Deploying Six Sigma practices to General Electric subsidiaries in a developing economy

An empirical analysis

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Abstract

Purpose – The purpose of this paper is to investigate Six Sigma implementation in the subsidiaries of General Electric (GE) located in Brazil and to explore the role of the quality culture of headquarters in overcoming common obstacles to Six Sigma implementation reported by other studies.

Design/methodology/approach – An exploratory survey was the basis for gathering data for this study. A structured questionnaire was developed covering issues related to Six Sigma implementation, such as experienced benefits, main outcomes, and metrics adopted by companies. Data from eight GE subsidiaries were qualitatively analyzed. The findings were discussed in the light of other studies conducted in Brazil as well as in other developing countries in the context of the role of existing quality culture in overcoming barriers to Six Sigma implementation.

Findings – The findings revealed that Six Sigma at GE subsidiaries achieved better results in comparison with the results obtained by other Brazilian companies reported in the literature. GE quality culture aspects such as top management commitment, high investment in training, recognition schemes, and development of a well-planned infrastructure were identified as valuable to overcome common barriers to Six Sigma implementation. Moreover, the findings showed a strong alignment with the goals and practices of GE headquarters, which is an evidence of the quality culture that exists in GE and that allows all GE businesses achieve benefits with Six Sigma.

Originality/value – Since limited empirical research has been conducted concerning Six Sigma implementation in developing countries, this paper aspires to contribute to Six Sigma body of knowledge by illustrating the practices of a world benchmark corporation.

Keywords Six Sigma, Brazil, Developing countries, Quality management, General Electric

1. Introduction

Modern organizations are striving to apply appropriate strategies in order to improve their overall performance due to the increasing competition (Srinivasan et al., 2016). Six Sigma has been recognized as a powerful strategy to speed up improvements in product, service,
and all types of processes quality (Antony and Banuelas, 2002), and to enhance competitiveness (Cauchick Miguel et al., 2012).

In business terms, Six Sigma can be seen as a business improvement strategy to increase profitability, reduce quality costs, and improve operations efficiency and effectiveness in order to achieve customers’ expectations (Antony and Banuelas, 2002). Well-established organizations, such as General Electric (GE) and Sony, for instance, have demonstrated substantial financial returns due to the adoption of Six Sigma in different business processes (Patyal and Maddulety, 2015). Indeed, the emergence of Six Sigma has become one of the major developments in management practices (Azis and Osada, 2010).

Six Sigma research has attracted the attention of both practitioners and academicians (Aboelmaged, 2010), and the literature on the subject has considerably evolved in the last few years (Jones et al., 2010; Reosekar and Pohekar, 2014). There is a large number of tools and techniques within Six Sigma (Tjahjono et al., 2010), case studies of Six Sigma programs (Alsmadi et al., 2012; Brun, 2011; Prashar, 2016), and different critical factors for Six Sigma implementation have been explored in the literature (Antony et al., 2007; Ismyrlis and Moschidis, 2013). Although the literature has been evolving, the number of empirical studies on Six Sigma implementation is still limited (Patyal and Maddulety, 2015). Information derived from actual practices is necessary to enhance Six Sigma research, and more empirical studies still need to be carried out to enhance the construction of Six Sigma theory (Aboelmaged, 2010; Reosekar and Pohekar, 2014).

Furthermore, there is a limited amount of literature regarding Six Sigma practices in different organizational contexts (Patyal and Maddulety, 2015). The cultural context is, however, a critical aspect for Six Sigma implementation (Cronemyr et al., 2014; Sony and Naik, 2012). In fact, there are many factors that affect the success level of Six Sigma projects, and these factors vary among countries (Kuvvetli et al., 2016). The culture and business conditions of developing nations, for instance, are different in comparison with developed countries (Patyal and Maddulety, 2015). Many critical factors for Six Sigma deployment in developing countries have been reported by empirical studies, such as organizational infrastructure, cultural change, and lack of training (Aboelmaged, 2011; Douglas et al., 2015; Jesus et al., 2016). Differences in Six Sigma implementation in native company enterprises and transnational companies in developing countries have also been explored (e.g. Cheng, 2007). The previously cited authors’ findings revealed that lack of training and education is more critical in native companies than in transnational companies. Although some differences in Six Sigma implementation in different types of companies have been explored (Cheng, 2007), and it seems that each country has different success factors that have different importance level for Six Sigma projects (Kuvvetli et al., 2016), it is still necessary to investigate how organization’s culture profile influences Six Sigma deployment (Patyal and Maddulety, 2015). In fact, it seems that successful Six Sigma implementation is dependent on existing quality culture and quality maturity (Kuvvetli et al., 2016; Van Iwaarden et al., 2008). Organizational culture may differ between local and transnational enterprises (Cheng, 2007).

Actually, Six Sigma in developing countries has not being explored as much as in developed contexts (Alsmadi et al., 2012; Cauchick Miguel and Andrietta, 2010). Although a considerable amount of research about Six Sigma has been conducted in North America and US-based global companies such as GE and Motorola, only a few studies have been carried out in global companies outside the USA (Pisani et al., 2009; Tlapa et al., 2016). Given the globalization of many companies, it is still necessary to explore Six Sigma in the other parts of the world (Nonthaleerak and Hendry, 2006; Tlapa et al., 2016). In fact, multinational firms have an important role in the diffusion of Six Sigma (Wiele et al., 2010). The influence of the quality culture of multinational headquarters in Six Sigma implementation in its subsidiaries located in developing countries, however, was not fully explored in the literature.

