Mapping the DMAIC Tool in the Public Sector: A Bibliometric Literature Review

Marcos Candido da Silva (Corresponding author)
Master Degree Student, Federal University of Amazonas –UFAM. Manaus –AM. Brazil.
ORCID: https://orcid.org/0000-0002-4846-3165
Email: marcoscandidods@gmail.com

Sandro Breval Santiago
Ph.D., Federal University of Amazonas –UFAM. Manaus –AM. Brazil.
ORCID: https://orcid.org/0000-0002-0184-9845
Email: sbreval@gmail.com

Abstract

The quality and continuous improvement of products and processes continue to play an essential role in the business context, with the need for more responsive, flexible, and responsive organizations. Among the many tools and methodologies employed, DMAIC (Define, Measure, Analyze, Improve and Control), linked to Six Sigma, is used to improve existing products or organizational processes. Nevertheless, if in the private sector, the adoption and practice of these tools and methodologies are widely used, in the public sector, in turn, the applicability of DMAIC is little employed. In this perspective, and using the methodological resource of systematic literature review, this article aims to identify the applicability of the DMAIC tool in the public sector. The review indicates that while DMAIC still has low public evidence, the tool can be efficiently applied across the industry, enabling positive results for organizations, reducing costs, delivering efficient processes, and increasing customer satisfaction.

Keywords: DMAIC, Public Sector, Literature Review, Six Sigma, Efficiency.

Introduction

In the private sector, the pursuit of quality has been fundamental to the survival of any company. According to Krishnan (2016), organizations have been consciously plunging into the pursuit of implementing quality initiatives to improve their products and services in light of increasingly severe market conditions.

Successful companies are looking for ways to improve their productivity and efficiency, as well as reduce and control their costs. In public service, the need to provide excellent service to its citizens motivates government entities (Van Seaton, 2009).

In this context of searching for the quality of their products and processes, many organizations employ a Six Sigma tool called DMAIC, which is a methodology that encompasses five steps: defining,

measuring, analyzing, improving and controlling an existing process. According to Harry and Schroeder (2000), in Six Sigma, existing process or product improvement projects are carried out following the DMAIC methodology.

Six Sigma, as a methodology for process excellence, has been widely adopted in manufacturing and service companies. However, its applicability in the public sphere has not been widely explored, with little research on the usefulness of this tool in this area (Antony, Rodgers, and Cudney, 2017; Fletcher, 2018; Lameijer, Zwetsloot, Does, 2018; Kuvvetli and Firuzan, 2019). Although the frequent use of DMAIC is for solving the problem in the private sector, few studies address the practicality of this methodology in the public sector.

Given this, and assuming that the application of DMAIC in the public sphere would result in an improvement of its processes and consequent improvement of service to the community, this article proposes to answer the following question: from a bibliometric study, carried out in specific databases, would it be possible to draw a profile of academic production regarding the application of the DMAIC methodology in public organizations? Thus, in order to answer this problem, this work, through systematic literature review, has the following objective: to identify the practical applications of DMAIC in the public service.

This article has as structure five parts, namely: a) introduction; b) theoretical framework; c) methodology used and d) final considerations. Moreover, at the end is presented the bibliography employed in the research.

Theoretical Referential

Six sigma

Six Sigma is a highly quantitative management strategy that aims to dramatically increase an organization's profitability through improved process and product quality and improved customer and consumer satisfaction (Werkema, 2013a).

It is ratifying this concept, Pyzdek and Keller (2011) report that Six Sigma aims to increase business performance almost entirely without errors. Also, it is customer-driven, focusing on defect prevention, cost reduction, and cycle time reduction, identifying and eliminating non-value-added costs.

DMAIC

DMAIC is a tool used to improve processes and products in companies. According to Werkema (2013b), the DMAIC method is a standardized methodology used for conducting Six Sigma projects whose objective is the implementation of process and product performance improvement.

For process improvement in organizations, Six Sigma uses the DMAIC methodology, which, in a collaborative environment and a staff, identifies a problem and applies a set of tools and techniques in a logical way to arrive at a sustainable solution from the root cause (Shankar, 2009). DMAIC is a methodology structured in five phases: definition, measurement, analysis, improvement, and control of a process, as can be seen in Table 1.

Table 1

DMAIC Steps

Define	The phase identifies the problem or process that requires a solution. To this end, there is a need to be tied to the organization's priorities in order to make the necessary resources available.
Measure	The purpose of this step is to measure and collect necessary information about the process that needs improvement, seeking to understand better what is happening in the process.
Analize	This phase is intended to assist in understanding the factors that affect the process, understanding the cause and effect relationships of the problems encountered, performing statistical analysis of these data.
Improve	The phase enables a better understanding of the process to be improved, determining the form of intervention in the problem.
Control	Control the factors that influence the problem by confirming that the improvement was successful by monitoring it.

Source: Adapted from Shankar, 2009.

According to Improta et al. (2017), Many stages of DMAIC are identical to those used in the PDCA cycle and the Lean Manufacturing System. However, the difference introduced by Six Sigma concerning these is the application and use of statistics to perform data analysis.

