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Increasing Sigma levels in productivity improvement and industrial sustainability with Six Sigma methods in manufacturing industry: A systematic literature review

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A B S T R A C T

Industrial sustainability is an important attribute and becomes a parameter of the business success. Quality improvement with an indicator of increasing process capability will affect productivity improvements and lead to industrial competitiveness and maintain industrial sustainability. The purpose of this paper is to obtain a relationship between the consistency of the DMAIC phase to increase the sigma level in productivity improvement and industrial sustainability. This paper applied for a systematic literature review from various sources of trusted articles from 2006 to 2019 using the keywords "Six Sigma, Productivity, and Industrial Sustainability." A matrix was developed to provide synthesis and summary of the literature. Six Sigma approach has been successful in reducing product variation, defects, cycle time, production costs, as well as increasing customer satisfaction, cost savings, profits, and competitiveness to maintain industrial sustainability. Extraction and synthesis in this study managed to obtain seven objectives value that found a consistent relationship between the DMAIC phase of increasing sigma levels, productivity, and industrial sustainability. The broad scope of Six Sigma literature is very beneficial for organizations to understand the critical variables and key success factors in Six Sigma implementation, which leads to substantial long-term continuous improvement, the value of money, and business.

A R T I C L E   I N F O

Keywords:
Manufacturing;
Sustainability;
Industrial sustainability;
Six Sigma;
Increase of Sigma level;
Productivity improvement;
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1. Introduction

Customer satisfaction in maintaining industrial sustainability is the key to business success in an increasingly competitive industrial era. Organizational / industrial competitiveness is one of the important attributes in increasing customer satisfaction to maintain industrial sustainability [1] (Ramana and Basavaraj. Maintaining industrial / company competitiveness can be performed by increasing productivity / sales, expanding marketing reach, and maintaining customer retention/ loyalty by maintaining and improving the quality of its products [2, 3, 4]. Improving quality and productivity and maintaining customer satisfaction are important attributes in increasing competitiveness and maintaining industrial sustainability. Quality is an important issue in the highly competitive modern business world [1] (Ramana and Basavaraj, 2018); even quality is a key factor for consumers to decide on products and services offered by producers. Quality has customer satisfaction orientation [5] (Khawale *et al.*, 2017). In order to meet the quality of products expected by customers, an organization / company is always required to understand what is desired by customers by conducting various research and development to further design and create a product that has superior characteristics that are oriented to the desires and satisfaction of customers [6, 5]. Productivity is an indicator of success for an organization / company / country [7] (Maheshwari and Taparia, 2019). Productivity has the concept of how to produce or increase the production of goods and services optimally by utilizing resources efficiently [8] (Thorelli, 1960). Customer satisfaction is a response from the comparison of product performance with several standards before, during, and after consumption [9, 10, 11].

Customer satisfaction can be formed if the organization is able to provide product characteristics or attributes that meet customers' expectations and will have an impact on the reuse of products that have been used and can help improve the company's image through information about the products to other customers [12, 13, 14]. There are many strategies or methods or approaches that can be used in an effort to improve quality, productivity, and customer satisfaction, one of which is the Six Sigma approach. Six Sigma is a systematic and structured approach to increase performance / productivity and quality in meeting customer satisfaction to gain increased company profits [15, 16, 17, 18, 19].

Six Sigma has a systematic and structured method namely: Define, Measure, Analyze, Improve and Control (DMAIC) which is a stage of quality improvement with the concept of reducing the number of defects by up to 3.4 parts per one million opportunities which is very suitable in modern business that focuses on increasing customer satisfaction, productivity, and financial performance [15] (John and Areshankar, 2018). The basic concept of Six Sigma is to adhere to principles for process improvement through reducing variation, using statistical methods, focusing on customers, paying attention to processes, and management systems that focus on high yields that generate significant and continuous financial gains [20, 21, 22]. The level of readiness of the organization / company such as operating systems, measurement systems, employee involvement, environmental conditions, and the concept of continuous improvement greatly affect the success rate of Six Sigma implementation [23].

Six sigma success indicators in improving quality and productivity can be known by increasing the capability of the process (sigma levels) and the financial benefits obtained. Rahman *et al*. [17] in his research, succeeded in reducing defects such as broken stitches and open seam by 35 % and increasing sigma levels from 1.7 to 3.4. Rana and Kaushik [19] in the Six Sigma implementation have proven to reduce defects and increase productivity. In addition to other benefits that did not materialize (initiative, competitiveness), the DMAIC results showed that the defective washer thickness declined from 1550 PPM to near to 100 PPM within four months. In addition, Barbosa *et al*. [18] in his research using Six Sigma implementation (DMAIC), proved that it reduces defects and increase the Quality Rate of 41 % from 19 % to 60 % and Cp in Bead Apex process of > 1.33. Sardeshpande and Khairnar [24] used the Six Sigma method and succeeded in increasing the sigma level in the four wheels industry from 1.2 to 3.2. Subsequently, Ganguly [25] in his research, succeeded in reducing cycle time from 47 days to 20 days in one product cycle. Syafwiratama *et al*. [26] in his research, succeeded in increasing process capability (sigma levels) from 2.2 to 3.1 and making a profit of $ 18,394.2 per month. Furthermore, Malek and Desai [27] state that the Six Sigma approach is a paradigm that leads to business excellence based on the improvement of processes that have been proven to be widely adopted by various industries to respond to changes in customer desires or needs. This research succeeded in increasing sigma levels from 3.1 to 3.7 and reduced the reject rate from 15.50 % to 4.47 % or equivalent to 71.2 % and provide a cost-saving of INR 18,27,402.