Deploying Six Sigma practices to GE subsidiaries
In this sense, this paper aims to investigate the role of quality culture in the deployment of Six Sigma in companies located in developing countries. More specifically, the purpose is to explore how the existence of a well-structured quality culture in the headquarters may benefit the Six Sigma deployment in its subsidiaries in Brazil, so that they can contribute to overcome some common barriers faced by local companies when implementing Six Sigma in those contexts, as reported by other studies. In fact, given the differences in business climate in different countries, the success of Six Sigma might not be universal (Van Iwaarden et al., 2008). Additionally, the quality culture of headquarters may influence the Six Sigma deployment in other parts of the world, since the multinational headquarters act as a mechanism for diffusion of Six Sigma (Wiele et al., 2010), and it seems that organizations that already use Six Sigma may have a stronger quality culture (Davison and Al-Shaghana, 2007).

This study is focused on Six Sigma program in a group of GE companies that operate in Brazil. GE is one of the first and successful companies after Motorola implementing Six Sigma programs. GE adopted Six Sigma in a new way, extending it to every area of the organization (Brun, 2011). Latin America is one of the fastest-growing emerging markets for GE (General Electric, 2016); therefore, the analysis of Six Sigma practices in GE Brazil may be valuable for the Six Sigma empirical body of knowledge, since there is limited empirical research regarding Six Sigma implementation in subsidiaries of world-class companies around the world. Moreover, GE is well known for its quality culture, Six Sigma in GE is a major strategic initiative (Ingle and Roe, 2001), and it may be valuable to explore how the quality culture of a company like GE may benefit Six Sigma deployment in its subsidiaries. This is relevant especially in developing countries where it is still necessary to expand the knowledge about Six Sigma implementation and the critical success factors specific to the local or domestic challenges (Zulqarnain et al., 2013). Aspects such as the extent of Six Sigma implementation, main methods and tools, and Six Sigma training level were analyzed in order to understand better how the quality culture of GE is valuable to overcome barriers to Six Sigma implementation identified in other studies conducted in other companies around the country. Understanding how quality culture influences the implementation of Six Sigma regarding the main barriers reported by other studies may be valuable to inform management decisions regarding quality improvement and operating procedures when implementing Six Sigma in Brazil and other countries where similar barriers exist. Moreover, empirical research investigating Six Sigma implementation in Brazil is still scarce (Jesus et al., 2016) as well as in Latin America nations in general (Tlapa et al., 2016). Hence, the paper aims to offer contributions to the literature on this subject as well.

The remainder of this paper is structured as follows. Section 2 presents a brief literature review, addressing Six Sigma program and its diffusion in multinationals around the world, especially in developing countries. The main critical factors and obstacles for Six Sigma implementation in developing countries, including Brazil, were identified and summarized. Section 3 discusses the methods applied for gathering and analyzing data from the Brazilian GE subsidiaries. Section 4 presents the results and the findings regarding Six Sigma implementation in eight GE subsidiaries and quality culture aspects that contributed to overcome common barriers to Six Sigma deployment. Finally, conclusions are drawn in Section 5 concerning the usefulness and implications of this research, its limitations, and directions for future research.

2. Six Sigma program
Six Sigma is one of the last additions in the field of quality improvement and business process improvements methods (Ismyrlis and Moschidis, 2013). Many definitions for Six Sigma have been pointed out in the literature. Tjahjono et al. (2010) identified four
streams of thought of Six Sigma from the literature. The first stream defines Six Sigma as a set of statistical tools adopted within the quality management to construct a framework for process improvement. The second one defines Six Sigma as a philosophy of management. The third stream considers Six Sigma as a business culture, a top-down methodology in which the success of Six Sigma does not rely only on statistical tools and techniques but also on the commitment of the top management to ensure the involvement of organization staff. The fourth definition refers to Six Sigma as an analysis methodology that uses scientific knowledge.

Schroeder et al. (2008) identified core advantages of Six Sigma over quality philosophies, which involves the focus on financial and business results, use of a structured method for process improvement or new product introduction, use of specific metrics, critical-to-quality and use of a significant number of full-time improvement specialists (Reosekar and Pohekar, 2014; Schroeder et al., 2008). In addition to these advantages, when implemented correctly, Six Sigma can also bring many benefits for all types of organizations, including performance improvements and financial returns (Antony and Banuelas, 2002), transformation of the organizational culture, improved cross-functional teamwork, effective management decisions, reduced cost of poor quality, increased employee morale (Antony et al., 2007), improvements in consumer satisfaction (Henderson and Evans, 2000), and enhanced organizational learning (Jones et al., 2010).

