Six Sigma for improving cash flow deficit: a case study in the food can manufacturing industry

Maria-Victòria Sánchez-Rebull
Department of Business Management, Universitat Rovira i Virgili, Tarragona, Spain

Ramon Ferrer-Rullan
Department of Engineering Research, Ferrer and Asociados, Reus, Spain, and

Ana-Beatriz Hernández-Lara and Angels Niñerola
Department of Business Management, Universitat Rovira i Virgili, Tarragona, Spain

Received 3 December 2018
Revised 13 June 2019
14 July 2019
Accepted 26 January 2020

Abstract

Purpose – Cash flow deficit situations and working capital control are major challenges for many companies, especially those whose suppliers and clients have strong bargaining power. This study aims to describe the application of the Six Sigma methodology for solving these problems in a large German food can manufacturing company.

Design/methodology/approach – This paper follows the qualitative methodology of case study research. During different define, measure, analyse, improve and control process phases, the problem and critical aspects are identified to improve the quality of the payment process and improvements are suggested and implemented.

Findings – The results provide evidence of how Six Sigma can be useful in administrative–financial processes that are carried out within a company. This result is particularly interesting because it is about processes that have not applied Six Sigma methodology. For the company studied, this methodology has balanced its cash flow and this meant large amounts of savings, especially in bank interest to avoid having to ask for bank credits.

Originality/value – This case can be extrapolated to other companies, regardless of the company size, that present similar symptoms of cash deficit, especially if their bargaining power with suppliers and customers is low.

Keywords Six Sigma, Process improvement, Accounts payable, Can industry, Cash flow deficit

Paper type Case study

1. Introduction

Six Sigma is a philosophy that pursues excellence, offering reliable products or services. There is no standard definition about it. However, it is clear that it has two well-defined perspectives (Prabhushankar *et al.*, 2008). From a business point of view, Six Sigma is a powerful methodology that enhances the efficiency of business processes and significantly reduces product defects (Antony, 2006; Kwak and Anbari, 2006). This allows to achieve

International Journal of Lean Six Sigma
Vol. 11 No. 6, 2020
pp. 1105-1126
Emerald Publishing Limited
2040-4166
DOI 10.1108/IJLSS-12-2018-0137

customer satisfaction (Karout and Awasthi, 2017; Raisinghani *et al.*, 2005). On the other hand, from a statistical point of view, its goal, as its name suggests, is the reduction of variability in business processes (Kwak and Anbari, 2006; Linderman *et al.*, 2003; Snee, 2004). Six Sigma means that the company offers only 3.4 defects per million opportunities (DPMO), which means a high quality of 99.99966%. Its success in the industry began in the late 1980s when Motorola got the Malcolm Baldrige National Quality Award for its improved competitiveness through this quality strategy (Raisinghani *et al.*, 2005). Since then, it has been a business process improvement strategy that has reached all kinds of companies, industrial and services companies, including small and medium-sized enterprises (Vendrame Takao *et al.*, 2017) and, consequently, to all the processes.

Six Sigma has also been defined as a powerful problem-solving strategy (Prabhushankar *et al.*, 2008). There are multiple cases in literature applying Six Sigma and achieving substantial improvements in its performance (Snee, 2004) on employee satisfaction (Sunder, 2013) or increasing customer satisfaction (Karout and Awasthi, 2017) or solving specific problems in transactional projects (Antony *et al.*, 2012b).

The objective of this paper is to highlight the potential of Six Sigma methodology, detailing the problems of cash carried out in a large food can enterprise. Six Sigma has been previously implemented in other transactional environments (Antony *et al.*, 2012b). The case is interesting because in food can industry, suppliers and clients have great negotiation power and they influence and mark the rules, often very inflexible, in their conditions and payment terms. Porter pointed out the can manufacturing industry, to which the studied company belongs, is one of the industries whose collective resistance is "intense" (Porter, 1979, p. 137). The bargaining power of clients in an industry affects its competitive environment and also its ability to generate profitability (Porter, 2008). Strong clients, with high bargaining power can pressure the company to lower prices, improve product quality, set longer payment terms, etc. and all this represents costs for the company. Also, strong suppliers can also take advantage of their power, especially in terms of payment terms and supply time. Therefore, companies from this industry usually present liquidity problems.

Next, the structure of the article is detailed. Following this introduction, a theoretical part focused on the food can industry and its cash flow problems is presented in Section 2. Section 3 is dedicated to methodology and it briefly explains the define, measure, analyse, improve and control (DMAIC) steps. In Section 4, the case study is presented and the problem is contextualised. Section 5 describes how the objective is achieved through the phases of this methodology. In Sections 6 and 7, respectively, the results are discussed, and the managerial implications and the lessons learned are presented. Finally, the main conclusions of the research are highlighted.

2. Food can manufacturing industry and Six Sigma

Six Sigma has been carried out in multiple sectors. We find case studies conducted in automotive industry (Sambhe and Dalu, 2011; Surange, 2015; Valles *et al.*, 2009), electronics (Choi *et al.*, 2012; Patterson *et al.*, 2005), construction (Negi *et al.*, 2017; Siddiqui *et al.*, 2016; Stewart and Spencer, 2006), health care (Antony *et al.*, 2018; Benedetto, 2003), banking (Sunder, 2016; Sunder and Antony, 2015), tourism (Pearlman and Chacko, 2012), airlines (Gibbons *et al.*, 2012), among others. Thus, it was observed that Six Sigma has been widely implemented with different objectives in industrial and services companies (Raja Sreedharan and Raju, 2016; Sunder *et al.*, 2018).

Even in the food can manufacturing sector, which is the one that belongs to the company studied in this article, it has also been applied. For example, Rexam, one of the largest producers in the world (North American sector of this company has 12 plants, South

American sector has 10 plants and Europe and Asia have 21 plants), has applied it to improve the quality maintenance processes. Its target has been to gain more production time avoiding unplanned stops or breakdowns and to improve the communication about the maintenance actions, so it is essential to keep equipment in excellent condition (Nieminen, 2016). Moreover, to understand and improve recycling rates, Six Sigma methodology was used in Fayette County, Kentucky, a manufacturing enterprise of beverage cans (Das and Hughes, 2006).

2.1 Food can manufacturing industry peculiarities and the problem of cash

Food can manufacturing industry needs to produce high-quality cans approved for food use. The main raw material is electrolytic tinplate of several thicknesses and it represents between 17% and 41% of the weight of the cans. Tinplate is a flat rolled product, formed by steel (iron and carbon alloy) and covered by a layer of tin. It is an ideal material for manufacturing of metal containers because it combines the mechanical strength and conformability of steel with corrosion resistance of tin. With this material, complementary products are manufactured, e.g. a whole range of plugs, studs, handles, slings, lids and metal cans for food, produced synthetics, oils and derivatives.

Iron and ferrous metals market is the second largest commodity market after crude oil in terms of volumes. There are three key producers of iron who own between 70% and 75% of the market (DeGroot *et al.*, 2012). This means, an oligopolistic market where large companies have a great negotiation power. The price of iron, necessary for the production of steel products, has suffered different oscillations over the time. Moreover, on certain occasions, this increase in price comes with a decrease of domestic production which makes Europe more dependent on iron importations. In addition, China began to consume more of this material, going from 209 million tons in 2004 to more than 1,000 million tons in 2016. The demand growth and the integration of several global steelmakers resulted in a strong increase of steel price in all its varieties imposed by the large suppliers. Iron price increase has an unavoidable impact in the value chain of companies of the food can manufacturing industry, especially in the supply of materials. At the same time, the most important final clients of these companies are usually large supermarket chains which also have a great power of negotiation. This situation makes companies of this industry vulnerable and they barely negotiate with suppliers and clients the terms of accounts payable and receivables days. So, the financial departments of these companies have a great challenge in cash flow management.