Public Management

The state is the sovereign institution that is guaranteed by the legal order and organization of society. It is the instrument by which the politically organized society seeks to achieve its objectives at the political level so that it is through it that national societies regulate and coordinate their social and economic activity (Bresser-Pereira, 2010).

Health, education, justice, welfare, security, among others are services to be provided by the state to its citizens so that their functioning is fundamental for the population. Thus, due to its importance for the quality of life for its citizens and a large number of resources it manages, its excellent management has a decisive factor for society (Oliveira, 2012).

Thus, according to Nascimento (2017), public sector management should be part of a broad development project, providing improvement of organizations and methods, management information, training of their human resources, gaining strategic meaning, emphasizing efficiency and management based on the perception of the complexity of the environment and the problems that will be faced.

Methodological Procedures

The systematic literature review seeks relevant studies on a given theme in literature databases. For Tranfield, Denyer, and Smart (2003) the literature review is fundamental for any research project and aims to allow the researcher to perform mapping and make an existing intellectual assessment, specifying a relevant intellectual research territory to develop knowledge further existing.

The research took place between February and April 2019. Thus, to accomplish this study, the research steps were based on the Kitchenham and Charters (2007) guidelines, namely: a) review planning; b) conduct of the review and c) presentation of the review. Table 2 presents the defined steps.

Table 2

Systematic review steps

PLANNING	1. Identification of the problem 2. Definition of the research objective 3. Definition of search parameters 4. Definition of criteria
EXECUTION	5. Manual database search 6. Identification and selection of articles 7. Portfolio Definition 8. Critical analysis of articles
PRESENTATION	9. Presentation of Results 10. Evaluation of results

Source: Prepared by the authors, adapted from Kitchenham and Charters, 2007

Review Planning

In the planning phase, the first step was the identification of the research problem, which was achieved by finding that, although DMAIC, a process improvement tool, has been widely used in the private sector, in the public sector the applicability of this It is still poorly studied, so there are few empirical studies about its utility in the public sector. Based on this assumption, the problem arose through the following question: From a bibliometric study, carried out in specific databases, would it be possible to draw a profile of academic production regarding the application of the DMAIC methodology in public organizations?

After identifying the study problem, the objective definition was to identify practical applications of DMAIC in public service. Table 3 presents the article search criteria and parameters.

Table 3

Search parameters for review

Parameter	**Description**
Searched Databases	Scopus (Elsevier) Materials Science & Engineering Database Technology Research Database OneFile (GALE) Science Citation Index Expanded (Web of Science)

	Emerald Insight Engineering Research Database Materials Research Database Mechanical & Transportation Engineering Abstracts Materials Business File ScienceDirect Journals (Elsevier) Advanced Technologies & Aerospace Database Elsevier (CrossRef) MEDLINE/PubMed (NLM) Social Sciences Citation Index (Web of Science) Directory of Open Access Journals (DOAJ) Advanced Technologies Database with Aerospace Computer and Information Systems Abstracts Civil Engineering Abstracts SpringerLink	
Material used	Articles	
Research Period	From 2009 to 2019 (April)	
Exclusion Criteria	Review only “peer reviewed articles” Discard repeated articles Delete unavailable articles in full Delete non-free / inaccessible database articles	
Key words	“DMAIC” AND	“Public Administration” “Administração Pública” “Public Service” “Serviço Público” “Government Management” “Gestão Governamental” “Public Sector” “Setor Público”

Source: Prepared by the authors, 2019.

The first parameter was the selection of the CAPES Journal Portal as the database for the collection of articles, since, accessed within the University Campus, it allows full and unrestricted access to a large number of international journal databases, as well as provides access to several other scientific databases. Consequently, in the second parameter, the material to be analysed was defined: journal articles available in full. In the third parameter was delimited that the search period of the articles would be between 2009 and April 2019.

Following, filters for exclusion were determined: a) in the search in the journal bases, the option “peer-reviewed article” was selected; b) in the use of keywords, repeated articles were discarded; c) disposal of unavailable full content articles and d) deletion of those that were not accessible for free and/or with system access error. And finally, still in the search parameters phase, the word “DMAIC” and the boolean operator “AND” were combined with the following keywords: “Public Administration”, “Public Administration”, “Public Service”, “Public Service”, “Government Management”, “Government Management”, “Public Sector”, “Public Sector”.

Finally, three criteria defined choice of material to be analysed: a) empirical articles, in which there was direct and practical application of the DMAIC tool; b) articles that indicate results arising from implantation in a company object of research and c) the need for the company / organization object of study to be or to be part of the public sector.

Conduct of the review

At the end of the planning phase, the articles were manually searched on the platform, applying the keywords, using the option "peer-reviewed articles" as well as selecting the period between 2009 and 2019, which returned the period. One thousand sixty-nine results, as shown in Table 4.

Table 4

Keyword Application Results

		"Public Administration"		157 Results
		"Administração Pública"		2 Results
		"Public Service"		329 Results
		"Serviço Público"		2 Results
"DMAIC"	"AND"	"Government Management"	=	306 Results
		"Gestão Governamental"		0 Results
		"Public Sector"		270 Results
		"Setor Público"		3 Results
		Total		1,069 Results

Source: Prepared by the authors, 2019.

