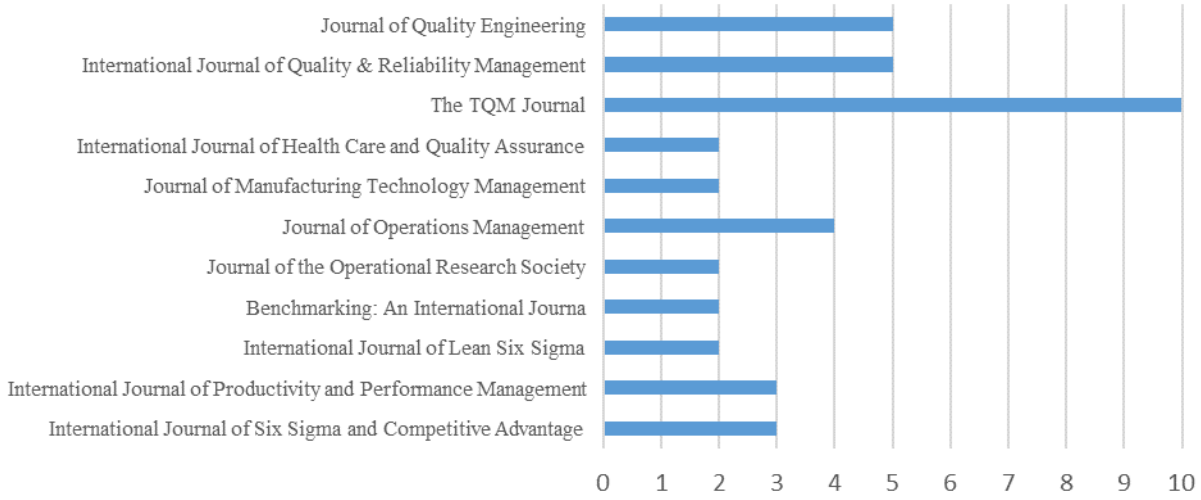

Fig. 1 – Number of published articles per journal. Source: own research

Considering all first authors as well as their co-authors, a total of 143 researchers contributed to the selected 62 articles (see figure 2). Almost half of all authors come from the USA. This also leads to the fact that most of the studies were conducted with US companies and experts. 40 papers focused their research on a specific country. The global distribution of the SS belt research demonstrates that 18 studies were conducted in the USA, followed by Asian countries (5 studies), the UK (6 studies) and the rest of Europe (6 studies) (figure 3). The second largest share of authors which makes almost 25% comes from the UK (see figure 2). This also includes Jiju Antony of the University of Strathclyde in Glasgow who is the most published researcher in this research field. Overall, he contributed to 15 research papers. He is the lead author of five papers, and a single author of three papers and a co-author of three more papers.

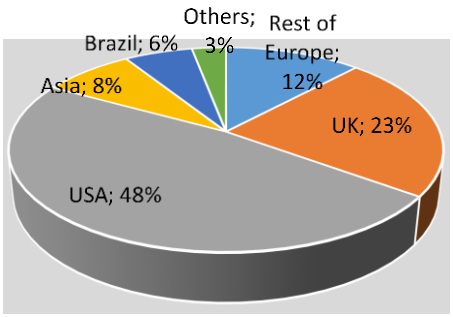

Fig. 2 - Distribution of Six Sigma belt sytem authors. Source: own research

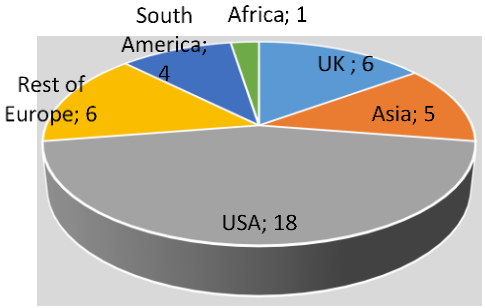

Fig. 3 - Distribution of Six Sigma belt system research countries. Source: own research

In total, 15 articles (almost 25%) have the term “Belt” in their titles, which means that the primary focus of these articles was the examination of the SS belt system (see table 3).