2.2 Six Sigma for solving financial issues

The need of efficient cash flow management has achieved consensus among researchers and practitioners. Under the pecking order model, developed by Myers (1984) and Myers and Majluf (1984), the availability of internal funds, through cash flow or current profitability, implies that firms have less need to make recourse to external debt, implying a lower debt ratio. Moreover, for a given level of cash flow, the amount of debt will be increasing in the investment being undertaken by the firm (Benito, 2003). This highlights the importance of cash flow balance. Cash flow volatility not only increases the likelihood that a firm will need to access capital markets, it also increases the costs of doing so (Minton and Schrand, 1999; O'Connor Keefe and Yaghoubi, 2016). O'Connor Keefe and Yaghoubi (2016) find that cash flow volatility is an important determinant of firm's debt and debt's cost. Thus, there is a positive relationship between cash flow volatility and the cost of debt (Black and Scholes, 1973).

A company could survive for a while without achieving profits or even with losses, but it may collapse because of lack of cash even if it has a very positive balance (Peer and Rosental, 1982). Some models have been developed to manage cash flow: mathematical models and cost and time integration models (Navon, 1996). Nevertheless, Six Sigma methodology has been barely applied to the financial company department, especially to solve a deficit cash flow situation, although it can help to improve cash flow, earnings or productivity in using assets (Foster, 2017).

Six Sigma may be used for monitoring accounting processes (Krehbiel *et al.*, 2007). We found, for example.

A big Portuguese car dealer group successfully used all the stages of a Six-Sigma DMAIC to improve the warranty billing process (paid by Car Brands). It shows that the project allowed car dealership managers to understand that the use of financial metrics did not control compliance standards for Car Brands, in warranty services, or assure a good cash-flow for the car dealers. Necessary changes and new metrics (% time compliance to do the service and bill it, % time compliance reception, % time to find a defective part in an audit) generated time benefits and consequently a more controlled cash flow (Cunha and Dominguez, 2015 p. 885).

Also related to financial processes, a project was carried out to streamline financial processes (included payroll, purchasing and payable accounts, accounts receivable, monthly reconciliation and budget), reduce cycle time and improve quality and accuracy in a city government (Furterer, 2016). In a logistics project, the methodology Six Sigma approach was used to improve the freight payment process. The results included a reduction in the number of payment processes from 38 to a single one-company process, 30% reduction in labour, 15% reduction in third-party logistics fees and a 25% savings from mode shifts as well as other soft benefits (Ogg, 2003). For the logistics services, in a large consumer electronics company, a project with Six Sigma was conducted to improve payment process, to have a more transparent process with zero failures using Lean Six Sigma methodology (Blackman *et al.*, 2013; Gutierrez-Gutierrez *et al.*, 2016). They describe the implementation of Six Sigma in the areas of international bank payments, foreign exchange and operating savings gained from simplification and centralisation of the treasury management function. Also, there was increased focus on quality processes within the treasury function and the operating companies, particularly on measuring, improving and controlling the accuracy and completeness of bank data for suppliers. This issue was that rejected payments had to be re-inputted to the netting system in time to complete the process. Motorola originally developed this technique in manufacturing. However, the use of this technique in a finance function was a new venture (Blackman *et al.*, 2013, p. 137). Therefore, Six Sigma can be applied to numerous and different processes that are carried out in a company regardless of the sector in which it operates, and one of those processes could be financial, as the payment process.

In this context, we detailed the great benefits that this business management improvement strategy produced in the financial area of a food can manufacturing company.

3. Research methodology

We use a case study-based methodology to gather the information and explain the implementation of the Six Sigma project that took place in the company. The case study methodology is widely used in Six Sigma research (Brady and Allen, 2006; Thomas *et al.*, 2016). This is a useful and valuable method of research, with distinctive characteristics applicable to different types of research (Tellis, 1997), which facilitates a closer access to the data of a company to research studies. It can also be used in combination with other methods. The food can industry provides a case study context to show the benefits of Six Sigma methodology in a finance department, an area where its use has been very scarce.

In this paper, the case of study is a descriptive, holistic and single case study (Yin, 1984) based on company data for demonstrating the applicability of Six Sigma. There exist different types of case studies. In particular, a descriptive case describes an event or a situation in its real-life context (Yin, 2003) and require that the investigator begins with a descriptive theory or face the possibility that problems will occur during the project (Tellis, 1997). It is also a holistic design of case studies as it is based on a single unit of analysis.

In addition, case studies can involve single or multiple-case designs. Single cases are used to confirm or challenge a theory, or to represent a unique, extreme or revelatory case (Yin, 1994). When a researcher has access to an especial and significant situation previously inaccessible, single case studies become relevant. Each single case study represents a complete study where data have to be gathered usually from different sources and the conclusions are obtained from the analysis of these data (Tellis, 1997).

Even if it is difficult to generalise the results obtained from a single case study, publications on case studies through the use of Six Sigma methodology have been growing. These case studies have contributed to professionals and researchers who have acquired a greater practical knowledge which helps this generalisation to become more consistent (Antony *et al.*, 2012a).

For this reason, it is important to guarantee, as far as possible, the reliability of case studies. Reliability can be reached in different ways in a case study. One of the most important methods is the development of the case study protocol (Tellis, 1997), as Yin (1984) recommended with these four sections: an overview of the project (project objectives, case study issues and topics being investigated); field procedures (credentials and access to sites and sources of information); questions to keep during the project; and guide for the report (outline and format for the narrative) (Yin, 1994).

In this sense, the team studied the problem in a company, gathering some important data and applying a brainstorming process, and drafted a project charter that includes the goal and project statement as well as other project's features.

The data gathered for the project were analysed using measurement system analysis through the gauge R&R tool, regression analysis, simulation, etc. Also, some graphical analyses such as histogram, Pareto diagram, process map, work flow diagram and flow chart were used for summarizing the data. Finally, from these data, understandable conclusions for the management of the company were reached. All these steps and tools are explained in the following sections.

4. Case study

The case focuses on a large food can manufacturing company in Germany ("CM" name anonymised) with an annual turnover of €800m, about 1,300 employees and a working capital of €22m. It is a true case and, the project was executed by management. The parent company, "US" company (name anonymised), was launching a Six Sigma deployment across all the functions and all the manufacturing sites (with sponsors, black belts, master black belts and with people from the different departments involved in each project). The case explained in this paper, include one of the projects. Concretely, the one to solve the problems of cash.

The main raw material used for the food can manufacturer was electrolytic tinplate of several thicknesses, as explained previously. The price of iron, necessary for the production of steel products, increased sharply in 2003 because of the concentration of operating companies mining. This increase was reflected throughout the value chain resulting in an increase of more than 25% in the price of the electrolytic tinplate used by CM. Moreover, the main suppliers of these raw materials were very large companies. At the same time, the most important final clients were Lidl, Carrefour, Oldenburger, Campbell, Tesco, DIA, Aldi, among others.

Therefore, as mentioned in the introduction, suppliers and clients of CM had a great power of negotiation. The model of the five competitive forces of Porter was one of the management tools of compulsory use in the "US" company, parent company of CM, so the management was very aware of the threat of these forces, in others words, the bargaining power of clients and suppliers that they represent.

The company studied had completed the implementation of the SAP software only two years before, which should ensure better management and control of its payments and collections system. Specifically, the accounting module at that time allowed setting alarms to warn of payment deadlines. However, there was no alarm when payments were made before the scheduled date. This fact, the advance payment of invoices, as it has been proved later, generated economic problems for CM. At the same time, because of the corporate culture, at the close period, normally monthly, the maximum number of payments were made, even if their expiry date were some days later. This fact, along with other reasons specific to the market where the company operated, meant that very often it was necessary to request money from financial institutions to cover the cash deficit. This represented a real problem of liquidity that worried the management, so they decided to intervene.

The implementation of Six Sigma in CM aimed to balance its cash flow. CM suffered from chronic problems of cash flow deficit. The deficit range was from €−7.5m to €−19m. One of the origins of the problem was the need to produce an inventory or stock (*make to inventory*) imposed by the client. Therefore, CM absorbed the effects of the seasonality of its retail sales instead of its clients. To produce inventory, it was necessary for CM to purchase large quantities of electrolyte tinplate and other raw materials in advance to ensure that it had the necessary stock. The payment terms established by tinplate manufacturers did not reflect the seasonality of CM clients. Moreover, the increase of the price of the electrolytic tinplate used by CM by over 25% aggravated the situation. This was the main cause of the negative cash flow periods.