Gandhi, Sachdeva, and Gupta [28] revealed that the Six Sigma approach is a systematic and scientific operations management methodology that aims to increase the ability of the production process by reducing waste. This research succeeded in reducing cylinder block defects from 28,111 to 9,708 DPMO and providing a profit of INR 12,56,640. Kosieradzka and Ciechańska [23] in their research with Six sigma implementation succeeded in increasing sigma levels from 3 sigma with DPMO = 33333.00 to 6 sigma with DPMO = 0 and Cp value = 1.91, Pp = 0.53, Cpk = 1.88, Ppk = 0.52 to Cp = 3.79, Pp = 3.32, Cpk = 3.34, Ppk = 2.29. Based on the statement of the research, there was a mistake of the DPMO value of Six Sigma should not be zero but 3.4. Chabukswar *et al*. [29] in his research stated that the basic concept of Six Sigma is to strengthen the process by modifying to increase the process capability to be able to produce defect-free products so that it can satisfy the customer. This research successfully identified the problem that was happening and managed to increase the process capability from 1.5 to 4 and reduce the process reworking 50 % and giving a profit of Rs 90 to 95 lakhs per year and increasing overall efficiency by 30 % in improving overall product quality. Morales *et al*. [30] in his research using Six Sigma, succeeded in reducing scrap from 18 % to 2 % in improving plant layout in an effort to increase productivity.

Chang and Wang [31] in their research using CPFR implementation (Collaborative planning, together with forecasting and replenishment) can increase forecast accuracy by 10-40 %, reduce inventory costs by 10-40 %, save transportation costs by 0.3 % and 1 % and increase customer service levels by 0.5-4 %. CPFR has been recognized as one of the most efficient methods to improve forecast accuracy, minimize inventory, increase service levels and reduce costs, research results using Six Sigma were known to reduce the Mean Absolute Percentage Error (MAPE) from 19.37 % to 5.26 %. They could reduce holdout products from 17.7 % to 5.18 % so that CPFR can help SCM to be better and can increase the confidence of business partners and increase the competitiveness of companies in an increasingly competitive era. Rahman and Talapatra [32] in their research using the Six Sigma approach in the casting industry, succeeded in reducing defect products (DPMO) from 609,302 to 304,651 and increasing the Sigma level from 1.2 to 2.0. In addition, Srinivasan *et al*. [33] used the Six Sigma method in the nozzle furnace industry and succeeded in increasing the sigma level from 3.31 to 3.67 and providing a cost saving of INR 0.125 million (the US $ 1953). Therefore, increasing the level of sigma proves that DMAIC is able to improve product quality, which results in cost reduction and increased competitiveness. According to the various literature studies above, it can be concluded that Six Sigma provides measurable indicators with the help of statistical methods and can be combined with other tools of analysis which are proven to be able to reduce product and process variability and be able to improve process capability through reducing defects, reducing process time so that it can reduce production costs, increase customer satisfaction and will certainly increase company profits in an effort to maintain the sustainability of the industry/organization on an ongoing basis.

2. Consistency of D-M-A-I-C phase, increase of Sigma level, productivity improvement and industrial sustainability

Six Sigma is a systemic, scientific, measurable, flexible and effective method of defining, measuring, analyzing, improving and controlling a problem to get better process capability by reducing process and product variations that aim to improve quality, increase productivity, increase satisfaction customers, increase competitiveness and also increase company profits in maintaining industrial sustainability. The structured method is known as the Define, Measure, Analyze, Improve, and Control (DMAIC) cycle, which has a concept of 3.4 defects per one million products [34, 35]. Broadly speaking, the intended DMAIC cycle can be understood in the description, as presented in Table 1. The table shows a general description of the DMAIC cycle performed in the problem-solving of each phase, including description and activities carried out in the implementation of the Six Sigma method.

Table 1 Description of the DMAIC cycle

Phase	Description of process activities
Define	Identify a problem/project *base on a business objective* Define project scope and goal bases on customer requirements Develop project charter and determined crucial to quality (CTQ)
Measure	Collect data, facts and carry out measurement systems Mapping process representations base on data collection Measure the process capability and study the differences (gaps) that occur

Table 1 Description of the DMAIC cycle (continuation)

Phase	Description of process activities
Analyze	Perform data analysis to find the cause of the problem Clarify the cause of the problem to find out whether the problem is a vital factor Determine the priority scale of each cause of the problem
Improve	Discussion to determine alternative improvements that can be implemented Carry out improvements according to the results of the discussion Verification of key variables in the implementation process
Control	Control process variations according to customer requirements Design monitoring and controlling strategies for improvement results Verify project objectives and plan for further improvement

2.1 Consistency of DMAIC phase

The Six Sigma approach is a systematic and scientific method of operations management that aims to improve the capability of the production process by reducing all wastes [28]. Six sigma approach with systematic phase namely DMAIC with statistical analysis tools has been proven to be widely adopted in various industries both manufacturing and services that can reduce various wastes, increase productivity, provide cost savings and increase company profits [36, 26, 33]. The consistency of the DMAIC phase in this study was analyzed from various studies to select research that was consistent in carrying out the entire DMAIC phase with standard tools that have been set on the Six Sigma method. The consistency of the implementation of the DMAIC phase using the Six Sigma method applied in various industries involving various research variables has succeeded in identifying, measuring, finding key factors, taking improvement actions and controlling problems so as to get better process capability (sigma levels) which is characterized by the reduction of defects, reduced cycle time, reduced accident rates, reduced breakdown / downtime, also improved planning accuracy with actual production and increased company / organizational profits. Through these indicators, the DMAIC Phase consistency proved to have a positive effect on improving quality and productivity and maintaining industrial sustainability.