Nevertheless, to achieve those benefits with Six Sigma, key factors have been discussed in the literature as essential. The management involvement and commitment have been recognized as the most important aspect of Six Sigma implementation (Coronado and Antony, 2002). People in the highest level of the organization must drive Six Sigma; a good example is GE’s former CEO Jack Welch’s involvement. Six Sigma also involves a substantial change in organization structure and infrastructure (Antony et al., 2007). In addition to top management, there also needs to be an effective organizational infrastructure in place to support the Six Sigma introduction and development program (Coronado and Antony, 2002). Moreover, a successful introduction and implementation of Six Sigma requires adjustments to the culture of the organization and a change in the attitudes of the employees (Coronado and Antony, 2002). Six Sigma also has a structured role system (the belt system) that involves four roles (Champions, Master Black Belts, Black Belts, and Green Belts) and has a requirement of appropriate and continuous training of the employees involved in its implementation (Ismyrlis and Moschidis, 2013). Training allows people to understand the fundamentals, tools, and techniques of Six Sigma, which is essential for successful implementation (Kuvvetli et al., 2016).

Moreover, Six Sigma cannot be treated as a stand-alone activity; it requires adherence to a whole philosophy rather than just the use of tools and techniques (Coronado and Antony, 2002). The tools and techniques may not be applied isolated, but they are also critical for successful Six Sigma implementation, and the workforce should be armed with the proper tools to successfully approach and complete Six Sigma projects (Henderson and Evans, 2000). Many publications suggest a step-by-step approach or road map using define, measure, analyze, improve, and control (DMAIC), define, measure, analyze, design, and verify (DMADV), and the design for Six Sigma (DFSS) methods as the most common methodologies to implement Six Sigma (Tjahjono et al., 2010).

Other critical success factors for Six Sigma implementation in different organizations have been pointed out in the literature. Cultural aspects, however, are seldom mentioned as a success factor in implementing Six Sigma (Cronemyr et al., 2014). Although Six Sigma is a structured method, each company has to adapt it to the culture of the specific company and country (Cronemyr et al., 2014). This is the case of Six Sigma practices diffusion from multinational headquarters to subsidiaries, as discussed next.
2.1 Six Sigma practices diffusion in multinationals around the world

Although Six Sigma has become the focus of business for a quarter of a century, organizations in countries outside the USA have also implemented Six Sigma (Pisani et al., 2009), in the process of transferring the best practices within multinational subsidiaries. However, Six Sigma has not gained the same attention in developing countries, and little academic research has been carried out to the extent of Six Sigma implementation in these contexts (Alsmadi et al., 2012). Actually, empirical research that explores how Six Sigma was implemented and the main aspects of the programs in world-class companies’ subsidiaries are still scarce.

The literature describes many mechanisms related to practices diffusion and knowledge transfer in multinational companies (Boscari et al., 2016). In the Six Sigma literature, Wiele et al. (2010) explored the role of multinational companies in the global diffusion of Six Sigma as a management practice. A theoretical framework was outlined by the previously cited authors, detailing the stages of diffusion as Six Sigma through the multinational supply chain. Undeniably, Six Sigma is adopted first by multinational headquarters and subsequently spread throughout the firms’ subsidiaries, until the entire organization has adopted, which allows the practice to spread across borders and rapidly grow in its utilization (Wiele et al., 2010).

Although some publications have compared Six Sigma implementation in multinationals in developed economies (e.g. van Iwaarden et al., 2008), in the context of developing countries, empirical studies are still limited. The cultural fit has been related as a major barrier to Six Sigma implementation (Lertwattanapongchai and Swierczek, 2014). The findings of the previously cited authors regarding Lean Six Sigma deployment in one subsidiary in Thailand demonstrated that the program was perceived as a headquarters initiative and it was not locally endorsed. The previously cited authors also pointed out that successful implementation of Six Sigma in multinational companies located in Thailand is related to a strong recognition of the organizational change process communication, top management leadership, and commitment.

Other studies exploring success factors and barriers to Six Sigma implementation in developing countries have also been carried out. Sivakumar and Muthusamy (2011) explored the critical factors for Six Sigma implementation in multinationals companies located in Malaysia. Their findings revealed that training and awareness, management commitment, Six Sigma level of absorption into the organization, and project assessment of all stages of implementation are necessary to successful implementation. Santos and Martins (2008) investigated Six Sigma implementation in four subsidiaries of multinational companies located in Brazil, and their findings revealed that the successful program implementation is related to management support, training, culture dissemination, strategic alignment, and dissemination of results. Jayaraman et al. (2012) investigated the critical factors for Lean Six Sigma implementation in six multinationals electronic manufacturing services industries in Malaysia. Management commitment, training, use of dashboards containing the progress updates of the projects, frequent communication, and assessment of the results were found to be significant for Lean Six Sigma implementation.

Kuvvetli et al. (2016) pointed out that although some success factors for Six Sigma implementation are evaluated as a whole, it seems that every country has its success factors, and factors such as top management support and organizational infrastructure which are in general valid in most countries have a different effect on the success. Studies conducted in developing countries including Brazil have shown that common obstacles for Six Sigma implementation in local companies are related to lack of infrastructure, training, and cultural change necessary to implement the program (Cauchick Miguel and Carvalho, 2014; Jesus et al., 2016). In addition, different types of companies (native country and transnational companies) face different obstacles when implementing Six Sigma, and organization
culture regarding Six Sigma systems differs between native and transnational companies (Cheng, 2007).