From the corporate point of view, this situation was unacceptable as it directly affected the interests of the shareholders. At the proposal of the group's European vice president, who had previously worked at the General Electric and had already led a Six Sigma implementation, the board of directors made the decision to implement this strategy in one of their plants to fix the problem. Once the problem was solved effectively, the solution adopted could be applied to other plants of the corporation that suffered similar problems. One of the strengths of Six Sigma is precisely that it analyses problems in depth to solve them in the long term and, its actions could become "transferable" to other similar cases.

Six Sigma is instrumented through the five DMAIC steps methodology and most of its papers apply it in different areas and industries (Srinivasan *et al.*, 2016). General Electric played a very important role in the development of Six Sigma as a methodology because they add the "define" step at the beginning of the measure, analysis, improve and control process to clarify the problem addressed (Antony *et al.*, 2017). DMAIC is especially useful when the cause of the problem is not clear (Snee and Hoerl, 2003) because its five steps are a systematic approach in the search for the best solution.

Kwak and Anbari (2006) detailed the key processes carried out in each step:

- *Define*: Define the requirements and expectations of the customer, the project boundaries and the process by mapping the business flow.

- *Measure*: Measure the process to satisfy customer's needs, develop a data collection plan and compare data to determine issues and shortfalls.
- *Analyse*: Analyse the causes of defects, sources of variation, determine the variations in the process and prioritise opportunities for future improvement.
- *Improve*: Improve the process to eliminate variations, develop creative alternatives and implement enhanced plans.
- *Control*: Control process variations to meet customers' requirements, develop a strategy to monitor and control process and implement the improvements of systems and structures.

In each step, it is important to get useful and reliable information for decision-making (Karout and Awasthi, 2017). In this sense, there are multiple tools and techniques that can be used in each step and represent a vital role in the success of the implementation process. Uluskan (2016) conducted a literature review where he identified the factors most used by the authors according to each step and objective. Some of them are: brainstorming, voice of costumer, process capability, critical to quality (CTQ) tree, flowcharts, value stream maps, box plots, failure mode effects analysis, control charts, cause and effect analysis, Pareto charts, hypothesis testing, ANOVA, etc. In the case studied, DMAIC was applied using different tools and techniques in each step. Table 1 summarises the main tools that were used to achieve the objectives of each phase or step in the case of CM.

5. Implementation of Six Sigma define, measure, analyse, improve and control methodology

The implementation process carried out in the five steps of Six Sigma DMAIC methodology is explained in the following sections.

5.1 Define

In the "define" phase, the main objective of the implementation must be defined, as well as the critical project to be developed. The company should eliminate "defect" through the application of Six Sigma and the expected economic impact (Table 2).

CM had suffered significant cash deficit in the previous 18 months. The reason was that the correlation between the company production and the demand level required by customers was needed to be achieved partially through its stock. For CM, this meant having to maintain a stock of products to ensure that customers were guaranteed the number of products they needed. Given that, in the sector, the majority of customers were large stores or commercial chains, their bargaining power was very large and the company worked

Phase	Tools used	Key learnings
D	CTQs, flow down and process map	Project definition critical and defects often difficult to define
M	Brainstorming and G R&R	Gauge capability can be used with attributes
A	Pareto, Histogram, DPMO and *Zst*	Understanding of project team gets stretched at this point
I	Regression analysis and simulation	People begin to see value
C	Process mapping and DPMO	Consolidation of work, important but not exciting and finishing skills required

Source: Own elaboration

Table 1. Summary of DMAIC in CM

Table 2.
Project charter

Problem statement	Goal statement	Project scope
Significant cash deficit in the previous 18 month lead to company to spend lot of money in bank interest	€120,000 savings per year	The project is scoped for suppliers' management
Project metric/CTQ *y*: Creditor days at cash critical times. Defect = invoice paid at less than contract terms in cash-critical month	Project team - Black belt (J.B.) - Master black belt (R.S.) - Sponsor (F.V.) - Finance team (2 people) - Purchasing team (2 people)	Project timeline 6 month

Source: Own elaboration

almost exclusively for them. CM felt obliged to work in that way. This form of fabrication required the purchase of materials in advance, especially if the supplier did not guarantee its supply when CM needed it. This in turn, meant that the payment terms did not reflect the CM seasonality, but rather theirs. As a result, this situation affected the company's working capital reducing its capacity to return value to CM shareholders.

Therefore, on the one hand, CM usually paid as many invoices as possible, even before the deadline, and, on the other hand, the operation department needed to buy raw materials regardless of whether there was enough cash for payments. In summary, there was not a good coordination between departments.

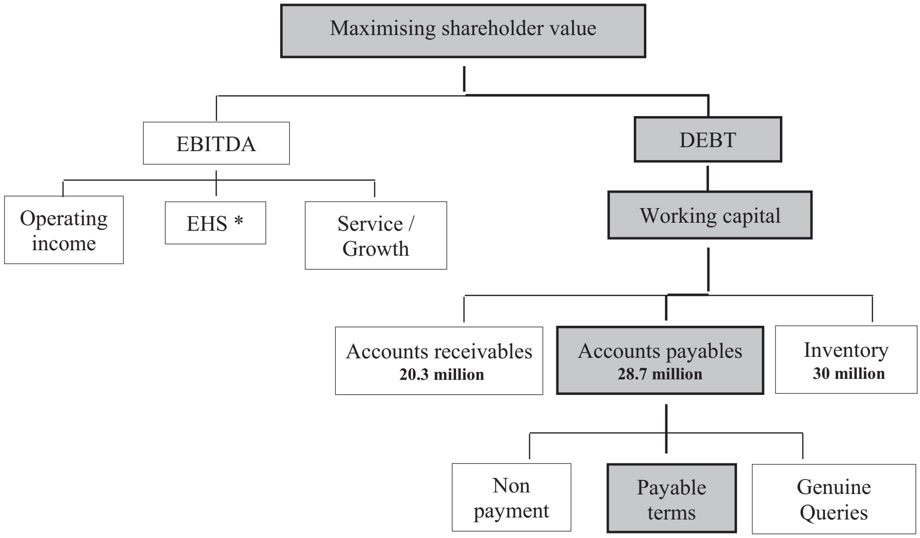
So, the main objective of implementing Six Sigma in CM was to ensure the optimisation of its accounts payable, especially in critical cash months. This was intended to balance and control the level of cash flow, on the one hand reducing or eliminating the advance payments of invoices (considered as defects in this project); and on the other, negotiating with supplier's new payment terms more in line with the average of the sector and with the payment terms that CM had agreed with its customers. In this way, by optimising the accounts payable, the company must be able to maintain a stable cash flow that facilitates an improvement of its relations with financial institutions. With this improvement, it was planned to achieve savings of more than €100,000 per year in interest payments.

To achieve the objective, we identified the variables that we wanted to improve, commonly identified as "Y", "*y*" and the "*x*" variables of the project, that are the factors that affect them and must be modified (Gijo and Rao, 2005). Specifically:

- Y is the main variable that must be monitored, that is, on which it is wanted to act. In our case, it is the working capital, which at that time was €21.6m.
- *y* is the unit to improve to get the Y to improve. We identify the creditors payment days as critical moments, we consider any invoice paid in a less time than expected as a defect.
- *x* are all factors that affect the current payment system and that influence the objective pursued. Therefore, *x* must be improved to avoid the defect defined.

Necessary data was obtained from the accounting module of the SAP software that the company had installed.