2.2 Sigma levels

Process capability / sigma level is used to determine the performance capability of a process in producing goods or services based on established technical specifications [37, 38] so that it is known whether the process is within the expected limits or strict controls are needed for the ongoing process. Gupta *et al*. [39] in a study of the tire industry in India, revealed that Six Sigma is known to reduce the standard deviation from 2.17 to 1.69, and increase process capability (Cp) from 1.65 to 2.65 and Cpk from 0.95 to 2.66. This study shows that Six Sigma using DMAIC phase successfully lower the deviation standard from 2.17 to 1.69 which means that product variations can be suppressed so that product quality is better, the stability of the process can be improved as indicated by an increase in the Process capability index (Cp) from 1.65 to 2.65 and Cpk from 0.95 to 2.66. However, the result of the decreasing deviation standard value to 1.69 is quite high. It still gives the possibility to bring up unexpected conditions to happen. Thus, it can be concluded that an improved process capability index will stabilize the process and produce better quality so as to indicate better productivity.

Primanintyo *et al.* [40] in his research using Six Sigma and DOE as the Improvement method, succeeded in increasing the sigma levels in the Curing process of the tire industry in Indonesia from 3.092 sigma to 4.029 sigma. Gerger and Firuzan [22] in their research, explained that Six Sigma's main focus is to reduce the potential variability of processes and products by using a structured continuous improvement methodology, namely DMAIC. Six Sigma provides discipline, structure, and a foundation for solid decision making based on simple statistical analysis. The real strength of Six Sigma is simple because it combines the strength of people / management (project sponsor, project team leader) with the strength of the process (floor production / project team members) to get good process capability to improve organizational competitiveness. This research succeeded in reducing cycle time by 50 % from the previous conditions and can provide a profit of $ 167,895 per year. Zasadzień [41] revealed in the study that a complex and flexible system for achieving, maintaining, and maximizing business achievement is characterized by understanding customer needs and the use of facts, data, and statistical analysis in an organized manner and based on lean management and continually creating new ones. The better the solution by referring to the next process, aimed at minimizing the cost of poor quality while increasing customer satisfaction, this study succeeded in reducing downtime from 18 hours to 9 hours. According to these research examples, interpretation of sigma level improvement shows that process capability and level of process and product variation are better so that the potential for defects produced is more controlled. Customer satisfaction and company profitability can certainly be increased.

2.3 Productivity improvement

Productivity is an indicator of the success of an organization / company [7]. Productivity has the concept of how to produce or increase the production of goods and services optimally by utilizing resources efficiently [8]. An increase in productivity due to the literature can be interpreted as how companies / organizations utilize their resources in the form of tangible and intangible assets effectively and efficiently to obtain optimum profits. The Six Sigma method (DMAIC) is a structured method for identifying, analyzing cause and effect, as well as opportunities for improvement of an ongoing problem that aims to maintain the stability of the process to get product quality improvement and increase company profits [18]. The implementation of Six Sigma has been proven to reduce disability and increase productivity, in addition to other benefits that do not materialize, such as initiative and competitiveness [19]. Six Sigma is a scientific, systematic and superior method of responding to changes that occur in the business world and is able to improve quality and productivity through reducing the variety of processes and products [27, 28, 23]. There is a positive relationship between the Six Sigma approach to productivity improvement due to some literature, which is characterized by a decrease in variations in processes and defects that result in decreased cost production and increase cost-saving, competitiveness, and company profits.

2.4 Industrial sustainability

Industrial sustainability is the key to business success in an increasingly competitive industrial era, even in the last two decades, a total of 92 % of 200 companies published their industrial sustainability reports independently or in an integrated manner [42]. Sustainability reports have evolved over time and are considered an important component of organizational operations that are communicated annually to stakeholders through the sustainability report [43]. In this context, stakeholders increasingly demand transparency and accountability from companies regarding tangible sustainability performance [44]. This proves that the sustainability of an industry is an important attribute in the business world. Improving product / service quality and satisfaction, as well as maintaining customer loyalty, are strategies that can be carried out by the industrial world in maintaining the sustainability of the industry. [45, 46, 47] state that customer satisfaction affects the creation of customer loyalty, which will affect the company's revenue or profit and this is a major factor of industrial sustainability.

3. Materials and methods

The systematic literature review (SLR) method is a method of literature review that identifies, evaluates, and extracts / sites research findings that are useful in answering determining research questions [48]. Bolderston [49] revealed that a good literature review adopts several important rules, such as: (1) is able to extract new ideas from previous research by synthesizing and summarizing previous sources. New theories can be built from the evidence discussed and may provide new directions for future research. (2) A literature review may also facilitate the use of the best available evidence in daily practice to provide answers to research questions. This study is a systematic literature review on the implementation of Six Sigma and looks for the relationship between the consistency of the DMAIC phase to improve process capability (sigma levels) and productivity to increase customer satisfaction in maintaining industrial sustainability.

This study is initiated by collecting a variety of literature in the form of trusted articles from various sources, such as Google Scholar, Research Gate, Proquest, Academia.edu, and other sources using the keywords "Six Sigma, Productivity, and Industrial Sustainability." Furthermore, the works of literature obtained are then classified by name and country of author, year of publication, publisher, research variables, research objectives, tools used, and research results with the target of obtaining a literature review matrix that is useful for providing synthesis and summary of the literature that has been obtained to answer the research question as mentioned earlier. The phases used in this study can be seen in the Conceptual framework of literature review, as presented in Fig. 1.

Fig. 1 describes the whole phase and a review of each phase in this study that starts from defining the research goals, namely: The consistency of the DMAIC phase to increase process capability (sigma levels) and productivity improvement and industrial sustainability. The concept of sigma level, productivity, industrial sustainability, and Six Sigma approach are preliminary discussions followed by a collection of literature for the synthesis of the consistency of the DMAIC phase, sigma level, and productivity improvement, and industrial sustainability. Materials and Methods discuss the concept of Systematic Literature Review (SLR), followed by the conceptual framework of the literature review, which is an overview of the stages of this study. Stages of results and analysis presented include gaps / findings of the literature review, objective of the research, and recommendations for further research. In the last stage, the conclusions and limitations of the study and statements about this study are presented.