Prior reading of the titles and abstracts of the texts was the step to identify and select articles to meet the objective, identifying 67 articles. Although aligned with the objective of the research, some articles have blocked the full access to the content.

Consequently, when performing the full reading, and using the defined criteria, the following were excluded: a) 09 (nine) non-empirical works, without direct and practical application of the DMAIC tool; b) 01 (one) research without the exposure of the results from the implementation and c) 42 (forty-two) articles not linked to the public sector. Thus, 15 (fifteen) articles constituted the final portfolio of this study. Finally, the selected material was analyzed, identifying: a) the number of articles published per year; b) published journal; c) number of publications by author; d) areas of application of the tools; e) objectives and results achieved; f) objectives and results achieved; g) duration of implementation; h) important aspects and i) critical success factors.

Presentation of the review

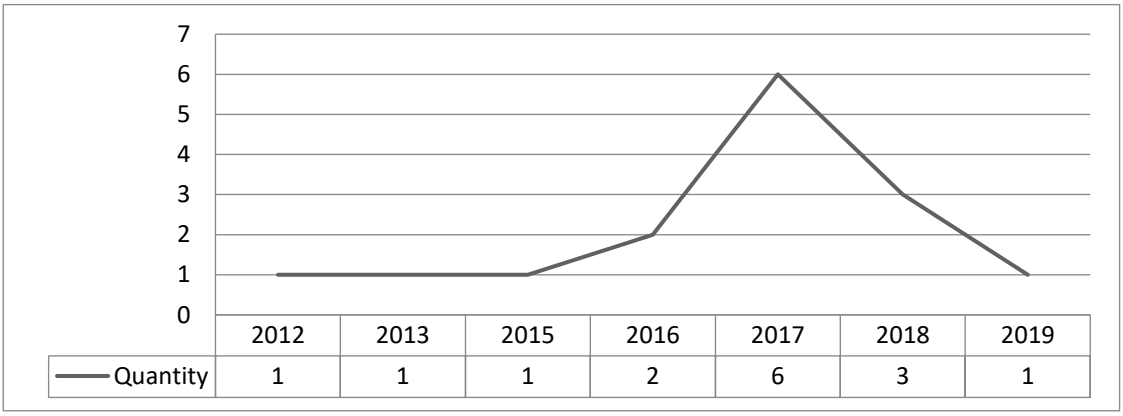
The following item presents findings and discussions of the research.

Results and Discussions

In this section, we will present the results of the literature review on the theme to which this paper proposed. The analysis of the period from 2009 to 2019, as observed in Figure 1, the years 2012, 2013, and 2015, there was only one publication each year. On the other hand, the year 2016 has a record of two authors, and in 2017, there was the apex of publications, with a record of six articles. In 2018, compared to the previous year, there was a reduction in publications, with a record of three works. Finally, in 2019, there was a single publication on the topic researched.

Figure 1

Number of Articles



Source: Prepared by the authors, 2019.

After the quantification stage of articles published per year, the periodicals began to be verified. According to Table 5, among the most published journals, three papers were presented in the Journal of Evaluation in Clinical Practice and two papers in the International Journal of Health Care Quality Assurance, both specializing in health. Already, in the "International Journal of Productivity and Performance Management" there are two articles. Moreover, finally, a single work was released respectively in the following journals: "BMC Health Services Research", "Einstein", "International Journal for Quality Research", "International Journal of Lean Six Sigma", "International Journal of Quality & Reliability Management", "Leadership in Health Services", "Saudi Journal of Medicine & Medical Sciences", and "Total Quality Management & Business Excellence".

Table 5

Published Journals

Journal	**Quantity**
Journal of Evaluation in Clinical Practice	3
International Journal of Health Care Quality Assurance	2
International Journal of Productivity and Performance Management	2
BMC Health Services Research	1
Einstein	1
International Journal for Quality Research	1

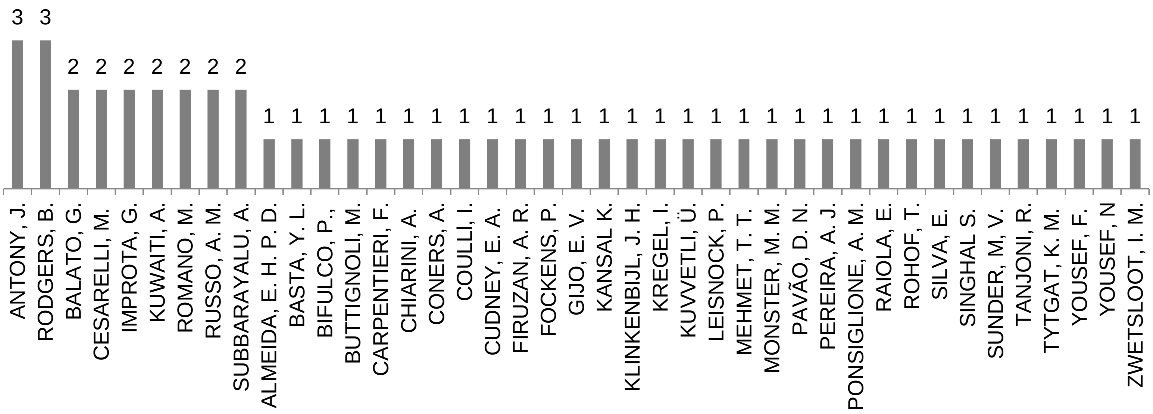
International Journal of Lean Six Sigma	1
International Journal of Quality & Reliability Management	1
Leadership in Health Services	1
Saudi Journal of Medicine & Medical Sciences	1
Total Quality Management & Business Excellence	1

Source: Prepared by the authors, 2019.