A Six Sigma project requires the identification of the CTQs (Gijo and Rao, 2005). CTQs of the project were identified in the first step of DMAIC (Figure 1). A CTQ is a variable or attribute that directly influences the quality of a process that in this case is of a financial nature and whose ultimate goal is the maximisation of the company's profit and the value of



Note: *= Environmental health safety
Source: Own elaboration

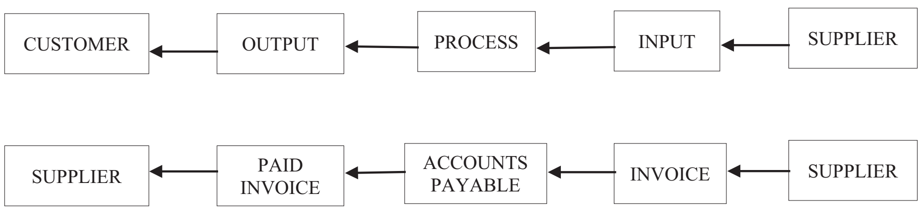
Figure 1. Project CTQs

the shareholder. In the case, the main CTQ, or higher level, of the project was the working capital (Figure 1), hence it is considered as the "Y" of the project and the lowest level CTQ (*y*) was the number of payment days to creditors at critical moments of cash. As shown in the figure, Six Sigma acted in payments made according to the contract, not on the pending payments or invoices not paid.

Finally, process map affected by this project is shown in Figure 2. It represents in an orderly manner the stages that comprise the supplier–client cycle at process level and at financial level.

5.2 Measure

The unit of measure used "*y*" was "creditor days", so the first step was to measure the period of time in which the payments were made to creditors. Through a brainstorming process in which relevant personnel from different departments and members of Six Sigma



Source: Own elaboration

Figure 2. Process map

implementation team participated, the following consensus was reached (standard performance) before proceeding to the analysis of the data:

- The definition of the defect was "invoices paid before the expected deadline in critical months of cash".
- The unit to be taken into account for the subsequent analysis was: "supplier invoice".
- Opportunity = 1. This means that there was 1 chance that each invoice that was to be analysed was right or wrong, that is, within or outside of the specifications established for payment in the corresponding contract.

The definition of the standard performance served to facilitate a later repeatability and reproducibility. Ensuring repeatability implies confirming that if the research was repeated, there would be very little variability in the calculations, while reproducibility refers to the variability that could occur because of the change of operator. Measurement system analysis was performed using gauge R&R tool (Raisinghani *et al.*, 2005; Sunder, 2016). For the validation, three CM operators were chosen. They had to analyse 30 invoices that were randomly chosen from SAP data. The three operators reviewed invoices separately, and on two occasions, the payment days of each of the 30 invoices as a measurement for the analysis. The information derived from these checks is shown in Table 3. If the invoice had been paid within the specified time or later, the invoice passed the analysis (PASS). If, on the contrary, it had been paid before the scheduled date, then it was a defect (FAIL). These two options, PASS and FAIL, appear as attributes in the table. The result gave a gauge of 100% in repeatability and in reproducibility given that there had been no discrepancy between the different measurements made by them. It is observed in the sample analysed that there were more cases of FAIL than PASS (17 out of 30). Therefore, it was found that more invoices were paid in advance, i.e. errors.

The repeatability, reproducibility and accuracy of the measurement system was checked and found a 100% of gauge. Hence, the current measurement system was considered adequate to collect data and did not require further improvement.

5.3 Analyse

In view of the fact that the measurement system was correct, the third phase of DMAIC, the analysis phase, was proceeded. It was intended to answer some questions such as: What are the critical months in terms of cash in CM? Which supplier could be chosen in first place for study? With this supplier, what was the maximum payment term in those months? What was the company capacity to be able to assume these defects or fails? And, what were the sources of variability in the payment system?

To answer the aforementioned questions, in the first place, analysis of the evolution of collections (cash in) and payments (cash out) of prior periods was carried out. It is observed that the critical months were those corresponding to the second quarter (April, May and June) (Figures 3 and 4). Therefore, it meant that it was not possible to maintain payment deadlines to suppliers, especially during those three critical months.

Secondly, to decide which provider to study first, a Pareto diagram was made with raw material suppliers (Figure 5). The reason was that tinplate represented 62.4% of the total payments made to suppliers. The high volume of payments done demonstrated the complexity of the process that they were analysing. It can be observed that the six largest suppliers had represented only 1.4% of all suppliers, but they amounted 73% of the total volume of purchases and CM payments.

Known population		Operator #1		Operator #2		Operator #3	
Sample #	Attribute	Try #1	Try #2	Try #1	Try #2	Try #1	Try #2
1	Pass	Pass	Pass	Pass	Pass	Pass	Pass
2	Pass	Pass	Pass	Pass	Pass	Pass	Pass
3	Fail	Fail	Fail	Fail	Fail	Fail	Fail
4	Pass	Pass	Pass	Pass	Pass	Pass	Pass
5	Fail	Fail	Fail	Fail	Fail	Fail	Fail
6	Fail	Fail	Fail	Fail	Fail	Fail	Fail
7	Pass	Pass	Pass	Pass	Pass	Pass	Pass
8	Pass	Pass	Pass	Pass	Pass	Pass	Pass
9	Pass	Pass	Pass	Pass	Pass	Pass	Pass
10	Fail	Fail	Fail	Fail	Fail	Fail	Fail
11	Pass	Pass	Pass	Pass	Pass	Pass	Pass
12	Pass	Pass	Pass	Pass	Pass	Pass	Pass
13	Pass	Pass	Pass	Pass	Pass	Pass	Pass
14	Fail	Fail	Fail	Fail	Fail	Fail	Fail
15	Fail	Fail	Fail	Fail	Fail	Fail	Fail
16	Fail	Fail	Fail	Fail	Fail	Fail	Fail
17	Pass	Pass	Pass	Pass	Pass	Pass	Pass
18	Fail	Fail	Fail	Fail	Fail	Fail	Fail
19	Fail	Fail	Fail	Fail	Fail	Fail	Fail
20	Pass	Pass	Pass	Pass	Pass	Pass	Pass
21	Fail	Fail	Fail	Fail	Fail	Fail	Fail
22	Fail	Fail	Fail	Fail	Fail	Fail	Fail
23	Fail	Fail	Fail	Fail	Fail	Fail	Fail
24	Pass	Pass	Pass	Pass	Pass	Pass	Pass
25	Fail	Fail	Fail	Fail	Fail	Fail	Fail
26	Fail	Fail	Fail	Fail	Fail	Fail	Fail
27	Fail	Fail	Fail	Fail	Fail	Fail	Fail
28	Fail	Fail	Fail	Fail	Fail	Fail	Fail
29	Pass	Pass	Pass	Pass	Pass	Pass	Pass
30	Fail	Fail	Fail	Fail	Fail	Fail	Fail
% Appraiser score			100%		100%		100%
Score vs attribute			100%		100%		100%

Source: Own elaboration

Table 3. Measurement systems analysis

Suppliers were ordered according to purchase volume (Table 4). The six most important suppliers had payment terms equal to or greater than 60 days, which was the period that had been estimated as industry average. The four most important suppliers had a payment term of 75 days, while the others shown in Table 4 were small suppliers who charged less than 60 days (the amount of that 16% was about €7.63m). Among them, the seventh one was chosen as target supplier for further analysis. This supplier was the first who had a lower payment term compared with industry average and, it represented a purchase spend of 2.9%.

Thirdly, the frequency in terms of number of invoices and their payment days was also analysed for the target supplier (Figure 6) to detect any abnormality in them. If we analyse them, the target supplier had paid 877 invoices with an average of 37 days and a median of 37 days. Likewise, the evolution of these payment terms for such invoices was analysed noting that the disparity detected did not respond to a specific pattern.