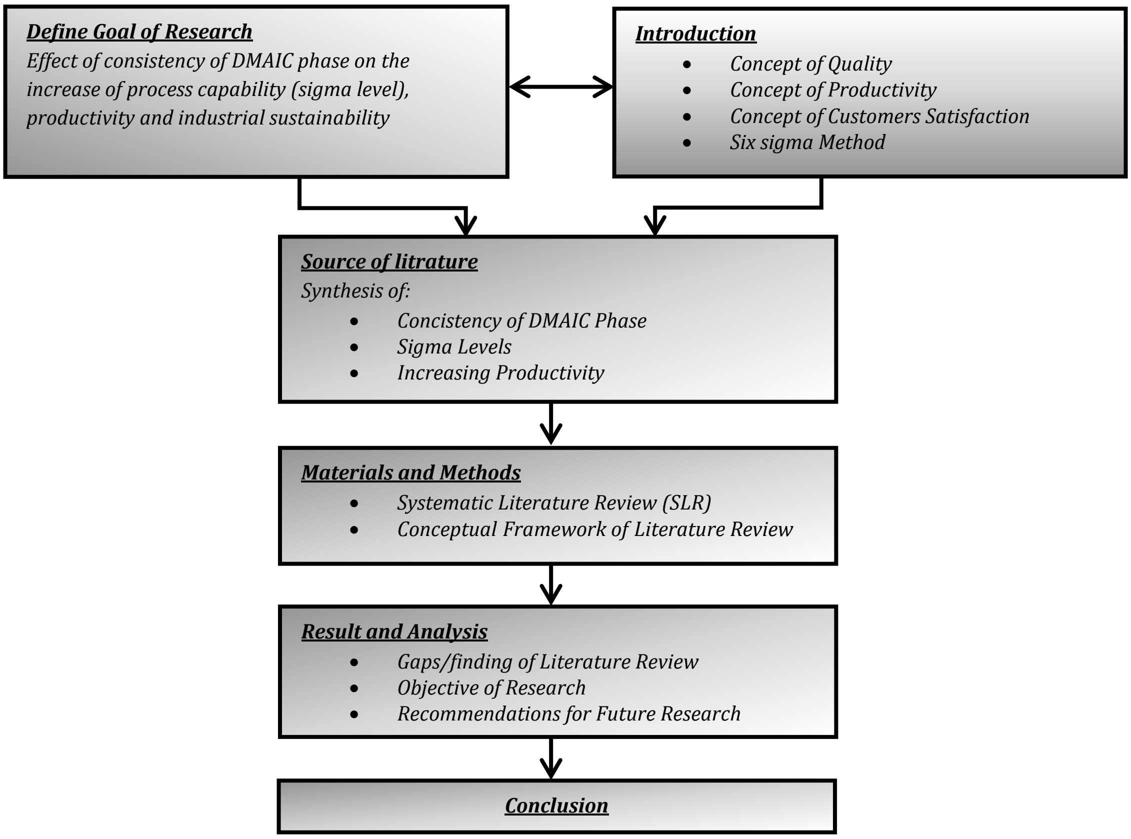

Fig. 1 Conceptual framework of the literature review

4. Results and discussion

4.1 Gaps/findings of literature review

The study is a literature review, which is a review of various journals and proceedings about the Six Sigma implementation in the manufacturing industry from various publishers starting from 2006 to 2019. Details of the literature and tools used in this study and the findings obtained can be seen in Table 2.

Table 2 Tools for literature review used and the research findings

No.	Author, Year, Country, Industry, Variable	Tools used					Result
		Define	Measure	Analyze	Improve	Control	
1	[1] Ramana and Basavaraj, 2018, India, Capacitor, Defects	VOC, VOB, Business mapping, SIPOC diagram, CTQ analyze	Brainstorming cause and effect diagram (CED)	Pareto diagram	Brainstorming purpose of solution (FMEA)	Standardization	Operational standard procedure, training, and control plan to reduce defects
2	[17] Rahman *et al.* 2018, Bangladesh, Garment, Defects	Voice of Customers (VOC)	Pareto diagram, sigma level measurement	Defect rate (DR), CED	DOE, ANOVA	Defect rate (DR)	Reduce defects by 35 %, increase sigma level 1.7 to 3.4
3	[19] Rana and Kaushik, 2018, India, Automotive SMEs, Defects	VOC, Flow diagram, SIPOC diagram	Gauge R&R study	RCA, Brainstorming Trial base on Comparison Worst of Worst (WOW) vs. Best of Best (BOB), Histogram	Corrective Actions with testing	PPM measurement, standardization	Reduce defects from 1550 PPM to almost 100 PPM in 4 months
4	[18] Barbosa *et al.* 2017, Italia, Tyre, Defects	Data collection of customer requirements (NC classification parameter)	CED, Brainstorming, Pareto diagram, $\bar{X}$ and R chart	Cp analysis	Taguchi DOE method	Validate the experimental results (cpk analysis and Quality Rate)	Increase quality rate from 19 % to 60 % and Cp > 1.33
5	[24] Sardeshpande and Khairnar, 2014, India, Automotive, Defects	SIPOC diagram, Process mapping	Control chart, Cost-benefit analysis, CTQ tree	Pareto Chart, Histogram, CED	Regeneration analysis, RCA, QFD	Process capability	Increase the sigma level from 1.2 to 3.2
6	[50] Kumar and Naidu, 2012, India, Garment, Employee Absenteeism	Data collection	Focused group discussion	Pareto diagram, CED	Corrective action	Control plan	Reduce employee absenteeism from 25-35 % to 11%
7	[25] Ganguly, 2012, India, Aluminium, Cycle Time	Historical data, VOC, SIPOC diagram	Defining all possible causes (FMEA), CTQ matrix, MSA	Scatter diagram, linear regression, ANOVA	DOE	Control plan (control chart, MSA)	Reduce cycle time of Rolling mill 47 days to 20 days
8	[26] Syafwiratama *et al.* 2016, Indonesia, Polyester, Defects	Data collection, Pareto diagram	Sigma level, four-block diagram	Brainstorming vital factor analysis (t-test)	DOE	X bar chart, Sigma level, four-block diagram	Increase sigma level from 2.2 to 3.1 and profit of $18,394.2 / month
9	[27] Malek and Desai, 2015, India, Casting, Defects	SIPOC, CTQ tree	Gauge R & R, p chart, capability process (sigma level)	CED, Regression analysis, why-why analysis	DOE, monitoring improvement p chart, COPQ analysis	Control plan, Operation-al standard procedure	Increase sigma level from 3.1 to 3.7 and profit of INR 18,27,402

