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SIX SIGMA METHODOLOGIES: IMPLEMENTATION AND IMPACTS ON PORTUGUESE SMALL AND MEDIUM COMPANIES (SMES)

Abstract: Six Sigma is a disciplined approach for dramatically reducing defects and producing measurable financial results (Anand, 2006; Linderman et al. 2003). It should not be a simple statistical tool, but rather a strategic management approach by supporting key projects aligned with the business goals and customer requirements.
Although associated with considerable Return on Investments, there is not enough evidence of Six Sigma application within Portuguese companies. It is the aim of this exploratory research to study Six Sigma utilization by Portuguese Small and Medium Enterprises (SMEs). The descriptive analysis and the statistical tests carried out, point to lack of knowledge with this Methodology (Higher at Top Management level) and a sense of comfort with the existing management systems (mainly ISO 9001). The authors recommend increasing Six Sigma training and education and additional studies to gather further knowledge and contribute to more competitive and sustainable organizations.

Keywords: Six Sigma, Quality Management, Quality Improvement, SMEs

1. Research context

Although it is available from more than 20 years, and had quite positive results in companies like Motorola and General Electric, Six Sigma application in Small and Medium Enterprises SEMs) has never been extensive (Andrietta and Miguel, 2007; Antony *et al.,* 2008; Conceição and Major, 2011).
In Portugal, SEMs account for 99,9 % of the total non-financial companies with a most major impact in the country economy (www.iapmei.pt).

In this exploratory research, we try to evaluate the application level of Six Sigma in Portuguese SEMs, the motivations that lead these types of companies to apply this methodology and corresponding results:

- Characterization of 2012 Excellency SMEs (a recognition given by IAPMEI, (www.iapmei.pt), a Portuguese Government Agency;
- Characterization of respondents, namely their position in the company, their education level and Six Sigma knowledge level;

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- Evaluate the 2012 SMEs Excellency Six Sigma application;
- Identify benefits and problems in Six Sigma application;
- Identify the methodologies and tools most adequate for Six Sigma implementation in these type of companies.

2. Research methodology

This research based on the methodologies prescribed by Gil (1991) and Marconi and Lakatos (2003), comprehended the following six steps (Figure 1):
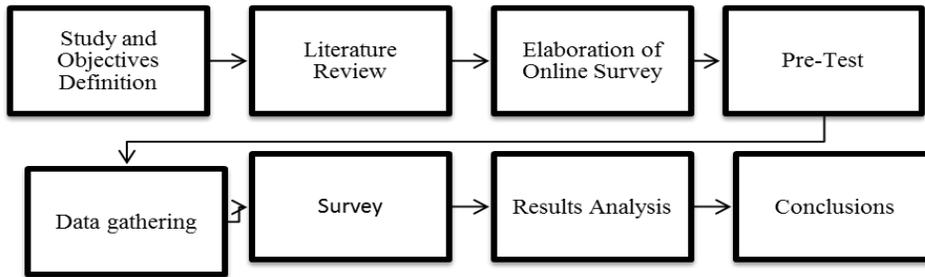

Figure 1. Research Phases

Six Sigma applications in SMEs was chosen as study objective and we selected 2012 Excellence SMEs as study population due to its economic stability and access of contacts trough IPAMEI database. These companies follow the classification of EU Commission Regulation nº 2003/361/CE of 6 May 2003 that includes amongst other the following criteria: less than 250 workers and 40 million euros sales volume or total balance smaller than 27 million euros.

PME Excellency status is awarded by IAPMEI (Agência para a Competitividade e Inovação) with the aim to identify and recognize SEMs with superior performance.

In 2013, there were 1.314 companies awarded as 2012 Excellency PMEs with more than 45 thousand direct labor positions and responsible for a total sales volume bigger than 6,3 thousand million euros in 2011 (Source: IAPMEI, FINCRESCE Consolidar Lideranças).

The research objectives have taken into consideration the object being study and the possible interest of this research and literature review focus was on Six Sigma application in SMEs.

The survey was developed using as reference Alsmadi *et al.* (2012), Antony *et al.* (2008), Carvalho *et al.* (2007) and Antony and Banuelas (2002) and G*oogle Docs software*, with closed questions and a *Likert* 1-5 scale. Depending on the number of questions to answer, completion time estimation was between three and eight minutes.