Consequently, we proceeded to the verification phase of the most prolific authors, that is, the authors with the highest index of publications of the theme analyzed. In this phase, the authors were separated individually for a better presentation of the results. This time, and as can be seen in Figure 2, Antony, J. and Rodgers, B. emerge as the researchers who contributed the most with publications on the studied subject, each collaborating with three published works. Accordingly, Balato, G.; Cesarelli, M.; Improta, G.; Kuwaiti, A.; Romano, M.; Russo, A. M. and Subbarayalu, A. participated with the publication of two works, respectively. Thus, these were the researchers who stood out about the others.

Figure 2

Publications by Author



Source: Prepared by the authors, 2019.

Finally, only one published article contributed by the following authors: Almeida, E. H. P. D.; Enough, Y. L.; Bifulco, P.; Buttignoll, M.; Carpentieri, F .; Chiarini, A .; Coners, A .; Coulll, I .; Cudney, E.A .; Firuzan, A. R .; Fockens, P .; Gijo, E. V .; Kansal K .; Klinkenbijl, J. H .; Kregel, I .; Kuvvetli, Ü .; Leisnock, P .; Mehmet, T.T .; Monster, M. M .; Peacock, D.N .; Pereira, A. J .; Ponsiglione, A. M .; Raiola, E .; Rohof, T .; Silva, E .; Singhal S .; Sunder, M, V .; Tanjoni, R .; Tytgat, K. M .; Yousef, F .; Yousef, N. and Zwetsloot, I. M.

The next phase determines areas of the public sector where the tool was applied. As can be seen in Table 6, nine of the fourteen studies applied the tool in the health sector, representing 60% of the total. These results indicate the broad applicability of DMAIC in the public health sector. In turn, two types of research brought the application of DMAIC in different sectors of the public, offering examples of its

applicability in several areas. Finally, the applicability in the areas of service delivery, public security, and the municipal executive presented, respectively, only a single work.

Table 6

Application Areas

Area	Health	Miscellaneous	Provision of Services	Public Safety	Municipal Executive	Public Transportation
Quantity	9	2	1	1	1	1

Source: Prepared by the authors, 2019.

In the subsequent stage, the analysis, categorized in their respective areas, of the proposed objectives and the results achieved for each published work was carried out. In this perspective, most of the articles presented their structure divided according to the steps of DMAIC (Definition, Measurement, Analysis, Improvement, and Control), presenting in each step the tools and techniques used.

Preliminarily, and by Table 7, there are papers on health. As can be seen, the use of DMAIC in the public health sector was effective, bringing excellent results in the departments where the methodology was employed. Studies have indicated different DMAIC jobs: Chiarini (2012) used DMAIC to mitigate risks that doctors and nurses were likely to handle, prepare, and administer cancer drugs. In addition to achieving reduced risk for the professionals performing those activities, the author points out that the process has become more efficient by reducing operating costs and process waste through training provided to employees and creating instructions standardization of tasks. Also, there was a centralization of activities through the creation of a unit for drug management, including providing better storage of medicines.

Table 7

Health Goals and Results

References	**Objetive**	**Results Achieved**
Chiarini (2012)	Investigating how Six Sigma and its tools could reduce the risks related to cancer drug preparation, handling, and administration. As well as analyze the economic improvements achieved by using Six Sigma.	a) Risk reduction for doctors and nurses; b) More efficient processes; c) Cost reduction; d) Waste reduction; e) Better storage of medicines; f) Training, work instructions and software; g) Creation of a centralized unit for drug management.
Improta et al. (2015)	Use Six Sigma to reduce the length of stay of patients undergoing hip replacement surgery.	a) Reduction of hospitalization time by 44%; b) Reduction of queues; c) Quality improvement in the provision of services; d) Reduction of operating costs; e) Increased customer / patient satisfaction.