Table 2 Tools for literature review used and the research findings (continuation)

No.	Author, Year, Country, Industry, Variable	Tools used					Result
		Define	Measure	Analyze	Improve	Control	
10	[51] Naidu, 2011, India, Steel, Breakdown Time	Brainstorming	Data collection of repair time and inspection time	Average data breakdown in one year, Pareto concept	Maintenance schedule	Regression & correlation analysis	Decrease breakdown from 92.42 hours To 59.0 hours
11	[28] Gandhi, Sachdeva, and Gupta, 2019, India, Casting, Reject of Product	CTQ analysis with VOC and Pareto diagram	Data collection, Pareto diagram, CED	P chart, t-test (Anderson-Darling), Why-why analysis	Three possible solutions	Sigma level measurement, overall rejection trend, t-test, Cost-Benefit Analysis	Reduce reject from 28,111 to 9,708 DPMO and provides a profit of INR 12,56,640
12	[23] Kosieradzka and Ciechańska, 2018, Poland, Various, Defects	SIPOCR	Data collection and control of element, Pareto concept	Capability analyzed Cp and Cpk and Pp and Ppk Cause Effect matrix, PFMEA	The 8D process	Cp and Cpk and Pp and Ppk measurement, SPC (control chart)	Increase sigma level from 3 to 6 and Cp = 1.91, Cpk = 1.88, to Cp = 3.79, Cpk = 3.34
13	[29] Chabukswar *et al.,* 2011, India, Pharmaceutical, Defects and Rework Time	VOC, Process flow diagrams, Baseline of the manufacturing process	Data collection	Verification of relationships and causality of factors	DOE	Control plan, SPC	Increase sigma level from 1.5 to 4.0, and provide a profit of Rs 90 to 95 lakh/year
14	[30] Morales *et al.* 2016, Mexico, Concrete Blocks (Construction), Breakdown, and Scrap	Process map, Pareto diagram	Measurements of the conveyor downtime	CED, CE matrix	Discussions relation of possible caused matrix	SPC	Reduce scrap from18 % to 2 %, breakdown molding from 87 to 43 cases
15	[52] Zhan, 2008, USA, Motor, Average Speed Variation	Establish a project scope with clear goals	CTQ tree, Normality test, speed motor measurement	DOE, Pareto chart	Modeling & Simulation	SPC	Reduce Deviation Standard by 74 %, target of 60 %
16	[53] Gajbhiye et al. 2016, India, Casting, Hazards and Risk Controls	SIPOC, SMART, PDCA, SWOT analysis and Cause and Effect analysis	5-S Audit (Safety, Sort, Straighten, Shine, Sustain)	5-Why + Safety Analysis, FMEA, RCA	5-S Audit, Safety Control Sheet, Safety Improvement Plan, and Post Kaizen EHS Checklist.	Safety Improvement Plan and Post Kaizen EHS Checklist	Decrease hazards and risk controls score machining section from 2.34 to 4.34
17	[31] Chang and. Wang, 2008, Taiwan, Various, Forecasting	Historical data, Mean absolute percentage error (MAPE)	Collect data sales	MAPE, autocorrelation function (ACF), partial autocorrelation function (PACF),control chart	ARIMA model	Control charts	Reduce MAPE from 19.37 % to 5.26 % and (holdout) from 17.7 % to 5.18 %
18	[54] Chang et al. 2012, Taiwan, Semiconductor, Production Planning	SIPOC, Questionnaire	t-test, Mann–Whitney test, and error measures	Sigma level, Control chart	Comparison planning vs. actual result	Cp measure, Questionnaire	Reduce average delay from 0.54 to 0.30

Table 2 Tools for literature review used and the research findings (continuation)