As payments to this supplier only represented part of the problem, the solution required considering more providers and more invoices. It was determined the company capacity to assume these payments in the critical months. SAP data revealed that those critical months

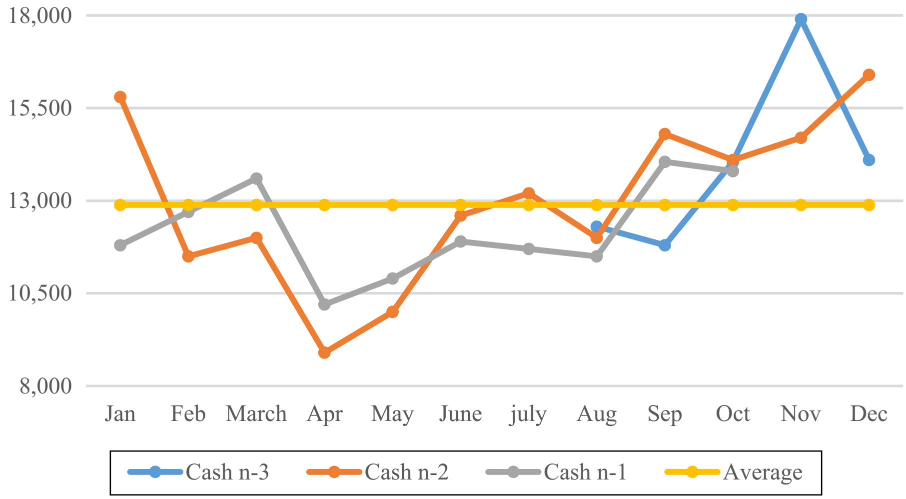


Figure 3. Cash in (in thousands of euros)

Source: Own elaboration

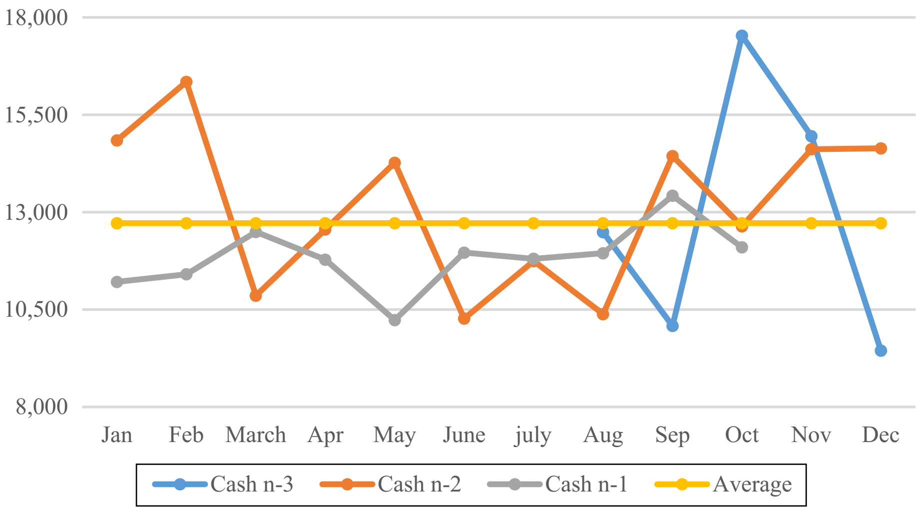


Figure 4. Cash out (in thousands of euros)

Source: Own elaboration

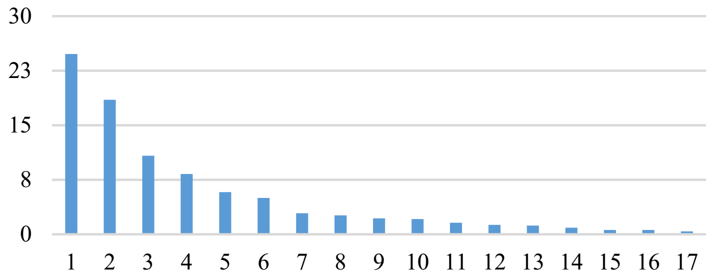
before the implementation of Six Sigma, 198 invoices out of 216 were paid in less than 60 days, which represents the number of defects of the project. In terms of the definition of defect of the Six Sigma methodology, this data suppose that the company works with a value of DPMO of 916,667, which means that the company will end up paying 916,667 invoices of each million in 60 days. The short-term capacity, or short-term Six Sigma level

(Zst), was less than 1. This value of 1 Sigma in the short term is very low as the scale of Six Sigma goes from 0 to 6.

In addition, 8 invoices were found paid in less than 30 days, which represents a DPMO of 37,037 and a Zst of approximately 3.3. We were, therefore, facing a common problem in many companies, but complex.

Finally, in the analysis phase, CM should identify the sources of the payment system variability (X's), that is, the sub processes of the company that affected the objective of the project.

The relationships between variable "current payment term days" and "production" and "cash balance" was investigated to establish a common method for executing payments, and to make decisions that involve all the organisation in the same line. Through a statistical regression, it was found that there was no relationship between these variables. It took 18 months (18 observations) of the 2 years prior to the implementation of the Six Sigma project (Table 5). This result was consistent with the transactional nature of the project. That is, it was demonstrated that statistics was not the best tool.



Source: Own elaboration

Figure 5. Distribution of CM raw material suppliers in purchase volume (in %)

Supplier	% Spend	Days	1st semester n−1 (millions of euros)
1	24.8	75	11.55
2	18.5	75	8.60
3	10.8	75	5.02
4	8.3	75	3.86
5	5.8	60	2.72
6	5	90	2.30
7	2.9	30	1.33
8	2.6	30	1.20
9	2.2	60	1.04
10	2.1	30	0.97
11	1.6	30	0.76
12	1.3	8	0.60
13	1.2	30	0.55
14	0.9	0	0.44
15	0.6	90	0.29
16	0.6	60	0.28
17	0.4	0	0.17

Source: Own elaboration

Table 4. Comparison between CM suppliers in terms of volume and payment term

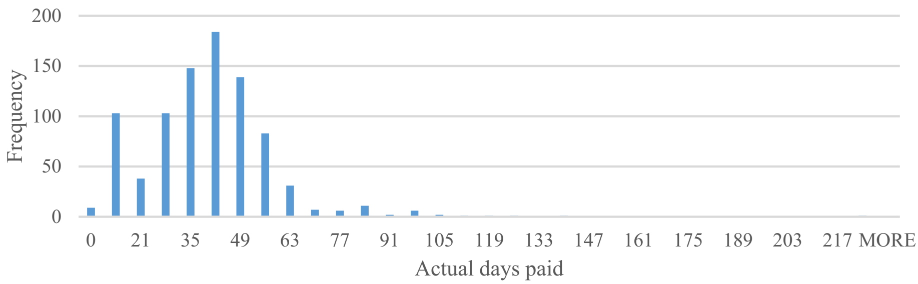
Considering that statistics did not help to solve the problem, the next action was to carry out multiple simulations, in Excel, of the cash flow with different days of payment to see the effect that these produced on cash balance, especially in the critical months. These simulations were carried out with 8 previously detected suppliers whose payment terms were less than 60 days (Table 4). All simulations were shared to provide transparency to the process. These were the perfect visual tools for all the personnel involved to understand that it was necessary to establish a clear policy and protocol regarding the payment terms to suppliers.

In the company, there were several views of this according to the department to which we refer. For example, from the point of view of different departments, for the purchasing department, a short payment period implied incentives and discounts from suppliers. For financial control, the payment days had a marked influence on cash balance. However, the operations department considered that this data apparently did not affect them. The fragmented vision of the company is a frequent mistake in management. It should be considered that ultimately the damage is global.

On the other hand, employees who were involved throughout CM's payment system were also sources of variability. Therefore, it can be said that the sources of variability came from both, process that was established to make payments to suppliers and people who made decisions and executed the process. Therefore, it was a problem related to people and internal process of cash control.

5.4 Improvement

In this phase, the company had to set the improvement objectives and establish a new method of operation and tolerances in relation to the suppliers' payment system. Payment work flow improvement is shown in Figure 7.