Moreover, the findings of the study conducted by Van Iwaarden et al. (2008) suggest that successful Six Sigma implementation is related to quality culture aspects of organizations such as top management commitment, the ability to show successful projects, high investment in training, and high investment in management time. Thus, the existence of quality culture may foster Six Sigma implementation process and help to overcome the implementation obstacles, because the existence of quality experience is very important for the success of Six Sigma projects (Kuvvetli et al., 2016). The proposition explored in this study is that the existence of quality culture in multinational companies such as GE may contribute to overcome common obstacles when deploying Six Sigma in its subsidiaries in developing countries, such as those identified for Six Sigma implementation in local companies that do not have a well-defined quality culture. Next section outlines the research procedures for this investigation.

3. Research design

An exploratory survey was conducted in this study (see Cauchick Miguel and Andrietta, 2010). This kind of survey is valuable when the purpose is to gain preliminary insight on a topic and to provide preliminary evidence of association among concepts, as established by Forza (2002). This paper analyzed the implementation of Six Sigma in subsidiaries of a world-class company, considering how the quality culture of the headquarters would be valuable to overcome common obstacles faced by local companies when implementing Six Sigma, as already reported in the literature.

Among other companies, GE subsidiaries were identified using multiple sources, including professional magazines on quality management subject, structured internet search, and data from consulting companies that offer services in Six Sigma. Twelve GE subsidiaries were identified, and eight of them agreed to answer the survey instrument. They were then considered as the units of analysis in this study, within the total of survey responses. The companies also agreed that they could be nominated as GE subsidiaries for this particular work. Figure 1 provides an overview of the research process adopted, based on survey guidelines proposed by Forza (2002).

A structured questionnaire was designed for data collection. The survey instrument was developed based on Six Sigma literature and mostly included closed-end questions. The questionnaire was structured to start with general questions and end with more specific ones. The questions were divided into three blocks: general aspects of the company (6 questions), Six Sigma program implementation (21 questions), and Six Sigma metrics and methods (6 questions). Table I summarizes the survey instrument blocks.

Instructions on how to fill out the questionnaire were provided. Attempts were also made to explain the terms and to limit assumptions about the knowledge of the audience, by providing descriptive notes about the terms when appropriate.

A pilot test of the questionnaire was conducted in two rounds. First, it was posted to a Master Black Belt from a large company located in Brazil for a general revision. Afterward, the questionnaire was sent to four companies in order to check it concerning its form and contents. The questionnaire was then improved according to respondents’ recommendations on both rounds. Then, a final instrument was posted.

The questionnaire response data were then analyzed. Aspects related to the Six Sigma implementation (e.g. employees training and approach for project selection), successful implementation aspects when compared to other companies that implemented the program in the country, and some experienced benefits with Six Sigma implementation were examined in the light of the literature. Previous studies conducted in the country (e.g. Cauchick Miguel and Carvalho, 2014; Carvalho et al., 2014; Jesus et al., 2016) and in other...
developing countries were identified in the literature and the obstacles and critical factors found out by them were compared with the Six Sigma implementation process in GE. Aspects related to GE quality culture were identified to overcome the obstacles reported by other studies conducted in Brazil and other developing countries. The main survey results and discussion are presented next.

4. Findings and discussion
The main findings are presented in this section according to the questions of the survey instrument. It starts with the general profile of the companies, followed by Six Sigma program implementation, main results, and metrics. As requested by the company managers, the subsidiaries are not nominated.

4.1 Companies general information and characteristics
GE subsidiaries survey participants operate in Brazil in the following businesses: aircraft, renewable energy, healthcare, plastics, industrial solutions, lighting, and oil and gas.

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1. Company data</td>
<td>Sector, number of employees, annual revenue, market share</td>
</tr>
<tr>
<td>2. Six Sigma program</td>
<td>Program history in the organization, personnel structure and training, number, scope and criteria for selecting the projects, and the main results achieved</td>
</tr>
<tr>
<td>3. Methods and metrics in the Six Sigma program</td>
<td>Analysis of the Six Sigma methods and metrics applied by the companies</td>
</tr>
</tbody>
</table>

Figure 1. Research process structure

![Research process structure diagram]
All respondents are located in the southeast region of Brazil. Five of the eight companies can be categorized as large-sized companies (more than 500 employees), and three as medium-sized companies (between 51 and 500 employees), according to the company size classification proposed by the Brazilian National Quality Award foundation. Regarding the annual revenues, it varied from US$30 to 210 million. Concerning the market share, the companies classified themselves as follows: one as a market leader, two of them as having a market share from 50 to 80 percent, two other subsidiaries with a market share of 30 and 50 percent, two firms have a market share under 30 percent in the business activity they operate, and one did not provide this information.

It is evident that Six Sigma is a corporate initiative widespread among all GE businesses. Six Sigma became part of GE culture around the world to ensure that there are no problems with any product or service that the company provides, as already pointed out by Henderson and Evans (2000). Other aspects of Six Sigma program implementation are presented next.

4.2 Implementation of Six Sigma program
Results showed that the first time the program was introduced in a subsidiary that operates in Brazil was in 1996, one year after Six Sigma implementation at the GE in the USA in 1995 (Henderson and Evans, 2000). The remaining of the subsidiaries implemented the program in the following three years until 1998. This aspect is aligned with Wiele et al. (2010), which pointed out that that diffusion occurs along the supply chain from headquarters to subsidiaries, and there is an adoption lag (as noticed in the GE subsidiaries in Brazil where the program started one year later). This aspect is also in accordance with Henderson and Evans (2000), which pointed out that GE in the USA promptly spreads the program to other corporate units around the world.