After pre-test, the final survey was send to the available 2012 Excellency SMEs emails in June 2014 and after one month we got 62 replies (estimated response rate of 5.6%, based on the number of emails send).

Microsoft Excel 2007 and *Statistical Package for the Social Sciences* (SPSS) Version 22 were used for the subsequent analysis.

Statistical analysis and hypotheses testing were the methods used to draw conclusions in this research.

3. Six sigma literature review

3.1 General Findings

Six Sigma is a disciplined approach for dramatically reducing defects and producing

measurable financial results (Anand, 2006; Linderman *et al*., 2003). There are other Six Sigma definitions some more oriented toward methodologies e.g. DMAIC-Define, Measure, Analyze, Improve and Control for effectiveness improvements (McAdam and Lafferty, 2004), Lean Six Sigma for effectiveness and efficiency improvements; DFSS- Design For Six Sigma using DMADV- Design, Measure, Analyze and Improve for incremental improvements and IDOV- Identify, Design, Optimize and Validate for radical improvement (McCarty *et al*., 2004). Other definitions focus on metrics like process capabilities. Six Sigma definition as a Management Approach incorporates the other definitions and several authors emphasize that it should not be a simple statistical tool, but rather a strategic management approach by supporting key projects aligned with the business goals and the customer requirements and will be the framework used for this research.

However, for some author Six Sigma did not bring really nothing new to the existing portfolio of quality tools and methodologies and it is not the tools and methodologies by themselves that assure the success but rather their implementation process.

Six Sigma is more than a continuous improvement program and involvement of all the employees in the companies is very important. Each Six Sigma project should have a team with people from different knowledge and hierarchical levels.

Although we would not find specific literature for the right numbers of Master *Black Belts*, *Black Belts* and *Green Belts* needed for the success of a Six Sigma Team, we could find some suggestions (QSP, 2000):

- 1 *Master Black Belt* for each 30 *Black Belts*;
- 1 *Black Belt* for each 100 employees;
- 1 *Green Belt* for each 20 employees.

Several authors, e.g., Chang, (2002), do stress the importance of good People training in Six Sigma for its success so Training

should be a top priority.

ISO International Standard ISO 13053-1:2011 (www.iso.org) chapter 8, does presents a recommendation on training for each Sig Sigma Team Member (ANEX II) and the number of days needed to achieve these goals (ANEX III).

Cooperation and alignment towards common goals between all Six Sigma Team members are also keen for the project success. Figure Two summarizes the proposed structure for Six Sigma applications:
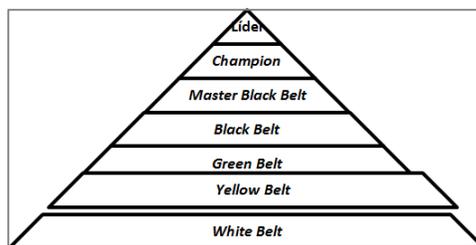
Figure 2. Six Sigma Overall Structure

Several authors have studied the relevant factors for Six Sigma Project success (Antony and Banuelas, 2002; Chang, 2002; Conceição and Major, 2011; Kwak and Anbari, 2006; Henderson and Evans, 2000).

In addition to Six Sigma training, Top management commitment, the use of Six Sigma as strategic tool with key projects aligned with the organization strategy, the identification of the projects Return of Investment and cultural soft skills of the teams employees are amongst the key success factors identified by those authors.

Concerning the factors that have most impact on the lack of Six Sigma success those include not fulfilling the success factors, like lack of Top Management commitment, disconnection with Strategy and inability to perform a cultural change (Júnior and Lima, 2011).

3.2 Application of six sigma in SMEs

Since Motorola started to apply Six Sigma that we have seen its application in big

companies. However, accordingly to Snee and Hoerl (2003) there are no specific reasons why not to apply Six Sigma at SMEs.

Due to its smaller size SMEs are more agile and providing there is Top Management commitment and support it should be easier to implement Six Sigma in SMEs and achive

positive results.