Source: Own elaboration

Figure 6. Payment frequency of target supplier invoices

Table 5. Regression statistics

	Beta (no standardised)	Standard error	*T*-stat	*p*-value
Intercept	40.7698309	17.9750264	2.26813746	0.03852067
Production var.	−0.00111055	0.0019388	−0.57280415	0.57526375
Cash balance	−0.00066776	0.00056389	−1.18421148	0.25475543

Note: Dependent variable: current payment terms days; adjusted R^2 = 0.1135363; F = 0.96058333 (no sig.)
Source: Own elaboration

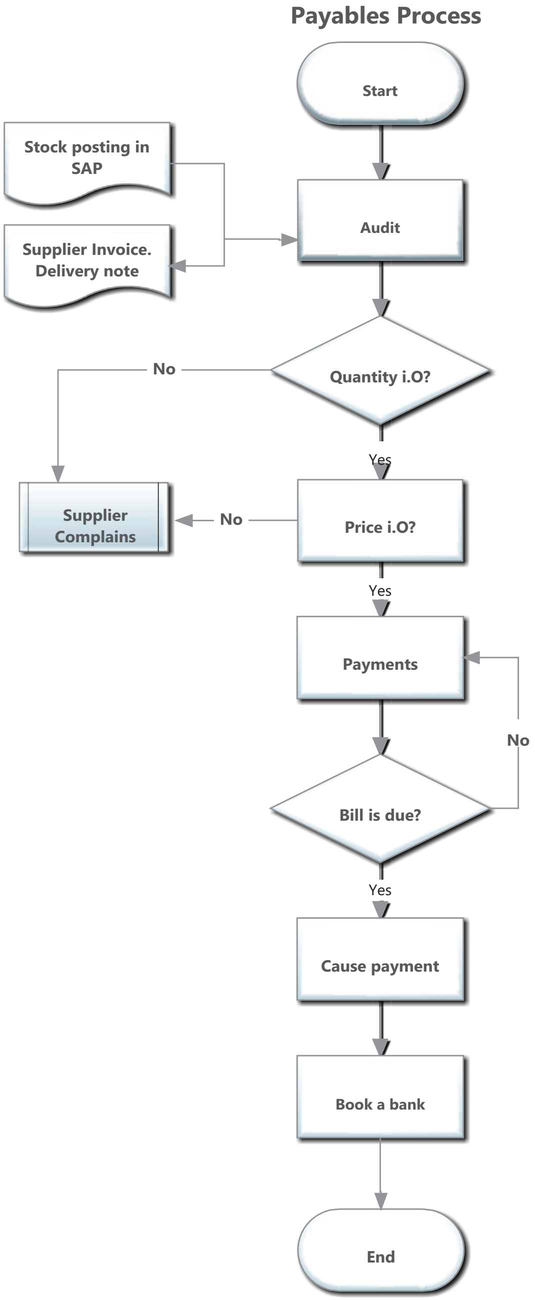


Figure 7. Work flow improvement diagram

In this sense, the company set the following improvement objectives:

- Reduce defects or DPMO value by 80%. This would mean that the number of invoices paid in less than 60 days would be 20, and those paid in less than 30 days would be only 2. The new values of DPMO at 60 days would be 91,667 and at 30 days would be 3,704.
- Improve short-term performance capacity (30 days) to 4.18 Sigma, and less than 60 days of 2.85 Sigma. These values would be in line with other competitors in the sector.
- Maintain, as a reference, 60 days as payment days after doing benchmarking in industry.

It was decided to change all payment terms to 60 days for the critical months (it was called flexible payment), except for those suppliers who were already paying to longer term. This implied establishing a new "method of operation and tolerances". To this end, a letter was drafted that was sent to all suppliers whose payment term was less than 60 days, informing them that from then on, it would be 60 days. A personalised communication was issued to each supplier justifying and reasoning the change. Data and conclusions collected from monitoring the Six Sigma method created a clear and transparent understanding for all the parties involved. Data is aseptic and this allows effective and realistic decision-making. Opinions, on the other hand, are completely discarded in the Six Sigma methodology. It is a positive point of the Six Sigma methodology, which proves numerically the decisions and proposals.

The letter sent to suppliers was written impeccably and with data generated by SAP. Most suppliers understood the situation, some even felt identified. Certain suppliers who refused to accept the new conditions, such as our target supplier, were informed of the end of the contractual relationships and CM looked for an alternative. The large suppliers stayed within the established 75-day deadlines. Before this decision, even some of these suppliers lent themselves to collaborate improving the price of raw materials that, shortly before the implementation of the project, had increased significantly.

It was at this point that the Six Sigma team and the management of the company began to understand that they were in front of an integrated supplier–client strategy that reverted to the cash balance company level.

To ensure that payments were made at least to 60 days, the rules in SAP were set according to the instructions received from the purchasing and financial control departments. Any modern enterprise resource planning (ERP) system allows different rules to be accommodated for the same supplier or client. This function was not incorporated when SAP was implemented in CM, so it was necessary to introduce an alarm for certain suppliers that was activated during the critical months to avoid the mistake of paying them in advance. It was necessary, therefore, human intervention in the computer application was required.

5.5 Control

In the last step of DMAIC (control phase), the validation methodology for measuring results was followed. It was necessary to ensure that CM could commit to pay suppliers on time with the new process. The SAP system was reconfigured to operate with the new standards, so changes implemented were made official. Thus, it was possible to confirm the capacity of the process to guarantee the different payments in the agreed terms, that is, without defects

(DPMO = 0). This meant that the capacity of the process had actually been improved by increasing the Sigma level to 4.2.

The company acquired the routine of periodically reviewing and analysing its cash balance, especially in the months that had previously proved critical.

As a final result and closure of the project, after several months, the actions taken showed that CM would not need to resort to the bank credit line of €11m needed to absorb the previous cash imbalances caused by inventory rules and seasonality. The financial interest savings were €49,000 in the year of implementation of Six Sigma and €120,000 in the following year, which allowed to achieve the expected economic objective.

6. Discussion

This case study conducted in a large company dedicated to the food can manufacture illustrates how Six Sigma may be implemented with higher or less intensity regardless of the type of process or company. In particular, financial processes carried out in the company can also be the objective of a quality improving project. However, quality improvements in this area have not been widely studied in the previous literature, especially as regards the application of the Six Sigma methodology (Blackman *et al.*, 2013; Cunha and Dominguez, 2015; Furterer, 2016; Gutierrez-Gutierrez *et al.*, 2016; Krehbiel *et al.*, 2007; Ogg, 2003).

In this work, it can be seen that the usefulness of the Six Sigma methodology in administrative–financial issues can be common in several companies, as it is in this specific case, the cash flow management through payables and receivables days, in line with Black and Scholes (1973) and O'Connor Keefe and Yaghoubi (2016). In addition, it should be highlighted that the context of the case as occurs in an industry where suppliers and customers have great bargaining power, i.e. the competition is very high. This power can choke companies, even large, especially for the financial costs involved in going to bank financing when necessary.

Well-designed payment and collection processes can guarantee financial stability and balance cash flows in a company to counter suppliers bargaining power. Otherwise, company may lead to continued request for external financing and high interest payments may become a significant problem (Blackman *et al.*, 2013). Previous studies have shown that companies cash flow has a significant relationship with working capital management (Appuhami, 2008; Chiou *et al.*, 2006; Nazir and Afza, 2008; Taleb *et al.*, 2010). This working capital was the variable on which it was intended to act, i.e. "Y". In turn, according to the industry, there were significant differences in terms of working capital, which, moreover, changes over time. Precisely, competitors may influence these changes (Filbeck and Kruege, 2005). That will imply a necessary control to ensure the permanent balance achieved. SAP software, implemented by CM, should facilitate this control by providing reliable data. In this sense, as benefits were obtained from the implementation of ERP systems in Motorola, SAP in CM also led directly to an improvement in the consistency of the data originating from the manufacturing systems (Blackman *et al.*, 2013).

Company situation after implementing the Six Sigma reflected economic benefits measured in improvements in the payment terms conditions more in line with competitors, renewal of suppliers that did not accept the new requirements, alarms settings in SAP to avoid mistakes, among others. A special mention is needed regarding the great interest savings achieved in CM with Six Sigma, as it was expected according to Minton and Schrand (1999) and O'Connor Keefe and Yaghoubi (2016). These results are also consistent with debt being issued in response to the shortfall between cash flow and investment under the pecking order model (Myers, 1984; Myers and Majluf, 1984).