No.	Author, Year, Country, Industry, Variable	Tools used					Result
		Define	Measure	Analyze	Improve	Control	
19	[32] Rahman and Talapatra, 2015, Bangladesh, Casting, Defects	Data collection, Pareto diagram	Baseline performance (sigma level), Pareto diagram	CED	DOE, ANOVA comparison of data before vs. after improvement	Control plan	Reduce defects (DPMO) from 609,302 to 304,651, increase Sigma level from 1.2 to 2.0
20	[33] Srinivasan *et al.* 2016, India, Furnace, Defects	Pareto diagram, VOC, SIPOC diagram	Descriptive statistic, Gauge R and R	Brainstorming, CED	DOE, sigma level measurement	Comparison before after of data	Increase sigma level from 3.31 to 3.6 and provide cost-saving of INR 0.125 million (US$1,953)
21	[5] Khawale *et al.* 2017, India, Piston, Defects	SIPOC	VOC to CTQ	CED	DOE	Control plan	New standard operation procedure
22	[55] Purnama, Gunanto, and Sugengriadi, 2019, Indonesia, Manufacturing (other), Environment Management	Data collection	Pareto diagram	Stratify of data analysis, RCA	Corrective action (training)	SOP	Increase positive trend from 220 % to 700 %.
23	[56] El Hassani, Benlaajili and Nokra, 2017, Maroco, Sugar, Defects	5W 1H, Process map, a Black box of the process	Study of R & R, ANOVA, Control Charts, Process Capability	DOE, Pareto chart	Desirability study, The boxplot, Process Capability	Control Charts, standardization	Increase Average cp Aperture/ Opening Medium (OM) from 0.43 to 1.47 Coefficient of Variation (CV) from 0 to 1.5
24	[57] Soković, Pavletić and Krulčić, 2006, Slovenia, Automotive part, Cycle Time	Historical data	Pareto chart, discussion	FMEA, ANOVA, Correlation matrix	Brainstorming, Experiment, Cp analysis, and gage R & R	Control plan	Reduce production time, control time ($ 72,000)
25	[20] Hassan, 2013, Egypt, Wire, Waste Reduction	SIPOC Diagram	Process Mapping, Data Collection (Pareto chart), Sigma level calculations, Down Time Measurements	CED, AHP	Action plan	Control plan	Increase the sigma level from 3.2 to 3.6
26	[58] Rathilall and Singh, 2018, South Africa, Automotive Part, Key Factor LSS	Questionnaire	validity and reliability measure with Cronbach's alpha test	Gap analysis	Pearson's Chi-squared test	Gap analysis	Found six-item Critical factors of LSS implementation
27	[41] Zasadzień, 2017, Poland, Plastic, Downtime	Data collection	Process map	FMEA	Creation matrix	Control plan, standardization	Reduce downtime from 18 hours to 9 hours
28	[15] John and Areshankar, 2018, India, Machining, Defects	Brainstorming, Pareto diagram	Normality test, Cp analysis	Individual chart, CED	DOE, ANOVA	Individual chart, Cp analysis, Pareto diagram	Increase Cp of diameter and thickness from 0.27 and 0.35 to 1.03 and 1.69

Table 2 Tools for literature review used and the research findings (continuation)

No.	Author, Year, Country, Industry, Variable	Tools used					Result
		Define	Measure	Analyze	Improve	Control	
29	[16] Anand *et al*. 2007, India, Automotive Part, Reject of Product	FGD, data history	Critical to Quality (CTQ), QFD	DOE, Control Chart	Fuzzy-rule, Anova	CPk analysis, control chart	Increase punch load Cpk from 0.447 to 1.33
30	[59] Kaushik and Khanduja, 2007, India, Thermal Power, Defects	SIPOC diagram	Gauge R&R	Run chart, process capability analysis, CED, Bar chart	SWAS (Steam water analysis system), Training, action plan	Documentation	Increase sigma level 2.0 to 3.0 and reduce COPQ Rs from 304,77 lakh to Rs 331,2 lakh per year
31	[60] Desai and Prajapati, 2017, India, Plastic, Defects	SIPOC diagram, Pareto diagram, process map	Data collection	Brainstorming, CED, Multi-voting, Cause validation, Why-why analysis	Preventive maintenance, SOP, kaizen	SOP with visual aids	Defects reduced and gave savings of INR 10.80 lacs
32	[22] Gerger and Firuzan, 2016, Turkey, Aerospace, Cycle Time	Data collection	Production flow chart, CED	Effect of weight on human bone	Comprising of ex and new apparatus weight	Control plan	Reduce cycle time by 50 % and provide a profit of $ 167,895 / year.
33	[21] Sławik et al. 2010, Poland, Automotive Part, The Variation Rate	Modeling	Comparison differences between time scales in which aeration processes occur	CED	DOE analysis, Simulation	Gage R&R	Reduce variation of absorber lake from 92 % to 2.4 % with a variation of tolerance base Gage R & R 710 by 68 %
34	[36] Hussain, Jamshaid and Sohail, 2014, Pakistan, Textile, Defects	Data collection, flow process diagram	Cp measurement	CED, Pareto chart	Risk matrix table, corrective actions	SPC, FMEA	Increase sigma level from 2.2 to 3.0 with a profit of $26,000 per month
35	[61] Gijo et al., 2011, India, Automotive, Defects	SIPOC diagram, process map	Gage R & R, Kappa statistic	CED, cause validation plan, Pareto, cause validation plan, process capability analysis	DOE, Taguchi S/N Ratio, ANOVA	Cause solution matrix, standardization	Defects reduction from 16.6 to 1.19 %, sigma level improvement from 2.47 to 3.76, annualized savings about US$2.4 million
36	[62] Anderson and Kovach, 2014, USA, Construction, Repair rate	SIPOC diagram, Process map	Histogram, Pareto charts	CED, FMEA	Prioritization matrices, training,	Control plan, run chart, visual inspection, checklist	The weld repair rate decreased by more than 25 %, which translated into a savings of $90,000
37	[63] Sharma et al, 2018, India, Amplifier, Defects	SIPOC diagram	P-chart, Pareto diagram	CED, Current Reality Tree (CRT) map	Training, process instruction guide	P-chart, Pareto diagram	Improving the sigma level of the anodising process from 3.62 to 3.91

Table 2 Tools for literature review used and the research findings (continuation)

No.	Author, Year, Country, Industry, Variable	Tools used					Result
		Define	Measure	Analyze	Improve	Control	
38	[64] Kumaradivel and Natarajan, 2013, India, Flywheel Casting, Defects	SIPOC diagram	CTQ tree, Cause-and-effect matrix, Pareto chart	Cp analysis, FMEA, Key Process Input and Output Variables (KPIV, KPOV), Pareto diagram	Experimental design matrix, ANOVA	Histogram, SPC, PDCA	The rejection percentage declined to 4.69 from 6.94
39	[65] Lo *et al*., 20019, Taiwan, Optic Elements, Defects	Abberation measurement for good-precision molded lenses, process analysis	Process capability	CED, Taguchi, ANOVA	Optimal combination of process capabilities	Standardization, built-in monitoring system	C_{PU} for optical lenses is enhanced from 0.57 to 1.75
40	[66] Chen *et al*., 2009, USA, Plasma Cutting, Defects	Brainstorming	Cause and Effects Matrix, System capability measurements	Multi-Vari Analysis, T-tests	Taguchi	Control Plan, Continuous improvement	The optimal setting combination gave no defects from the 30 plasma-cut holes in the confirmation run. It maintains feed rate for productivity and improves quality.