Tab. 3 – Literature overview about the Six Sigma belt system. Source: own research

Author and year	**Author country**	**Research focus**	**Research method**	**Journal**
Hoerl et al. (2001)	USA	BB training curriculum	Literature Review	Journal of Quality Technology
Ingle and Roe (2001)	Ireland	BB implementation	Review	The TQM Magazine
Rasis et al. (2002a)	USA	Structuring of a GB project	Case study	Journal of Quality Engineering
Rasis et al. (2002b)	USA	Structuring of a GB project	Case study	Journal of Quality Engineering

Black and McGlashan (2006)	USA	BB characteristics	Empirical study	International Journal of Six Sigma and Competitive Advantage
Green (2006)	USA	GB overview: projects, benefits, training	Empirical study	International Journal of Six Sigma and Competitive Advantage
Green et al. (2006)	USA	Implementation of SS in small companies with focus on Green Belts	Case study	International Journal of Six Sigma and Competitive Advantage
Johnson et al. (2006a)	USA	Structuring of a BB project	Case study	Journal of Quality Engineering
Johnson et al. (2006b)	USA	Structuring of a BB project	Case study	Journal of Quality Engineering
Antony et al. (2007)	UK	BB characteristics	Empirical study	The TQM Magazine
Ho et al. (2008)	Taiwan	Key success factors for GB projects	Empirical study	Journal of Air Transport Management
Hagen (2010)	USA	Impact of BB coaching expertise on project management outcomes	Empirical study	The Quality Management Journal
Laux et al. (2015a)	USA	Barriers for completion of GB projects	Empirical study	International Journal of Lean Six Sigma
Laux et al. (2015b)	USA	Planned GB project planning versus actual duration	Literature Review	Journal of Technology, Management, and Applied Engineering
Antony and Karaminas (2016)	UK	BB roles/responsibilities and skills	Empirical study	International Journal of Quality & Reliability Management

Seven articles are empirical studies, five articles are case studies and the remaining ones are literature reviews. The majority of the papers were published until 2010. Only three papers were published at a later point. Eight papers are focused exclusively on the BB. These are from the following researchers: Hoerl et al. 2001; Ingle and Roe, 2001; Black and McGlashan, 2006; Antony et al. 2007; Antony and Karaminas, 2016; Johnson et al. 2006 a. In his study Hoerl et al. (2001) developed a BB curriculum and compared this with the General Electric curriculum model. It was found that the General Electric model is mainly applicable to processes within financial organizations, general business operations and e-commerce processes while the model proposed by Hoerl et al. (2001) is mainly oriented on manufacturing organizations and focuses on explaining the use of certain tools and their integration through the project approach. Ingle and Roe (2001) compared the different implementation strategies of BB programs used in Motorola and GE. The authors concluded that the GE program has a more structured and intensive approach to train BBs in a shorter period of time which leads to a greater number of accredited BBs as compared to Motorola approach. Furthermore, they warn explicitly about the dangers of focusing mainly on metrics than on the mission in BB training, since some employees become BBs solely to benefit from promotion opportunities. The researchers Black and McGlashan (2006), Antony et al. (2007) as well as Antony and Karaminas (2016) conducted empirical studies to analyse BB characteristics. Black and McGlashan (2006) surveyed companies in a wide variety of industries in the USA, Antony et al. (2007) conducted their survey with UK manufacturing organizations and the respondents of Antony and Karaminas (2016) study came from 14 different countries whereby the majority was from India and the UK. The conclusion of these studies is that several characteristics are more essential than others. The key attributes include effective communicators, change agents, customer advocators, team builders, personnel with a results-driven mind-set and positive thinkers, etc. Another empirical study was carried out by Hagen (2010) who investigated the impact of BB's coaching expertise on project management outcomes within SS programs by collecting data of 140 BBs and 176 team members from six organizations in the USA. The results showed that the BB coaching expertise has a positive relation to the project performance. With regard to BB case studies, Johnson et al. (2006a; 2006b) published two papers focused on demonstrating the

application of the DMAIC process at BB level with the intention to provide the reader with an approach on how to structure a BB project and on how to use this model as an excellent practice example for other similar projects in future.