7. Managerial implications and lessons learned

In this article, we have described the problem of cash deficit during certain periods in a large German food can manufacturing company. It was solved through the implementation of Six Sigma methodology. The study shows how the project team developed the DMAIC phases and tools in an orderly manner to arrive to the solution. The different phases followed allowed to improve the "working capital", the CTQ variable.

The success achieved was motivated by the extension of the payment days to suppliers. This led to considerable savings in terms of financial interests. The financial interest savings were €49,000 in the year of implementation of Six Sigma (half year) and €120,000 in the following year. The finance department confirmed that savings obtained were real and, therefore, the value of the Six Sigma methodology is well demonstrated. However, supervision and control of the implemented project is necessary to ensure that the level of defects or invoices paid in advance continues to be zero, that cash flow remain stable and that the "power" of suppliers and clients remains balanced with the company, speaking in terms of the five competitive forces model of Porter.

The lessons learned from the case need to be transferred to the different business units across the organisation, as CM was a subsidiary of US, the parent company.

Transactional business, such as financial services or many of the operations in traditional manufacturing businesses, cannot be met with traditional Six Sigma methodology, as data in most times are qualitative and discrete. In transactional Six Sigma projects, statistics do not really help but the rigour of Six Sigma does. This case is an example of the use of Six Sigma in a transactional process achieving a great reduction of costs.

Nowadays the world is more transactional and to be able to apply Six Sigma in non-productive areas opens a range of possibilities. Moreover, the use of Six Sigma in transactional or commercial situations offers a new dimension in terms of rigour of problem-solving and performance improvement in service sector quality (Goh, 2002).

8. Conclusions

Six Sigma has been widely applied to different industries, especially to eliminate defects, reduce processes variability, improve production quality and increase the satisfaction of the companies' stakeholders. The main contribution of this article focuses on the application of Six Sigma in the financial area of a company and not in production processes in which it has been widely applied and disseminated in the previous literature. Its objective was to balance company cash flow to improve its working capital. With this study, we intend to provide a solution by shedding light on a crucial problem for companies, i.e. cash flow management by using Six Sigma. With this case, we also demonstrated the applicability of Six Sigma in an area where its use has been scarcely attendant. In addition, it should be noted that the project addressed was transferable to other units of the same company and, therefore, it could be applied in other companies that present the same economic situation regardless of its size, industry etc. Moreover, this problem can be common in other companies, regardless of the sector in which they operate, so study results could be easily extrapolated.

On the other hand, the context was also interesting because the food can industry presents some peculiarities. In this industry, the bargaining power of clients and suppliers is very high and therefore, the situation was more difficult to manage.

This work confirms that the Six Sigma is expanding to other fields. Therefore, a greater use of this methodology in other aspects regarding the financial area of the company could be explored in the future.

References

Antony, J. (2006), “Six sigma for service processes”, *Business Process Management Journal*, Vol. 12 No. 2, pp. 234-248.

Antony, J., Gijo, E.V. and Childe, S.J. (2012a), “Case study in six sigma methodology: manufacturing quality improvement and guidance for managers”, *Production Planning and Control*, Vol. 23 No. 8, pp. 624-640.

Antony, J., Bhuller, A.S., Kumar, M., Mendibil, K. and Montgomery, D.C. (2012b), “Application of six sigma DMAIC methodology in a transactional environment”, *International Journal of Quality and Reliability Management*, Vol. 29 No. 1, pp. 31-53.

Antony, J., Snee, R. and Hoerl, R. (2017), “Lean six sigma: yesterday, today and tomorrow”, *International Journal of Quality and Reliability Management*, Vol. 34 No. 7, pp. 1073-1093.

Antony, J., Palsuk, P., Gupta, S., Mishra, D. and Barach, P. (2018), “Six sigma in healthcare: a systematic review of the literature”, *International Journal of Quality and Reliability Management*, Vol. 35 No. 5, pp. 1075-1092.

Appuhami, B.A.R. (2008), “The impact of firms’ capital expenditure on working Capital management: an empirical study across sigma industries in Thailand”, *International Marketing Review*, Vol. 4 No. 1, pp. 8-21.

Benedetto, A. (2003), “Adapting manufacturing-based six sigma methodology to the service environment of a radiology film library”, *Journal of Healthcare Management/American College of Healthcare Executives*, Vol. 48 No. 4, p. 263.

Benito, A. (2003), *The Capital Structure Decisions of Firms: Is There a Pecking Order*, Banco de Espa, Madrid.

Black, F. and Scholes, M. (1973), “The pricing of options and corporate liabilities”, *Journal of Political Economy*, Vol. 81 No. 3, pp. 637-654.

Blackman, I.D., Holland, C.P. and Westcott, T. (2013), “Motorola ‘s global financial supply chain strategy”, *Supply Chain Management: An International Journal*, Vol. 18 No. 2, pp. 132-147.

Brady, J.E. and Allen, T.T. (2006), “Six sigma literature: a review and agenda for future research”, *Quality and Reliability Engineering International*, Vol. 22 No. 3, pp. 335-367.

Chiou, J., Cheng, L. and Wu, H.-W. (2006), “The determinants of working capital management”, *Journal of American Academy of Business*, Vol. 10 No. 1, pp. 149-155.

Choi, B., Kim, J., Leem, B.H., Lee, C.Y. and Hong, H.K. (2012), “Empirical analysis of the relationship between six sigma management activities and corporate competitiveness: focusing on Samsung group in Korea”, *International Journal of Operations and Production Management2*, Vol. 32 No. 5, pp. 528-550.

Cunha, C. and Dominguez, C. (2015), “A DMAIC project to improve warranty billing’s operations: a case study in a Portuguese car dealer”, *Procedia Computer Science*, Vol. 64, pp. 885-893.

Das, S.K. and Hughes, M. (2006), “Improving aluminium can recycling rates: a six sigma study in Kentucky”, *JOM*, Vol. 58 No. 8, pp. 27-31.

DeGroot, H., Rademaekers, K., Smith, M., Svatikova, K., Widerberg, O., Obersteiner, M., Marcarini, A., *et al.* (2012),. *Mapping Resource Prices: The past and the Future, Final Report: Ecorys*, Rotterdam.

Filbeck, G. and Kruege, T.M. (2005), “An analysis of working capital management results across sigma industries”, *American Journal of Business*, Vol. 20 No. 2, pp. 11-20.

Foster, T. (2017), “Does six sigma improve performance?”, *Quality Management Journal*, Vol. 14 No. 4, pp. 7-20.

Furterer, S.L. (2016), *Lean Six Sigma in Service: Applications and Case Studies*, CRC press.

Gibbons, P., Kennedy, C., Burgess, S. and Godfrey, P. (2012), “The development of a value improvement model for repetitive processes (VIM): combining lean, six sigma and systems thinking”, *International Journal of Lean Six Sigma*, Vol. 3 No. 4, pp. 315-338.

Gijo, E.V. and Rao, T.S. (2005), "Six sigma implementation–hurdles and more hurdles", *Total Quality Management and Business Excellence*, Vol. 16 No. 6, pp. 721-725.

Goh, T.N. (2002), "A strategic assessment of six sigma", *Quality and Reliability Engineering International*, Vol. 18 No. 5, pp. 403-410.

Gutierrez-Gutierrez, L., de Leeuw, S. and Dubbers, R. (2016), "Logistics services and lean six sigma implementation: a case study", *International Journal of Lean Six Sigma*, Vol. 7 No. 3, pp. 324-342.

Karout, R. and Awasthi, A. (2017), "Improving software quality using six sigma DMAIC-based approach: a case study", *Business Process Management Journal*, Vol. 23 No. 4, pp. 842-856.