However, in reality there are few cases of Six Sigma application in SMEs and the literature review points out for the following possible reasons (Table 1):

Table 1. Contributing factors for difficulties in implementing Six Sigma in SMEs

Authors	Factors
Nonthaleerak and Hendry (2006)	• Considerable investment needs
Antony *et al.,* (2008)	• It is difficult to choose between the many programs available: Six Sigma, TQM, ISO, EFQM and the one that best suits the SMEs needs; • ISO 9000 standards series are considered enough; • Lack of success stories; • Lack of Top Management commitment and Six Sigma understanding; • Wrong idea concerning high statistical level of difficulty required for Six Sigma
Raghunath and Jayathirtha (2013)	• Lak of resources; • Resistance to change; • Poor Top Management leadership; • Lack of Six Sigma knowledge and training; • Department and cultural barriers; • Idea that Six Sigma is too complex; • Wrong choice of process parameters; • Failures in data collection; • Poor choice of Six Sigma projects

In summary there are several reasons that might lead SMEs not to adopt Six Sigma, ranging from lack of resources and success stories, to poor leadership and knowledge.

3.3 ISO 13053:2011

The first ISO Six Sigma International Standards were published in September 2011:
• ISO 13053-1: DMAIC Methodology.
• ISO 13053-2: Tools and Techniques.

While these standards do not cover yet the DAMAIC methodology they could be a good tool to help disseminate Six Sigma with the more than 1 Million SO 9001 certified organizations (source: ISO Survey 2013, available at www.iso.org).

4. Research results

4.1 Respondents data

The 62 respondents were a very specific

target population, the 2012 Excellency SMEs and selection was justified by its market position and economic stability. Most respondents were from North Region of Portugal, with companies between 20 to 40 employees and being Commerce and Services the main activity sector, while Industry represented 42% of responses.

We noticed that 42% of the respondents

SMEs (25) had no quality, environmental or health and safety management system implemented, which is a remarkable conclusion considering we are dealing with "Excellency Portuguese SMEs".

ISO 9001:2008 was the most common management system implemented by the 2012 Excellency SMEs companies (see Figure Three):
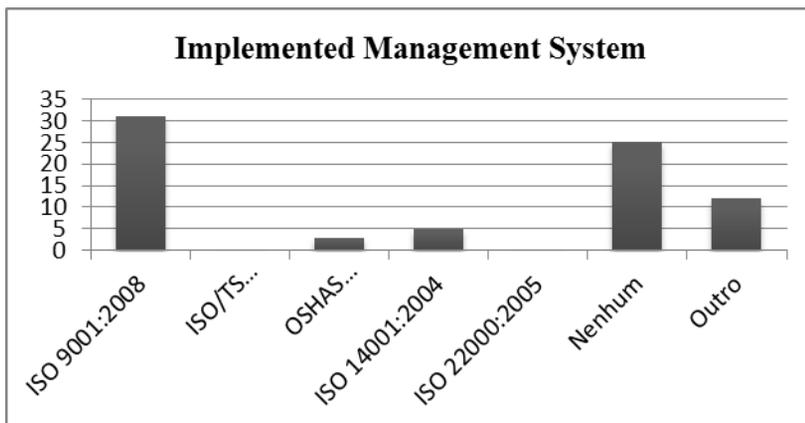

Figure 3. Implemented management systems

Concerning positions of the respondents in the companies, we got the following results
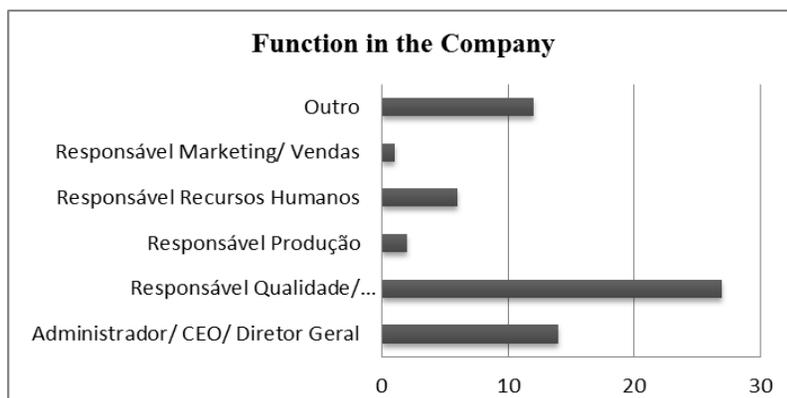
(see Figure Four below):

Figure 4. Function in the Company

In respect to formal education most (45) of the 62 respondents had BSc degrees and nine had MSc (87% of the employees respondents with university/polytechnic education).