Yousef and Yousef (2017)	Use Six Sigma to reduce errors in medication administered to patients in a hospital.	a) drastic error reduction; b) Increased safety for the patient; c) Training of medical staff; d) Process automation.
Mehmet (2013)	Apply Six Sigma to minimize Intra and postoperative complication rates at a cataract surgery unit in a Turkish public hospital.	a) Decrease in complication rate from 13% to 1%; b) Increased efficiency of internal processes.
Kuwaiti and Subbarayalu (2017b)	Study the effect of the Six Sigma DMAIC approach on reducing nosocomial infections	a) Decrease in the hospital stay rate; b) Increased patient safety; c) Increased patient satisfaction; d) Decrease in mortality rates; e) Cost reduction; f) Reduction of hospital stay.
Improta et al. (2017)	Application of DMAIC to decrease the length of hospital stay for knee prosthesis surgeries.	a) 44% reduction in hospital stay; b) Quality improvement in the provision of services; c) Cost reduction; d) Estimated savings of 260 thousand euros; e) Patient satisfaction.
Basta (2016)	Reduce the time to send/dispatch medical reports with the application of Six Sigma.	a) Goal achieved (90.6%) was higher than initially set (12.8%); b) Increased efficiency in the daily reporting process.
Pavão (2018)	Verify the impact of Six Sigma on reducing incorrect accounting entries of inappropriate income and expenses in a public hospital.	a) Reduction of incorrect entries; b) Made the process more efficient; c) ensuring compliance with accountability; d) Greater cost accuracy and posted results.
Kuwaiti and Subbarayalu (2017a)	To evaluate the impact of DMAIC on reducing the fall rate of patients in a hospital.	a) Goal achieved (70%) was higher than initially set (60%); b) Creation of a fall prevention program.

Source: Prepared by the authors, 2019.

Therefore, Improta et al. (2015) present how DMAIC subsidized the reduction of hospitalization time of patients undergoing hip prosthesis surgery. After the application of the tool, the length of hospital stay decreased by 44%, providing improved quality of services, cost reduction, waiting time in the hospital, so these improvements reflected in the increased satisfaction of patients treated at the hospital.

In turn, Yousef and Yousef (2017) published a DMAIC application study to decrease medication application errors in medical center patients. As a result, errors have been drastically reduced, bringing more excellent safety for patients. To this end, the professionals underwent training, especially regarding the handwriting of doctors, since the highest rate of errors was when prescribing drugs by the doctor. Also, the prescribing process was automated to reduce the recurrence of errors.

Similarly, DMAIC proved effective in minimizing Intra and postoperative complication rates in a cataract surgery unit in a Turkish hospital, reducing this rate from 13% to 1%, increasing the efficiency of the internal procedures of the cataract surgery sector (Mehmet, 2013). Similarly, Kuwaiti and Subbarayalu (2017b) show that DMAIC was effective in reducing the number of nosocomial infections. Moreover, application of the tool provided: decreased hospitalization rate, increased safety, and patient satisfaction, attenuation of mortality rates, cost reduction, and length of hospital stay.

In the study published by Improta et at. (2017) it has been reported that the application of DMAIC reduced by 44% the reduction in the length of hospital stay for knee prosthesis surgeries. At the same time, there was an improvement in the quality of services offered, cost reduction, and the authors estimate annual savings of 260 thousand euros. Basta (2016), in turn, stipulated that sending daily medical reports on a given hospital case would be reduced by 12.8%. However, the tool was able to reduce reporting time to another industry by 90.6%, causing reports to be dispatched almost immediately, far beyond the preliminary stipulations, dramatically increasing the efficiency of that process.

Pavão et al. (2018) present the only case study found in Brazilian soil in a public hospital in the interior of São Paulo. The study found that DMAIC reduced the number of incorrect accounting entries and expenses, making accountability under current legislation and making the process more efficient. Finally, Kuwaiti and Subbarayalu (2017a) present a study in which DMAIC reduced the number of patient falls in the hospital environment by 70%, creating a permanent fall reduction program throughout the hospital.

That said, we began to analyze the applicability of the method in the area called “miscellaneous”, which exposes different cases of the use of DMAIC in the public context, as presented in Table 8. The work presented by Antony, Rodgers, and Cudney (2017) the objective of this paper was to discuss the use of Six Sigma and its possible applications in the public sector context. To this end, it explained four contexts in which the DMAIC tool was used to achieve the objectives. The tool concludes that: The tool can be applied across all public sector organizations, creating more effective processes, increasing customer satisfaction, reducing costs, and saving organizational resources. Also, it guaranteed quality, punctuality, and reliability in providing the services performed.

Table 8

Objectives and results from various areas

References	Objective	Results Achieved
Antony, Rodgers, and Cudney (2017)	Discuss the use of Six Sigma and its possible applications in the public sector context.	a) The methodology has the potential for application in all public sector organizations; b) Created efficient processes; c) Increased customer satisfaction; d) Cost reduction; e) Resource-saving; f) Guaranteed quality, punctuality, and reliability in the provision of services.

Antony, Rodgers, and Gijo (2016)	Demonstrate the application of Six Sigma in the UK public sector, and some of the successful applications of this methodology.	a) Methodology applicable to the health, justice, education and municipal executive sector; b) Increased efficiency in the provision of services.

Source: Prepared by the authors, 2019.

Similarly, Antony, Rodgers, and Gijo (2016) published a study similar to the previous one. In this, the researchers demonstrated, through the presentation of case studies, success in the use of DMAIC in the UK public sector. The method proved to be efficient and effective, improving service delivery in the justice, health, education, and local government sectors.

Regarding these two studies, unlike other research presented, the authors demonstrated multiple cases, leaving the scope of restriction to the specific internal environment, and encompassing multiple studies, increasing the effectiveness and valuation of the applicability of the tool. Patient safety is a typical result of these studies. In most studies, there is a concern with preserving the life of patients.