Beside the papers focusing on BBs, the other seven papers are taking the lesser-trained GBs into consideration. These are from the following researchers: Rasis et al. (2002a; 2002b), Green et al. (2006), Green (2006), Laux et al. (2015a; 2015b). There were also case studies carried out on this subject. Similar to the article of Johnson et al. (2006a; 2006b), Rasis et al. (2002a; 2002b) published two papers presenting an application of the DMAIC process at GB level in order to provide the readers with a profitable learning experience. In another case study, Green et al. (2006) present an approach of implementing an effective quality improvement program in a small manufacturing company by using widespread training of GBs. The employees had to participate in a training program with approximately 24 hours of classroom instruction. In addition, they also had to complete a GB project within 12 to 18 months for which they were receiving a compensation through a reward after successful graduation. During the project they were mentored by BBs. Furthermore, the certified GBs were expected to complete an additional GB project per year during their regular job assignments to maintain the certification. Since the project timeline was fixed for one year, the dedicated time for GB projects remained low (around 2-3% of the working time). Nevertheless, the duration of the project (12 months) as well as the data collection and team direction were identified as the main project barriers. As a consequence, GB projects should be designed with a shorter duration in the future. This can be achieved by adopting more lean-oriented project scopes and selecting the projects based on strategic company targets through a balanced scorecard. Green (2006) also compared the actual GBs performance in five companies against the intensity of their GB training and project duration by using structured in-depth interviews and surveys of 14 individuals. It was noted that trainings vary considerably from a few days to up to several weeks, sometimes with strong focus on classroom training and sometimes electronic-based training. Moreover, the GB project durations varied considerably from three months to up to two years, with an average of nine months which greatly exceeds the recommended duration. As common barriers emerged lack of data, unclear goals, and improper scopes and especially less time due to regular working duties. A similar study was conducted by Laux et al. (2015a) who identified barriers for GB project completions utilizing critical success factors through a survey of 18 accredited GB practitioners from a single global US manufacturing enterprise. The significant factors that contributed to a lack of GB project completion were identified as wrong project selection as well as poor project management and leadership skills. The primary factors noted by the GBs themselves were priority conflicts between SS and functional duties, time constraints and a lack of applying project management and SS tools. In addition to this study, Laux et al. (2015b) researched the timeliness of completed GB projects based on the data of the same company mentioned above. The results of this study reveal that the actual duration of the DMAIC phases of the various projects differ significantly from the planned duration. Nearly 50% of the projects took 56 days longer than planned which shows a very low process excellence. A higher focus on project management with a classified project portfolio management and initial project planning ought to improve the timeliness of GB projects. Finally, an empirical study with a similar research objective was carried out by Ho et al. (2008). This study explored key success factors that increase GB project completions by using a survey of certified GBs within a single Asian aircraft service maintenance company. The importance of the following success factors critical to GB projects became apparent: top management commitment and participation, business strategy tied to customer demands, use of data that is easily obtainable, investment of essential resources in the form of time for project completion and reward system for employees.

5 SUMMARY AND CONCLUSION

This paper´s objective is to provide a comprehensive overview about the current research status of the Six Sigma belt system. For this review, 62 research papers from the years 2000 to 2016 were considered. Most of these papers include observations or recommendations regarding a SS belt system structure. The research aimed to provide an overview on the number of articles published per year, their authors and the countries in which the research was conducted, the number of articles published in different journal types as well as the focus of the research and the different research methods that were conducted. 15 out of the 62 analysed articles focused specifically on the investigation of the SS belt system. These articles include empirical studies, case studies as well as reviews in which primarily the roles and characteristics, barriers and success factors, training and project structure of the BB and the lesser trained GB level were examined. The MBB as well as YB level were not the focus of any of the papers that have been published until now. Based on this finding, it can be concluded that both of these belt levels should receive more attention in the future research since both play very important roles in the SS organization.

Furthermore, it could be found that the research of the SS belt system was mainly conducted with focus on large manufacturing industries. This indicates that the SS belt system for smaller companies has not yet been adequately studied and provides a field of the future research opportunities. Moreover, the authors are mainly based in the US or UK. For this reason, most research was conducted in these countries. This means that this research field has so far hardly been sufficiently explored in other regions. For this reason, further case studies, empirical studies and expert interviews about this research field ought to be conducted in different regions of the world in order to validate the current findings and recommendations and to determine a standard roadmap on how to implement a strong SS organizational infrastructure led by SS belt roles.

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