However, more than half of the respondents (58%) stated they had poor (week or insufficient) knowledge about Six Sigma, with only 32% considering having a

sufficient knowledge of Six Sigma. This is clear evidence that Six Sigma is not yet a known methodology within Portuguese Excellency SMEs, which is somewhat surprising since 58% of respondent companies are familiar with management systems and 50% has ISO 9001:2008 certifications.

Finally yet importantly, how many of the 62 respondents 2012 Excellency PMEs had implemented Six Sigma methodology: The answer was Zero; none had implemented Six Sigma Methodology.

The following were the main reasons appointed for not implementing Six Sigma:

- There are already satisfactory improvement mechanism implemented (Mean: 3.39; Standard Deviation: 0.93);
- Satisfaction with existing management systems (Mean: 3.42; Standard Deviation: 1.05);
- Satisfaction with present quality levels (Mean: 3.44; Standard Deviation: 1.07);
- Lack of knowledge of Six Sigma (Mean: 3.05; Standard Deviation: 1.19)
- Lack of Human Resources (Mean: 3.02; Standard Deviation: 1.03). 4.2. Intentions to implement Six Sigma

Concerning the intention to implement (or not) Six Sigma in the future only 6% answered in a positive way (with 65% stating maybe and 29% saying no).

4.1 Open questions

The survey section three had two open questions about adequacy of Six Sigma to their companies and Six Sigma value for SMEs.

Concerning adequacy of Six Sigma to SMEs 51% of the answers was neither agree/neither disagree. On the other hand, 45% of the respondents agreed that Six Sigma is adequate for SMEs with only 4% stating it as not adequate. In the authors' opinion, this is an indication of a severe lack of knowledge about Six Sigma, by the

respondents of the 2012 Excellency Portuguese SMEs.

As for the second open question concerning Six Sigma value for SMEs, answers were very similar with 49% of respondents with no opinion and only 3% stating they don´t agree this methodology is value added for SMEs.

5. Tests performed: Relationship between the level of Six Sigma knowledge and the function in the company

As shown by descriptive results analysis 58% of respondents answered to have low Six Sigma knowledge levels. We believe this might be a major reason for the non-implementation of Six Sigma in Portuguese SMEs.

Considering the final decision to implement or not this methodology belongs to Top Management and Quality Managers, we are going to try to find out if there is indeed a relationship between the level of Six Sigma knowledge and hierarchy of the decision makers and its implementation in SMEs.

We started by Case Processing Summary test, with the purpose of validating the answers received by checking if there are some missing data. With this test, we confirmed there was no missing, so we have all the complete data and can proceed with the statistical analysis.

Next, we made descriptive analysis of "Six Sigma Knowledge Level" by "Function at the Company", in order to get a detailed data analysis.

Through this analysis, we can verify that the level of Six Sigma Knowledge of Top Management is considerable lower than the correspondent level of knowledge of Quality/Environmental/Health and/or Safety Managers and Other Functions, as per Table Two and Three:

Table 2. Case Processing Summary

Function in the company		Cases					
		Valid		Missing		Total	
		N	Percent	N	Percent	N	Percent
Six Sigma Knowledge Level	Top Management (Board Member CEO, General Director)	14	100.0%	0	0.0%	14	100.0%
	Quality/Environmental/Health and/or Safety Managers	27	100.0%	0	0.0%	27	100.0%
	Other Functions	21	100.0%	0	0.0%	21	100.0%

Table 3. Summary of Descriptive Analysis

Cargo	Average level of Knowledge	Standard Deviation
Top Management (Board Member CEO, General Director)	1.71	0.825
Quality/Environmental/Health and/or Safety Managers	2.59	1.010
Other Functions	2.38	1.161

With the purpose to check if there is correlation between Function at the Company and Six Sigma Knowledge Level, we first test the normality of the sample trough Kolmogorov-Smirnov and Shapiro-Wilk tests (Table 4). In case the data have a normal distribution we can use parametric testes (also called T Test), and in case this does not occur we should use non-parametric tests.