Continually, and as outlined in Table 9, the service-related study shows the effectiveness of DMAIC in reducing the number of weather reports published with delays in a weather forecast company, avalanches, and customer data services. As a result, the number of late published reports reduced from 32% to 6%, making the process more efficient, and this reverberated on customer satisfaction as the satisfaction rate went from 77% to 85% (Kansal and Singhal, 2017).

Table 9

Objectives and outcomes in service delivery

References	**Objective**	**Results Achieved**
Kansal and Singhal (2017)	Use Six Sigma to increase customer satisfaction at a government company in weather, avalanche, and customer data services. (Mitigate Himalayan disasters and avalanches)	a) Reduced the number of late reports from 32% to 6%; b) Customer satisfaction rose from 77% to 85%; c) The reporting process has become more efficient.

Source: Prepared by the authors, 2019.

Therefore, in the area of "public services" Antony et at. (2018) presented a case study in which Six Sigma was successfully implemented using DMAIC in the administrative services of a Scottish police criminal justice division. The study identified excessive spending on travel payments and server attendance at external meetings, as explained in Table 10. This time, the tool made it possible to reduce server travel costs by 78%, as well as reduce travel costs by 43% servers that attended external meetings and events.

Table 10

Objectives and results in public safety

References	Objective	Results Achieved
Antony et al. (2018)	Present a series of learning points from a successful implementation of Six Sigma in an overall Scottish Police Service program	a) Optimizing the efficiency of internal processes in a police sector; b) 78% reduction in server travel costs; c) 43% reduction in the number of people attending external meetings.

Source: Prepared by the authors, 2019.

Also, as shown in Table 11, DMAIC has been used in several internal processes in a German city hall, providing the optimization of its internal processes and reducing costs. Thus, once again, it was proved that the tool was useful for solving those problems (Kregel and Coners, 2018).

Table 11

Objectives and results in the municipal executive

References	Objective	Results Achieved
Kregel and Coners (2018)	Expand knowledge about the implementation of Six Sigma in the public sector by implementing Six Sigma in a German municipality.	a) Increase in the efficiency of several inmates of the city hall; b) Cost reduction.

Source: Prepared by the authors, 2019.

Finally, Kuvvetli and Firuzan (2019) used DMAIC to reduce the number of public transport bus accidents in a city in Turkey by 20%, generating savings estimated at $ 130,000 annually, as shown in Table 12.

Table 12

Objectives and Results on Public Transport

References	Objective	Results Achieved
Kuvvetli and Firuzan (2019)	Reduction in the number of accidents involving buses in the urban municipal public transport service in a Turkish city.	a) Reduction of 20% in the number of accidents; b) Estimated savings of US $ 130 thousand per year.

Source: Prepared by the authors, 2019.

It was possible to verify the reach of the objectives proposed by the authors, so that in some cases, the achieved results exceeded the initial objectives, proving the applicability of the DMAIC in the public sector.

It is worth highlighting some typical results observed in several of the studies mentioned above. DMAIC provided cost savings in Chiarini (2012); Improta et al. (2015); Kuwaiti and Subbarayalu (2017);

Improta et al. (2017); Antony, Rodgers, and Cudney (2017); Kuvvetli and Firuzan (2019); as well as in Kregel and Coners (2018). Another critical aspect pointed out by: Chiarini (2012); Mehmet (2013); Basta et al. (2016); Peacock et al. (2018); Antony, Rodgers and Cudney (2017); Antony, Rodgers and Gijo (2016); Antony et al. (2018); as well as in Kregel and Coners (2018), it was a fact that the tool enabled more efficient processes in the provision of public activities. In turn, the following cases also showed customer satisfaction: Improta et al. (2015); Kuwaiti and Subbarayalu (2017); Improta et al. (2017); Antony, Rodgers, and Cudney (2017) and Kansal and Singhal (2017).

Continuing this research, except for the works of Antony, Rodgers, and Cudney (2017); Antony, Rodgers and Gijo (2016) and Kansal and Singhal (2017) who did not inform the program implementation time, noting the average duration of the program implementation, so the respective areas had divided average times. Thus, as can be seen in Table 13, in the area of "health" the average time was 19.8 months; in the area "public safety" was 6 months; the "municipal executive" area presented 30 months; Finally, in the "public transport" area, the average implementation time was 12 months.

Table 13

Average Implementation Time

Area	**Referências**	**Average time**
Health sector	Chiarini (2012)	19.8 months
	Improta et al. (2015)	
	Yousef and Yousef (2017)	
	Mehmet (2013)	
	Kuwaiti and Subbarayalu (2017a)	
	Improta et al. (2017)	
	Basta (2016)	
	Pavão (2018)	
	Kuwaiti and Subbarayalu (2017b)	
Several areas	Antony, Rodgers, and Cudney (2017)	Uninformed
	Antony, Rodgers, and Gijo (2016)	
Provision of Services	Kansal and Singhal (2017)	Uninformed
Public security	Antony et al. (2018)	6 months
Municipal Executive	Kregel and Coners (2018)	30 months
Public transportation	Kuvvetli and Firuzan (2019)	12 months

Source: Prepared by the authors, 2019.