Seven of the eight companies stated that the need to implement Six Sigma came from the corporate headquarters, which supported the whole process. In another survey with Brazilian companies by Carvalho et al. (2014), they also identified that the headquarters decision to implement Six Sigma was a core driver for the program beginning in the country. The previously cited authors pointed out that the majority of surveyed companies, however, reported contracting outside consultants to facilitate the implementation of Six Sigma. Seven firms in that survey stated that the completion was fully supported by the corporate headquarter. This shows that the cultural change was supported by the headquarter. Seven subsidiaries pointed out that the Six Sigma program was implemented in a way to fit companies culture. In fact, Jesus et al. (2016) found out that cultural change to implement Six Sigma was not given the importance necessary in the companies around the country. The support of GE headquarters was, in fact, an important aspect to deploy Six Sigma in its subsidiaries in Brazil and it is related to GE culture. In general, in major global organizations, Six Sigma and other initiatives are implemented as big standardized programs where there is little room for adaptations (Cronemyr et al., 2014), but in GE subsidiaries Six Sigma was adapted to work as well as possible.

In addition, when asked about in which areas within a company started to implement Six Sigma, almost all subsidiaries answered that the Six Sigma initiated by the top management, and one of the companies reported that the quality area was the responsible for the beginning of the program. This is also an evidence of the top management commitment to the Six Sigma implementation in the Brazilian GE firms. Six Sigma is a top-down methodology, which means that the attempt for improvement begins from top management. This is one of the most important factors for Six Sigma implementation identified in other studies carried out in developing countries, as mentioned earlier, and clearly supported by the GE subsidiaries. In fact, management commitment is one of the elements of a quality culture (Davison and Al-Shaghana, 2007).
Although Six Sigma started at specific companies’ areas, it was also inquired about the other areas of the company that the Six Sigma program has been effectively applied. Data revealed that this occurred in all areas throughout the company, once again in accordance with Henderson and Evans (2000). Indeed, previous studies pointed out that the Six Sigma was implemented in all sectors of GE, i.e. in manufacturing, product development, customer service, accounting, etc. (Henderson and Evans, 2000; Ingle and Roe, 2001). On the other hand, in the broad results of the survey by Cauchick Miguel and Andrietta (2010), they pointed out that the program was implemented throughout the company in only 70 percent of the respondents. Moreover, in another set of firms, Carvalho et al. (2014) showed that the majority of Six Sigma projects in companies operating in Brazil were concentrated in the manufacturing and financial areas.

Other studies in developed countries (e.g. van Iwaarden et al., 2008) also suggested that Six Sigma implementation in all company does not always occur. Those findings in the literature confirm that the implementation of Six Sigma across many company areas is a distinctive characteristic of Six Sigma at GE, so this may be related to GE quality culture. This was also observed as valuable to the cultural change necessary to implement Six Sigma across all areas of the company.

Regarding the investments in Six Sigma, regrettably, only four respondents answered that question. Table II shows the investments made by each firm in the period of Six Sigma implementation. Although some of the companies did not answer, in general, the respondents have invested from 0.01 to 0.05 percent of its revenues in the Six Sigma program. The investment in the program by the number of employees presented a similar pattern in two subsidiaries (U5 and U8), and U8 demonstrated superior performance. Although it is a medium-sized company (that employs around 180 employees), the investments in the Six Sigma program are equal or better than the large subsidiaries. In contrast, the U1 had a low investment value in the Six Sigma program, which may be justified by its reduced number of the Six Sigma projects.

Lack of resources has been reported as one of the main barriers to Six Sigma implementation in other studies conducted in developing countries (e.g. Aboelmaged, 2011). Carvalho et al. (2014) also suggested that in organizations in which Six Sigma was implemented as isolated packages, human and financial resources are dissipated. The quality culture of GE allowed specific investments in the program during its implementation, which contributed to avoiding competition for resources and supported the implementation process.

### 4.3 Selection of Six Sigma program experts

The survey also aimed to obtain information related to the staff selection and training, since success with Six Sigma is directly linked to the resources allocated to the program

<table>
<thead>
<tr>
<th>Subsidiaries</th>
<th>U1</th>
<th>U2</th>
<th>U3</th>
<th>U4</th>
<th>U5</th>
<th>U6</th>
<th>U7</th>
<th>U8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of employees</td>
<td>700</td>
<td>6,300</td>
<td>650</td>
<td>120</td>
<td>1,700</td>
<td>180</td>
<td>1,700</td>
<td>180</td>
</tr>
<tr>
<td>Annual revenues (US$ million)</td>
<td>30</td>
<td>–</td>
<td>210</td>
<td>35</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>60</td>
</tr>
<tr>
<td>Annual investments in the program (US$)</td>
<td>3,000</td>
<td>182,000</td>
<td>–</td>
<td>–</td>
<td>265,000</td>
<td>–</td>
<td>–</td>
<td>30,000</td>
</tr>
<tr>
<td>% of the annual revenues for the program</td>
<td>0.01</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>0.05</td>
</tr>
<tr>
<td>Program investments per number of employees (US$)</td>
<td>4</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>150</td>
<td>–</td>
<td>–</td>
<td>150</td>
</tr>
</tbody>
</table>

Table II.