Table 4. Normality tests

Function in the company		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Six Sigma Knowledge Level	Top Management (Board Member CEO, General Director)	.307	14	.001	.767	14	.002
	Quality/Environmental/Health and/or Safety Managers	.212	27	.003	.906	27	.018
	Other Functions	.248	21	.002	.889	21	.022

By the Kolmogorov-Smirnov and Shapiro-Wilk tests, we reach the conclusions that these data doesn´t follow a normal distribution so we must use non-parametric testes to compare the Six Sigma Knowledge Level of the three groups.

We have therefore proposed two hypotheses for this study (Table 5):

- H0: Six Sigma Mean Knowledge Level is the same between the three different groups of functions in the company.

- H1: Six Sigma Mean Knowledge Level is different between the three different groups of functions in the company.

For the study of the hypotheses, we have used non-parametric Kruskal-Wallis test that is an extension of Wilcoxon-Mann-Whitney test and is a non-parametric test used to compare three or more populations (Table 6). This test is used to test the null hypotheses that all populations have the same distribution functions versus the alternative hypotheses that at least two of the populations have different distribution functions.

Table 5. Summary of Hypotheses Testing

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Nível de Conhecimento em Seis Sigma is the same across categories of Função na epresa	Independent Samples Kruskal-Wallis Test	.035	Reject the null hypothesis

Table 6. Kruskal-Wallis test
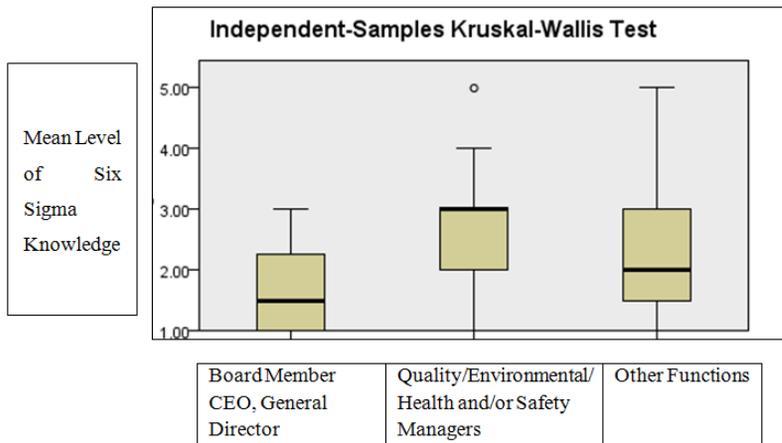
Through these results, we reject the null hypotheses and can with a 95% confidence level state that there are significate differences between the mean level of Six Sigma knowledge between the 3 groups considered in the companies: Top Management (Board Member CEO, General Director), Quality/Environmental/Health and/or Safety Managers and other Functions. It is particular relevant to notice that it is the Top Management (Board Member CEO, General Director) that present a lower mean Six Sigma Knowledge Level.

6. Discussion of results

Although the study has several limitations due to the low response level and small sample size, we could reach interesting conclusions concerning the characterization of Portuguese SMEs and its implementation of Six Sigma.

In this study we used a very specific target population, the 2012 Excellency SMEs due to its market position and economic stability. Most respondents were from North Region of Portugal, with 20 to 40 employees and

being Commerce and Services the main activity sector.

Although we have studied the awarded 2012 Excellency PMEs, 42% of the companies didn´t have no certified management system. There are considerable evidences of the positive effects of quality management systems implementation and certification in companies performance (Levine and Toffel, 2010), but there is still a considerable number of SMEs companies that have not done it, so this might give some indications on why there is a considerable lack of Six Sigma implementation on these type of companies.