As mentioned earlier, there was only one study conducted in Brazil, all other research occurred mainly in Europe and Asia, making it clear that although DMAIC offers several advantages when using it, there is no history of many cases applied in the public service Brazilian. We must ask why this data, because if the tool is useful, why not use it to achieve excellent results in Brazil?

It is relevant to highlight the context of the use of the tool in many of the cases assessed. Antony, Rodgers, and Cudney (2017); Antony, Rodgers, and Gijo (2016) and Antony et al. (2018), who were among the most prolific authors, point out that there were cuts in the public budget, requiring cost reductions and optimization of public services. That is, there was a context in which there was a need to look for

alternatives to achieve the public interest so that the public manager needed to be efficient, using the few resources available, so one of the ways out was the adoption of this tool widely used in private service, applied to the public sector.

From now on, it started to verify the critical success factors pointed out expressly by the studied authors. For Fernandes and Abreu (2014), critical success factors are critical points in which organizations need to have good results in order to be successful, achieving their goals. Table 14 presents the factors observed in this research.

Table 14

Critical Success Factors

Critical fator	**Cited by**
Resistance to change	Kansal and Singhal (2017); Kregel and Coners (2018); Kuvvetli and Firuzan (2019)
Organizational culture	Kansal and Singhal (2017); Kregel and Coners (2018); Pavão et al. (2018)
Employee psychological factors	Chiarini (2012)
Training	Chiarini (2012); Pavão et al. (2018); Yousef and Yousef (2017)
Senior Management Participation	Kregel and Coners (2018); Improta et al. (2015)
Motivation and team involvement	Improta et al. (2015); Kuwaiti and Subbarayalu (2017)

Source: Prepared by the authors, 2019.

Resistance to change, organizational culture, employee psychological factors, training, senior management participation, motivation, and team involvement were essential factors for the implementation of DMAIC in the organizations under study. Organizational culture, training, and resistance to change, since they presented themselves more often.

Final Considerations

Although DMAIC has high acceptance and uses in private sector companies, in the public sector, it is still incipient. From this context, this research aimed to identify the applicability of the DMAIC tool in the public sector, using the systematic literature review. Prospecting a portfolio of 15 articles made it possible to prove compliance with the proposed objectives, namely: a) empirical studies b) applied to the public sphere and c) indicating the results achieved.

The results of the analyses indicated that the tool finds a favourable environment for application in both public companies and private organizations. Firstly, by the fact that 100% of the evaluated works reached the objectives they intended, and in some cases extrapolated the previously proposed claims. Second, because the results achieved are extremely satisfactory for those who used DMAIC for process improvement, among others: cost reduction, increased efficiency, and consequent improvement in customer satisfaction.

Regarding the critical success factors, resistance to change, organizational culture, employee psychological factors, training, senior management participation, motivation, and team involvement were essential elements for the achievement of objectives in the cases assessed.

Besides, the study showed that the tool has full application in the health sector since 60% of the studies dealing with the application of DMAIC in such sectors. Antony and Rodgers were the authors with the highest index of publications on the theme. Also, the journal with the most significant number of publications, out of three, was the "Journal of Evaluation in Clinical Practice." Moreover, the authors pointed out that cuts in the public budget required cost reductions and optimization of public services, leading the public sector to seek other ways to achieve its results. Also, the study allowed the identification of the average duration of the tool implementation in the evaluated works, namely: "health" (19.8 months); "Public safety" (06 months); "Municipal executive" (30 months) and "public transportation" (12 months).

The difficulty of access to some articles was a limiting factor of this study since, despite appearing to be aligned with the objectives of this research, full access to the text was unavailable. Likewise, when analyzing each work, except for two papers that presented different case studies, it was found that each work was limited to the application environment, making it difficult to generalize since the public scope is vast.

Finally, noting that DMAIC studies in Brazil, concerning other countries are still scarcer, and mainly because this paper presents a single case study in Brazilian soil, consequently prompts propositions of new studies that investigate why not use them of the tool in the Brazilian public sector, given that the results from its use are efficient to reach the Brazilian public interest.

References

Antony, J., Rodgers, B., Coull, I., & Sunder M, V. (2018). Lean Six Sigma in policing services: A case study from an organizational learning perspective. *International Journal of Productivity and Performance Management, 67*(5), 935-940.

Antony, J., Rodgers, B., & Cudney, E. A. (2017). Lean Six Sigma for public sector organizations: is it a myth or reality*?*. *International Journal of Quality & Reliability Management, 34*(9), 1402-1411.

Antony, J., Rodgers, B., & Gijo, E. V. (2016). Can Lean Six Sigma make UK public sector organizations more efficient and effective?. *International Journal of Productivity and Performance Management, 65*(7), 995-1002.

Basta, Y. L., Zwetsloot, I. M., Klinkenbijl, J. H., Rohof, T., Monster, M. M., Fockens, P., & Tytgat, K. M. (2016). Decreasing the dispatch time of medical reports sent from hospital to primary care with *Lean Six Sigma. Journal of evaluation in clinical practice, 22*(5), 690-698.