Investments in the Six Sigma program implementation

Notes: *Data are related to the period when collected (not updated at the date of submission); \(^b\)the data provided by U2 for the investments in the program are related to the GE Global whereas the number of employees is related to the Brazilian subsidiary.
(van Iwaarden et al., 2008). The main criterion for selecting personnel in the Six Sigma program is the “career plan,” according to the respondents. Since it was a multiple-choice question, six companies also selected “indication” (by a manager, for instance), two firms selected “selection interview,” and one ticked the option “volunteering.” The adoption of the criteria for selecting employees is aligned with what is stated in the literature. Six Sigma requests organizations to carefully recruit and select potential employees in terms of their task-oriented skills, potential for working with a team, their dedication to quality, and their motivation and willingness to make improvements (Zu et al., 2008). Moreover, poor selection of candidates for belts training is a common failure in Six Sigma implementation (Alblivi et al., 2014).

Indeed, in GE, Black Belts and Master Black Belts are being identified as a primary source for future top leaders in the organization, and the selection of these professionals is crucial in GE (Ingle and Roe, 2001). This may explain why the main criterion for selecting staff in the Six Sigma program is the “career plan” in all firms. In addition, a robust company career plan may attract the best experts. People in GE are motivated from the very top level of management to take Black Belt positions, which allows for high selectivity of people going through the Black Belt roles (Hoerl, 2001). The involvement of organization’s key players is essential for successful implementation (Van Iwaarden et al., 2008). A Six Sigma program coordinator is a role often assumed by the quality manager that performs tasks such as monitoring ongoing projects, keeping the management committee informed, establishing channels for collecting ideas about possible projects, and coordinating training or employee recognition activities; however, this has received little attention in the literature (Grima et al., 2014). In the case of GE, all subsidiaries reported that they nominated a specific coordinator for the Six Sigma program.

Another main factor that rendered the implementation of Six Sigma difficult, as the availability of employees, was identified by another survey conducted in Brazil (Carvalho et al., 2014), and other developing countries. At GE, resources allocation to the program has been carefully considered, which is also an aspect of GE culture that contributed to the Six Sigma implementation in the subsidiaries under analysis. Results in the training process are addressed next.

### 4.4 Training of Six Sigma professionals

Training is part of the communication process to make sure that manager and employees apply and implement the Six Sigma techniques effectively (Yousefi and Hadi-Vencheh, 2016). As already mentioned, Six Sigma creates a hierarchy of process improvement specialists, known as “belt hierarchy” (Antony and Karaminas, 2016; Coronado and Antony, 2002; Zu et al., 2008). The professionals are allocated to each level according to their experience and also the training that they have received (Antony and Karaminas, 2016).

The survey asked about the number of employees involved in the Six Sigma program according to the belt hierarchy, the average training time applied by each company, and the dedication of each employee to the program. The results can be seen in Table III. The results revealed that seven subsidiaries have a certified Master Black Belt (one company did not answer the question), and all companies have at least 1 Black Belt and 50 Green Belts.

<table>
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<td>1,700</td>
<td>180</td>
<td>1,700</td>
<td>180</td>
</tr>
<tr>
<td>Number of employees per Master Black Belt</td>
<td>700</td>
<td>630</td>
<td>650</td>
<td>–</td>
<td>1,700</td>
<td>180</td>
<td>1,700</td>
<td>180</td>
</tr>
<tr>
<td>Number of employees per Black Belt</td>
<td>350</td>
<td>137</td>
<td>217</td>
<td>120</td>
<td>425</td>
<td>180</td>
<td>2,125</td>
<td>36</td>
</tr>
<tr>
<td>Number of employees per Green Belt</td>
<td>14</td>
<td>6.4</td>
<td>4.5</td>
<td>2.2</td>
<td>16.5</td>
<td>1.5</td>
<td>10.6</td>
<td>2.3</td>
</tr>
</tbody>
</table>

**Note:** Data are related to the period when collected.
The findings of GE subsidiaries are higher when comparing to the overall results by Cauchick Miguel and Andrietta (2010). The findings of Jesus et al. (2016) demonstrated that in fact, insufficient infrastructure regarding the number of Belts is common in other Brazilian companies, and this impacts negatively the cultural change necessary to Six Sigma implementation. The appropriate infrastructure existent in GE is also part of its quality culture, since training is a common element of quality culture (Davison and Al-Shaghaana, 2007), and surely contributed to successful Six Sigma implementation.

In addition, the numbers are also superior to empirical studies carried out in other developing countries. For instance, in a Lean Six Sigma survey in Africa (service and manufacturing organizations in East African), Douglas et al. (2015) revealed that the number of Green Belts in the organizations ranged from 1 to 30, the maximum number of Black Belts reported in any organization was seven, and there was only one Master Black Belt in all the respondent organizations (Douglas et al., 2015). In a study conducted in Saudi Arabia, Alsmadi et al. (2012) also pointed out that the number of professionals devoted to Six Sigma implementation was below the recommended in the literature and in some firms, they are absent (Alsmadi et al., 2012). Specialized training and availability of human resources, in fact, have been highlighted by previous research in developing countries as the main barriers to Six Sigma implementation in those contexts (Aboelmaged, 2011; Alsmadi et al., 2012; Cheng, 2007).