Krehbiel, T.C., Havelka, D. and Scharfenort, M. (2007), "Process monitoring in accounting: implementing pre-control charts", *The Journal of Applied Business Research*, Vol. 23 No. 4, pp. 93-104.

Kwak, Y.H. and Anbari, F.T. (2006), "Benefits, obstacles, and future of six sigma approach", *Technovation*, Vol. 26 Nos 5/6, pp. 708-715.

Linderman, K., Schroeder, R.G., Zaheer, S. and Choo, A.S. (2003), "Six sigma: a goal-theoretic perspective", *Journal of Operations Management*, Vol. 21 No. 2, pp. 193-203.

Minton, B. and Schrand, C. (1999), "The impact of cash flow volatility on discretionary investment and the costs of debt and equity financing", *Journal of Financial Economics*, Vol. 54 No. 3, pp. 423-460.

Myers, S. (1984), "The capital structure puzzle", *The Journal of Finance*, Vol. 39 No. 3, pp. 575-592.

Myers, S. and Majluf, N. (1984), "Corporate financing and investment decisions when firms have information the investors do not have", *Journal of Financial Economics*, Vol. 13 No. 2, pp. 187-221.

Navon, R. (1996), "Company-level cash-flow management", *Journal of Construction Engineering and Management*, Vol. 122 No. 1, pp. 22-29.

Nazir, M. and Afza, T. (2008), "On the factors determining working capital requirements", *Proceedings of ASBBS*, Vol. 15 No. 1, pp. 293-301.

Negi, P.S., Mandaliya, A., Mahida, A., Patel, A. and Patyal, V.S. (2017), "Six sigma in construction industry: a review", *International Journal of Productivity and Quality Management*, Vol. 22 No. 4, pp. 451-465.

Nieminen, H. (2016), *Improving Maintenance in High-Volume Manufacturing. Case: Ball Beverage Packaging Europe*, Lahti University of Applied Sciences.

O'Connor Keefe, M. and Yaghoubi, M. (2016), "The influence of cash flow volatility on capital structure and the use of debt of different maturities", *Journal of Corporate Finance*, Vol. 38, pp. 18-36.

Ogg, S. (2003), "Using six sigma to create value across the supply chain", *Annual Meeting – Council of Logistics Management*, pp. 6-10.

Patterson, A., Bonissone, P. and Pavese, M. (2005), "Six sigma applied throughout the lifecycle of an automated decision system", *Quality and Reliability Engineering International*, Vol. 21 No. 3, pp. 275-292.

Pearlman, D.M. and Chacko, H. (2012), "The quest for quality improvement: using six sigma at starwood hotels and resorts", *International Journal of Hospitality and Tourism Administration*, Vol. 13 No. 1, pp. 48-66.

Peer, S. and Rosental, H. (1982), *Development of Cost Flow Model for Industrialized Housing*, National Building Research Station, Technion, Haifa.

Porter, M.E. (1979), "How competitive forces shape strategy", *Harvard Business Review*, Vol. 57 No. 2, pp. 137-146.

Porter, M.E. (2008), "The five competitive forces that shape strategy", *Harvard Business Review*, Vol. 86 No. 1, pp. 25-40.

Prabhushankar, G.V., Devadasan, S.R., Shalij, P.R. and Thirunavukkarasu, V. (2008), “The origin, history and definition of six sigma: a literature review”, *International Journal of Six Sigma and Competitive Advantage*, Vol. 4 No. 2, pp. 133-150.

Raisinghani, M.S., Ette, H., Pierce, R., Cannon, G. and Daripaly, P. (2005), “Six sigma: concepts, tools, and applications”, *Industrial Management and Data Systems*, Vol. 105 No. 4, pp. 491-505.

Raja Sreedharan, V. and Raju, R. (2016), “A systematic literature review of lean six sigma in different industries”, *International Journal of Lean Six Sigma*, Vol. 7 No. 4, pp. 430-466.

Sambhe, R.U. and Dalu, R.S. (2011), “An empirical investigation of six sigma implementation in medium scale Indian automotive enterprises”, *International Journal of Productivity and Quality Management*, Vol. 8 No. 4, pp. 480-501.

Siddiqui, S.Q., Ullah, F., Thaheem, M.J. and Gabriel, H.F. (2016), “Six sigma in construction: a review of critical success factors”, *International Journal of Lean Six Sigma*, Vol. 7 No. 2, pp. 171-186.

Snee, R.D. (2004), “Six-Sigma: the evolution of 100 years of business improvement methodology”, *International Journal of Six Sigma and Competitive Advantage*, Vol. 1 No. 1, p. 1.

Snee, R.D. and Hoerl, R.W. (2003), *Leading Six Sigma: A Step-by-Step Guide Based on Experience with GE and Other Six Sigma Companies*, Prentice-Hall.

Srinivasan, K., Muthu, S., Devadasan, S.R. and Sugumaran, C. (2016), “Six sigma through DMAIC phases: a literature review”, *International Journal of Productivity and Quality Management*, Vol. 17 No. 2, pp. 236-257.

Stewart, R.A. and Spencer, C.A. (2006), “Six-sigma as a strategy for process improvement on construction projects: a case study”, *Construction Management and Economics*, Vol. 24 No. 4, pp. 339-348.

Sunder, M.V. (2013), “Six sigma-a strategy for increasing employee engagement”, *The Journal for Quality and Participation*, Vol. 36 No. 2, pp. 34-38.

Sunder, M.V. (2016), “Rejects reduction in a retail bank using lean six sigma”, *Production Planning and Control*, Vol. 27 No. 14, pp. 1131-1142.

Sunder, M.V. and Antony, J. (2015), “Six-sigma for improving top-box customer satisfaction score for a banking call Centre”, *Production Planning and Control*, Vol. 26 No. 16, pp. 1291-1305.

Sunder, M.V., Ganesh, L.S. and Marathe, R.R. (2018), “A morphological analysis of research literature on lean six sigma for services”, *International Journal of Operations and Production Management*, Vol. 38 No. 1, pp. 149-182.

Surange, V.G. (2015), “Implementation of six sigma to reduce cost of quality: a case study of automobile sector”, *Journal of Failure Analysis and Prevention*, Vol. 15 No. 2, pp. 282-294.

Taleb, G., Zoued, A. and Shubiri, F. (2010), “The determinants of effective working Capital management policy: a case study on Jordan”, *Interdisciplinary Journal of Contemporary Research in Business*, Vol. 2 No. 4, pp. 248-264.

Tellis, W. (1997), “Introduction to case study”, *The Qualitative Report*, Vol. 3 No. 2, pp. 1-13.

Thomas, A.J., Francis, M., Byard, R. and Fisher, P. (2016), “Implementing lean six sigma to overcome the production challenges in an aerospace company”, *Production Planning and Control*, Vol. 27 Nos 7/8, pp. 591-603.

Uluskan, M. (2016), “A comprehensive insight into the six sigma DMAIC toolbox”, *International Journal of Lean Six Sigma*, Vol. 7 No. 4, pp. 406-429.

Valles, A., Noriega, S., Sanchez, J., Martínez, E. and Salinas, J. (2009), “Six sigma improvement project for automotive speakers in an assembly process”, *International Journal of Industrial Engineering: Theory Applications and Practice*, Vol. 16 No. 3, pp. 182-190.

Vendrame Takao, M.R., Woldt, J. and da Silva, I.B. (2017), “Six sigma methodology advantages for small-and medium-sized enterprises: a case study in the plumbing industry in the United States”, *Advances in Mechanical Engineering*, Vol. 9 No. 10, pp. 1-10.

Yin, R.K. (1984), *Case Study Research: Design and Methods (Applied Social Research Methods)*, Sage Publications.

Yin, R.K. (1994), "Discovering the future of the case study method in evaluation research", *American Journal of Evaluation*, Vol. 15 No. 3, p. 283.

Yin, R.K. (2003), *Case Study Research: Design and Methods*, Sage Publications, Thousand Oaks, CA.

Corresponding author
Angels Niñerola can be contacted at: angels.ninerola@urv.cat