Bresser-Pereira, L. C. (2010). *The political construction of the State*. Lua Nova, São Paulo, n. 81, p. 117-146.

Chiarini, A. (2012). Risk management and cost reduction of cancer drugs using Lean Six Sigma tools. *Leadership in Health Services, 25*(4), 318-330.

Fernandes, A. A., & De Abreu, V. F. (2014). *Deploying IT Governance: From Strategy to Process and Service Management (in Portuguese)*. – 4ª ed. – Rio de Janeiro: Brasport.

Fletcher, J. (2018). Opportunities for Lean Six Sigma in public sector municipalities. *International Journal of Lean Six Sigma, 9*(2), 256-267.

Harry, M. J., & Schroeder, R. (2000). *The Breakthrough Management Strategy Revolutionizing the World's Top Corporotions*. Newyork, NY.

Improta, G., Balato, G., Romano, M., Carpentieri, F., Bifulco, P., Alessandro Russo, M., ... & Cesarelli, M. (2015). Lean Six Sigma: a new approach to the management of patients undergoing prosthetic hip replacement surgery. *Journal of evaluation in clinical practice, 21*(4), 662-672.

Improta, G., Balato, G., Romano, M., Ponsiglione, A. M., Raiola, E., Russo, M. A., ... & Cesarelli, M. (2017). Improving performances of the knee replacement surgery process by applying DMAIC principles. *Journal of evaluation in clinical practice, 23*(6), 1401-1407.

Kansal, J., & Singhal, S. (2017). Application and Validation of DMAIC Six Sigma Tool for Enhancing Customer Satisfaction in a Government R&D Organization. *International Journal for Quality Research, 11*(4).

Kitchenham, B., & Charters, S. (2007). Guidelines for performing systematic literature reviews in software engineering. In: *Technical repor*t, Ver. 2.3 EBSE Technical Report. EBSE.

Kregel, I., & Coners, A. (2018). Introducing Lean Six Sigma to a German municipality: an action research report. *International Journal of Lean Six Sigma, 9*(2), 221-237.

Krishnan, A. (2016). Implementation of quality initiatives in Indian public and private sector organizations: a comparative analysis. *International Journal of Quality & Reliability Management, 33*(2), 246-266.

Kuvvetli, Ü., & Firuzan, A. R. (2019). Applying Six Sigma in urban public transportation to reduce traffic accidents involving municipality buses. *Total Quality Management & Business Excellence, 30*(1-2), 82-107.

Kuwaiti, A. A., & Subbarayalu, A. V. (2017a). Reducing patients' falls rate in an Academic Medical Center (AMC) using Six Sigma "DMAIC" approach. *International journal of health care quality assurance, 30*(4), 373-384.

Al Kuwaiti, A., & Subbarayalu, A. V. (2017b). Reducing hospital-acquired infection rate using the Six Sigma DMAIC approach. Saudi journal of medicine & medical sciences, 5(3), 260.

Lameijer, B. A., Zwetsloot, I. M., & Does, R. J. (2018). Discussion of "Quality and statistical thinking in a parliament and beyond". *Quality Engineering, 30*(1), 27-33.

Tolga Taner, Mehmet. (2013). Application of Six Sigma methodology to a cataract surgery unit. *International Journal of Health Care Quality Assurance, 26*(8), 768-785.

Nascimento, E.R. (2017). *Public administration (in Portuguese).* rev. e atual. São Paulo: Saraiva.

Oliveira, R. (2015). *Public management: democracy and efficiency - a practical and political view (in Portuguese)*. Editora FGV, Rio de Janeiro.

Pavão, D. N., Buttignol, M., Pereira, A. J., Tanjoni, R., Almeida, E. H. P. D., Leisnock, P., & Silva, E. (2018). Efficiency in the operational process: reduction of incorrect entries and guarantee of compliance in the rendering of accounts. *Einstein* (São Paulo), 16(4).

Pyzdek, T., & Keller, P. (2011). *Six Sigma: The Professional Guide - A Complete Guide for Green Belts, Black Belts, and Managers of All Levels (in Portuguese).* Rio de Janeiro: Alta Books; 2011. 560 p.

Shankar, R. (2009). *Process improvement using six sigma: a DMAIC guide*. ASQ Quality Press.

Tranfield, D., Denyer, D., & Smart, P. (2003). Towards a methodology for developing evidence informed management knowledge by means of systematic review. *British journal of management, 14*(3), 207-222.

Van Seaton, H. (2009*). The organizational cultural perceptions of implementing six sigma in a government enterprise.* Issues in Innovation, 3(2), 71.

Werkema, C. (2013a). *Creating Lean Six Sigma Culture (in Portugese).* 2. ed. - Rio de Janeiro: Elsevier Brasil.

Werkema, C. (2013b). PDCA and Demaic Methods and Their Analytical Tools (in Portuguese) (Vol. 1). Elsevier Brasil.

Yousef, N., & Yousef, F. (2017). Using total quality management approach to improve patient safety by preventing medication error incidences. *BMC health services research, 17*(1), 621.