In Portugal, regardless of organization type and sector, ISO International Standard ISO 9001:2008 is widely used. Accordingly to ISO Survey 2013 (www.iso.org) there were in 2013, 7,041 certified organizations with ISO 9001:2008, followed by 1326 certified organizations with ISO 14001 certifications.
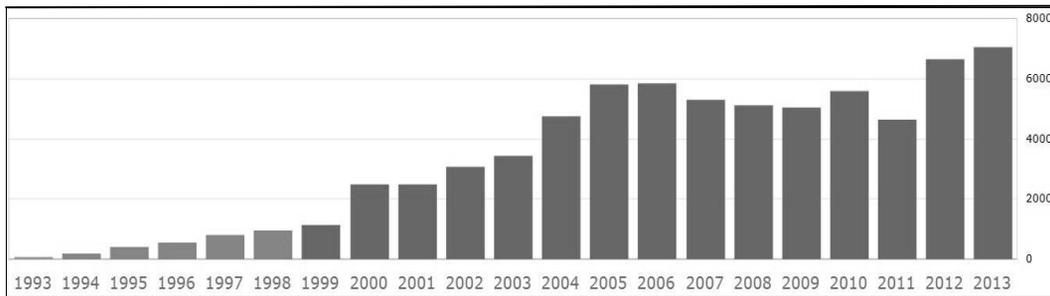
Source: www.iso.org

Figure 5. Evolution of ISO 9001 in Portugal

We have already concluded before that there are no intrinsic reasons for the non-application of Six Sigma in SMEs. How can we then explain the situation that we have found that none of the 62 Excellency PMEs that responded to our survey are using Six Sigma?

We think there are several factors to consider:

- Previous studies about Six Sigma adoption by Portuguese companies have shown that Six Sigma use in Portuguese Companies to be around ten to eight percent (Conceição and Major, 2011; Fonseca *et al.*, 2011) although the populations were not the same.

- In Brazil, Andrietta and Miguel (2007) identified that Six Sigma utilization reached its top level in 2000, due to benefits of Brazilian Group Brasmotor and General Electrics, which triggered the use of Six Sigma by Brazilian companies.

- In the United Kingdom Antony *et al.* (2008) confirmed that 27% of SMEs were implementing Six Sigma, although very recently started.

- The fact that none of the 62 respondents in this study was not using Six Sigma doesn´t mean there are no Portuguese SMEs implementing and having benefits with Six Sigma. Again the low response level and population size are and advice for some care in those analysis.

- Six Sigma is indeed less known in Portugal than ISO International Standards, Lean and Kaizen. If we make an analysis of the articles presented in conferences or published in Portuguese Journals we should come to these conclusions. When asked for the main reasons for not implementing this methodology the 2012 Excellency SEMs emphasized "The existing of satisfactory improvement mechanisms", "the satisfaction with existing Management Systems" and "the

satisfaction the present Quality levels". Indeed several studies (e.g., Antony *et al.*, 2008) have already identified Six Sigma lack of knowledge as the major source for SMEs not implementing this methodology in Turkey and in the United Kingdom.

- In the authors opinion the fear of the unknown and the perception that present improvement systems are enough to assure quality, productivity and companies competitive position are enough, might also be an excuse for not going after Six Sigma.
- Through the results of the Test of Hypotheses we rejected the null hypotheses and can with a 95% confidence level state that there are significate differences between the three gropus of functions at the company and their Mean Six Sigma Knowledge Level. It is particular relevant to notice that it is the Top Management (Board Member CEO, General Director) that present a lower Six Sigma Mean Knowledge Level, although Six Sigma is associated with considerable Return on Investments (Gupta and Sri, 2012), which should be particularly motivating for Top Mnanagement. This was also confirmed by the response "Lack of knowledge of Six Sigma (Mean: 3.05; Standard Deviation: 1.19)" as one of the main reasons for not implementing Six Sigma.
- And last but not least we made a check on curricula of the major Portuguese Universities and Polytechnic Institutions to find out that only one has Six Sigma as a formal curricular unit in their graduation courses.

We hope that by sharing this results we can put focus more attention on Six Sigma Training and Education leading to a much more intense implementation of this proven effective and competitive improvement methodology.

7. Research limitations and suggestions for future work

The authors would like to point out the several limitations of this study:

- A small sample size that could not be representative of the universe of Portuguese SMEs;
- Due to many obsolete email contacts, it was not possible to establish with confidence the real response rate.

For future research, we have the following suggestions:

- To try and use a much bigger and representative sample size (e.g., ISO 9001 certified companies);
- To do more segmented studies by sector of activities, and company size;
- To do a study on those PMEs that already have implemented Six Sigma (Conceição and Major, 2011; Fonseca *et al*, 2011) to check why and how they did it, what benefits they got and what difficult those companies had to overcome;
- To complement this qualitative research with a quantitative one to understand in a better way the results we get with quantitative methodology.

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