Green Belt training is delivered to all GE employees (Henderson and Evans, 2000). This may explain the higher number of specialized Six Sigma employees in GE subsidiaries when compared to other companies. It also illustrates that employees’ lack of knowledge is not a barrier to Six Sigma implementation in GE subsidiaries. Regarding the average training time for Six Sigma professionals, training requirements in GE are very specific (Ingle and Roe, 2001). During early times of Six Sigma implementation, the GE CEO Jack Welch changed the business structure and introduced a full 13 days of training for every employee, with the aim to have all employees trained in Six Sigma methodologies by the end of 1998 (Henderson and Evans, 2000). Later, the 13 days of internally provided training at GE were condensed to 10 days, expecting to meet business directive that all GE divisions be operating at Six Sigma levels by the year 2000 (Henderson and Evans, 2000). Moreover, the length of the training for Black Belts is approximately 16-20 weeks, or about 160 contact hours, spread out over about four months – candidates are usually trained for one week per month (Antony and Karaminas, 2016; Hoerl, 2001; Ingle and Roe, 2001). In comparison to other companies, the training in GE is more intensive, takes a shorter time and, therefore, results in a greater number of accredited Black Belts (Ingle and Roe, 2001).

Table IV presents the average training time applied in each subsidiary. For four respondents, the duration of training for Green Belts and Black Belts is aligned with the
literature, as discussed earlier. In the remaining four companies, the average training period is lower. Although the average training duration has been recommended in the literature, the curriculum of the belt program, in fact, should reflect the organization’s needs and requirements (Kwak and Anbari, 2006).

This survey also intended to find out whether professionals involved in the Six Sigma program dedicated full time to the program. The majority of Master Black Belts and Black Belts have a full-time dedication, whereas Green Belts have a partial dedication. Indeed, the literature shows that within GE, Master Black Belts and Black Belts have been full-time resources, freed up from their “regular jobs” to focus on Six Sigma while Green Belts do Six Sigma projects as part of their “regular job” (Gutierrez Gutierrez et al., 2016; Hoerl, 2001; Laux et al., 2015). In fact, a lack of dedicated Six Sigma professionals is a barrier to Six Sigma implementation (Aboelmaged, 2011), and this has been observed in other companies in developing countries (Aboelmaged, 2011; Alsmadi et al., 2012). Other studies (e.g. Grima et al., 2014) also pointed out that companies with full-time Black Belts are, in fact, a rarity. All the discussed aspects regarding GE infrastructure development for Six Sigma deployment are evidence of GE quality culture issues that were essential for successful implementation of Six Sigma in its subsidiaries.

4.5 Recognition of the professionals involved with the program
Concerning recognition granted to the professionals involved in the Six Sigma program, six firms answered that offer some type of compensation for Six Sigma specialists (two companies did not answer the question). For these six firms, there is a performance recognition (career boost), which is a driver for employees engagement. Three firms also reported that the professionals’ recognition takes the form of “non-financial awards.” Indeed, the qualification as a Black Belt is very important when employees are being considered for promotion at GE, and for some positions it is a prerequisite qualification (Henderson and Evans, 2000; Ingle and Roe, 2001). At early times, the way in which the CEO Jack Welch has linked leadership development in GE is one of the things that have contributed to the success of Six Sigma (Hoerl, 2001). On the other hand, more recent findings of Jesus et al. (2016) revealed that little importance is designated to incentives and bonuses related to Six Sigma in other companies in Brazil, which can discourage employees involvement with the Six Sigma. In fact, recognition and reward schemes are elements of a quality culture (Davison and Al-Shaghana, 2007). The presence of well-established recognition mechanisms in GE is another evidence that differences exist in the motives, obstacle managerial, and performance factors in relation to promoting the Six Sigma system in multinational and local companies, as already pointed out by Cheng (2007). Those differences may be considered relevant for cultural change and successful implementation of Six Sigma.

4.6 Results of Six Sigma program
One of the main purposes of the survey was to acquire data on the results the respondent companies obtained by applying Six Sigma. First, the companies were asked about the criteria adopted to select Six Sigma projects. One of the most common barriers identified to Six Sigma implementation in developing countries is the lack of selection and prioritization of Six Sigma projects (Aboelmaged, 2011; Alblawi et al., 2014; Yousefi and Hadi-Vencheh, 2016). Ineffective selection and prioritization lead to delay in results and also a great deal of frustration (Yousefi and Hadi-Vencheh, 2016).

The main selection criteria for the Six Sigma projects were identified by using a multiple-choice question. All companies selected the “alignment with the business strategy,” and seven firms also selected “increased customer satisfaction.” Indeed, the ability to impact business priorities and customer satisfaction are paramount in choosing which Six Sigma
projects to undertake in GE (Henderson and Evans, 2000). Therefore, it can be noticed that
the projects selection and prioritization in GE businesses in general are aligned with a
strategic plan and organizational goals, which has been pointed out in the literature as an
essential guideline for selecting any Six Sigma project (Kumar et al., 2009). Moreover,
three-quarter of firms also selected the “financial gains with the project,” “qualitative
gains,” “environmental impacts reduction,” and “improvements in safety and prevention
of accidents.” Those were already pointed out as relevant by other authors e.g.
(Banuelas et al., 2006; Yousefi and Hadi-Vencheh, 2016). Figure 2 shows the number and
average duration of Six Sigma projects carried out by the companies. The majority of
companies run more than 50 projects per year. This number is higher when comparing
with the findings by Cauchick Miguel and Andrietta (2010) in a survey conducted in
Brazil, which identified that 17 percent of a set of companies that operate in Brazil conduct
more than this figure annually. Similar findings were reported by other studies about
other developing countries (e.g. Douglas et al., 2015).

When considering the experienced benefits with Six Sigma program, all companies
cited “waste reduction,” “increased productivity,” “increased customer satisfaction,” and
“reduction of the processes variability.” Moreover, financial gains were reported by the firms.
Six companies answered the question about the financial gains (in average), and three of them
declared that they achieved values that ranged from US$25,000 to 50,000 per project.
Companies that run more projects per year were those that achieved the best financial results.
The companies also reported that no project is considered complete until the benefit has
been demonstrated and a team of financial auditors signs off, as already pointed out by
Henderson and Evans (2000).

Indeed, the benefits achieved are aligned with the ones achieved in GE headquarter
(Henderson and Evans, 2000), and also with the general benefits that Six Sigma can offer,
highlighted in other studies (e.g. Kwak and Anbari, 2006). Although van Iwaarden et al. (2008)
argue that given the differences in business climate in different countries, the success of
Six Sigma might not be universal, in the case of GE, the achieved benefits are similar than
those reported by the headquarter. The quality culture and high level of quality maturity that
exist in GE are, therefore, relevant factors that contributed to the successful implementation of
the Six Sigma program in its subsidiaries. All investigated aspects of the program
implementation were superior when compared with other studies that investigated Six Sigma
in similar contexts. Finally, the following section outlines some of the main methods and tools
used in Six Sigma programs.

![Figure 2](image-url)

**Figure 2.**
Number of projects and average duration in GE subsidiaries

- **Legend:**
  - ■ Number of projects implemented per year (in average)
  - □ Projects average duration (months)
4.7 Main methods and tools
Six Sigma relies on statistical tools and specifically designed processes and methods to achieve measurable goals (Albliwi et al., 2014). The lack of statistical knowledge has been pointed out in the literature as a common failure and a barrier to Six Sigma implementation (Aboelmaged, 2011; Albliwi et al., 2014; van Iwaarden et al., 2008), and an important obstacle to Six Sigma implementation in other developing countries. Thus, the companies were asked about the use of statistical tools to support the projects. All of them declared to use statistical tools and software (e.g. Minitab™ and Crystal Ball™), corroborating the work of Henderson and Evans (2000). The use of these tools contributed to the reduction of the variability in the processes, as stated previously regarding the benefits achieved by the companies.

Moreover, the survey also identified the use of the most common problem-solving framework (e.g. DMAIC, DFSS, and DMADV). As expected, all companies use DMAIC, and seven adopt DFSS and DMADV (one did not answer the question). In fact, previous work (Henderson and Evans, 2000) stated that the “define” phase of DMAIC was added by GE in recognition of the importance of having a well-scoped project and to be in line with the current practices across GE. In addition, the GE Medical Systems, a pioneer in the use of DFSS, reported that after 1998, all new products would result from the application of DFSS (Harry, 1998), which may also explain the usage of this method in all subsidiaries. The training of employees in those statistical tools is an evidence of the commitment to training, a strong element of GE quality culture. Having presented the findings, attention is turned to the concluding remarks, outlined next.

5. Conclusions
This study demonstrated that Six Sigma program at GE subsidiaries achieved superior results in comparison with other companies that operate in Brazil and also in other developing countries, based on previous publications. The findings confirmed that there are differences in relation to strategic integration, knowledge, and support when comparing a multinational company like GE and local companies cited by other surveys carried out in the country. GE quality culture aspects such as top management commitment, high investment in training, recognition schemes, and development of a well-planned infrastructure were identified as valuable to overcome common barriers to Six Sigma implementation reported by other studies in the country under analysis as well as in other developing countries. Moreover, the findings showed a strong alignment with the goals and practices of GE headquarters, which is an evidence of a high level of quality maturity that exist in GE and well-defined mechanisms of knowledge transfer and that allow all GE businesses around the world achieve benefits with Six Sigma.

Although this study is confirmatory, i.e. mainly contributes to the expected results since GE is a benchmark company in Six Sigma with a strong quality culture, some interesting points are raised as the role of quality culture issues in overcoming common barriers that are generally faced by other companies in the country and similar contexts. This study illustrates how a world-class company transferred the knowledge necessary to achieve positive results with Six Sigma in its subsidiaries and common practices related to the quality culture that may make a difference in the Six Sigma implementation. The identified quality culture issues and practices adopted by GE may be valuable to other companies that are implementing Six Sigma in locations where the same obstacles might occur, as a potential source of how to obtain success in the Six Sigma implementation. In addition, since there are still a limited number of studies regarding Six Sigma implementation in developing countries, especially in Latin America, this work offers contributions to the literature in this sense.
Nevertheless, more quantitative research is necessary to confirm these findings, so this is suggested for future work. Further studies may investigate the role of quality culture issues in Six Sigma implementation in multinational subsidiaries around the world, in order to demonstrate the cause and effect relationship and compare different practices.

References


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