Based on Table 2, the sources of literature above can be grouped as presented in Fig. 2a to Fig. 2e:

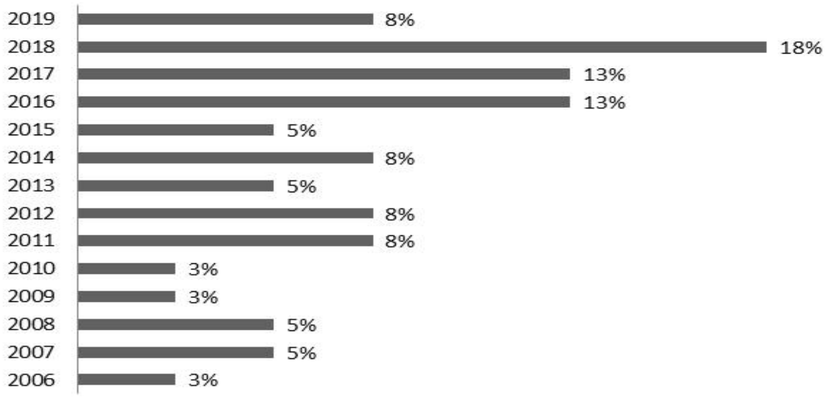

Fig. 2a Grouped sources of literature: Year of Published

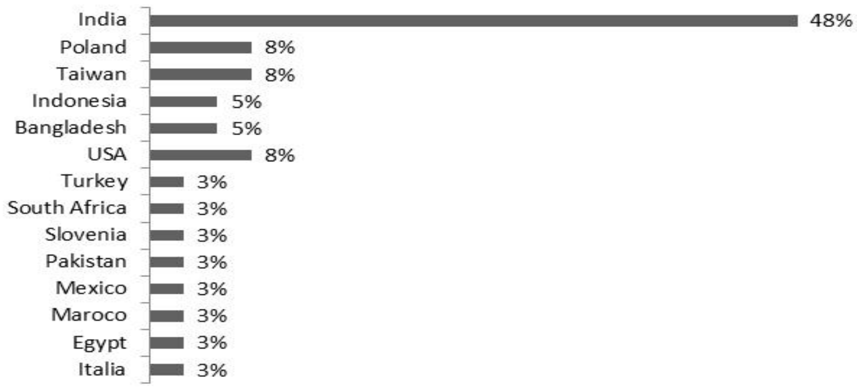

Fig. 2b Grouped sources of literature: Countries of Author

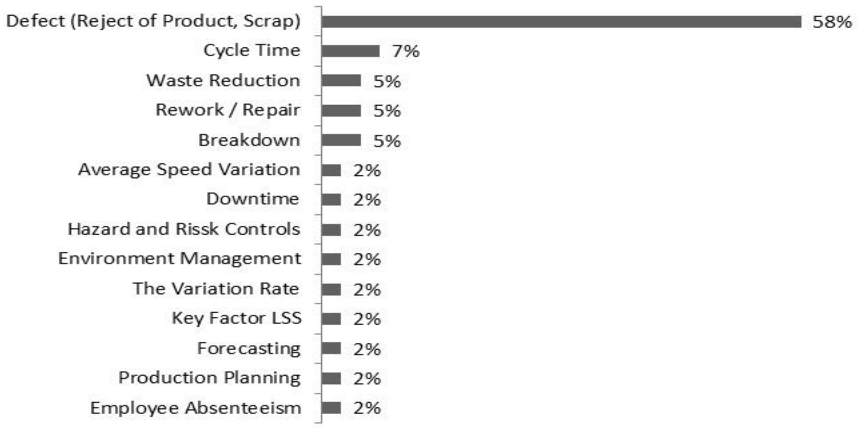

Fig. 2c Grouped sources of literature: Research Variable

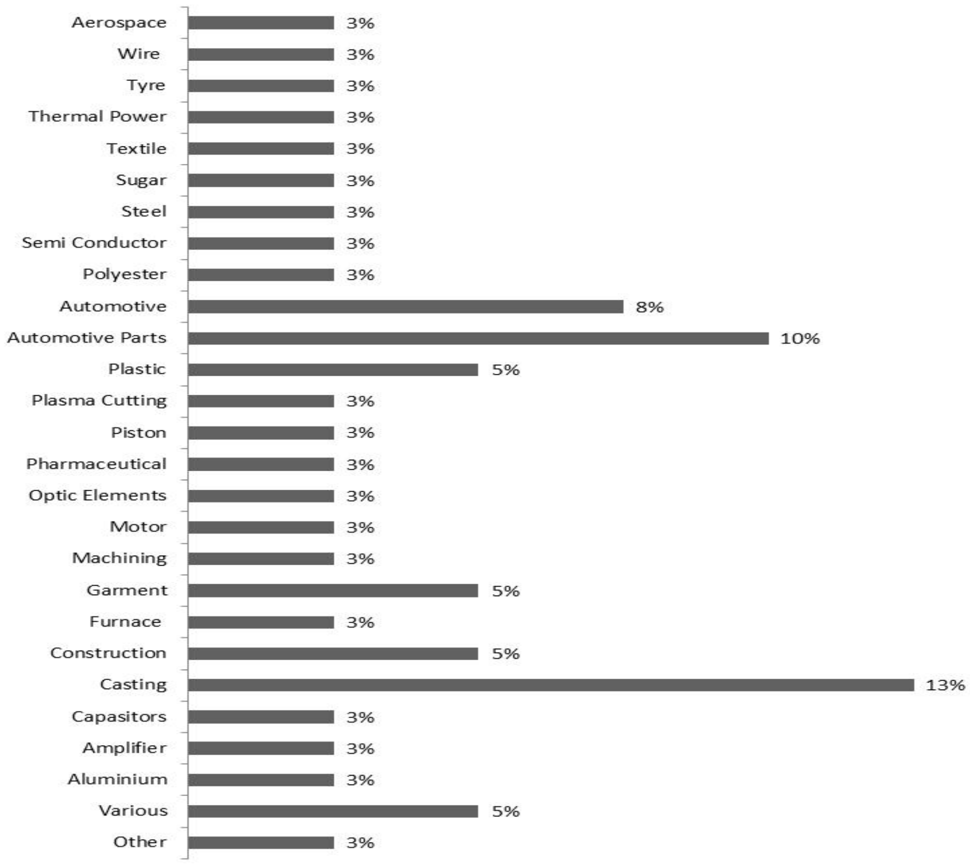

Fig. 2d Grouped sources of literature: Industries Type

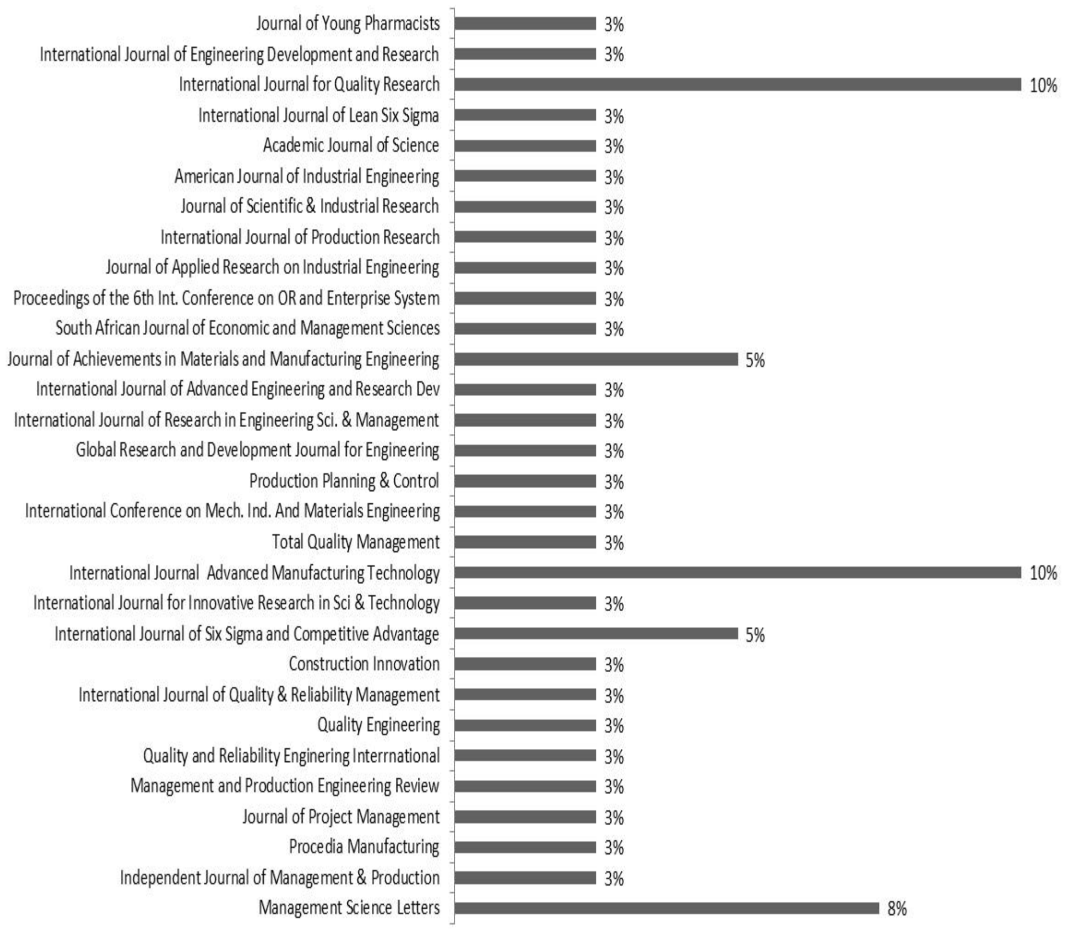

Fig. 2e Grouped sources of literature: Publisher of Research

Table 2 and Fig. 2a to Fig. 2e discuss Six Sigma as review literature starting from 2006 to 2019 from 14 countries with 27 types of industries and involved 14 research variables and 30 publishers. The implementation of Six Sigma based on existing literature studies shows varied results. This is thought to have occurred due to differences in researchers' analytical skills and organizational / company readiness in implementing Six Sigma. The company's readiness includes; operating systems, measurement systems, information integration systems, employee involvement, the concept of continuous improvement used, support for environmental conditions, and management commitment. Based on the literature, it is expected to represent the implementation conditions and the results obtained in the implementation of Six Sigma concept. It will be able to answer the objectives of this study by proving that the consistency of the DMAIC phase in Six Sigma will be able to increase the productivity of an organization / company. The Six Sigma literature is presented to illustrate the broad scope of the application of the concept. It is very beneficial for organizations to understand the critical variables and key success factors in the implementation of Six Sigma programs, which leads to substantial long-term continuous improvement for performance, the value of money, and business. This paper presents the facts of the successful implementation of Six Sigma, which is proven by data and presents the key success factors, variables, and interrelationships. Fig. 3 describes the research results and variables.

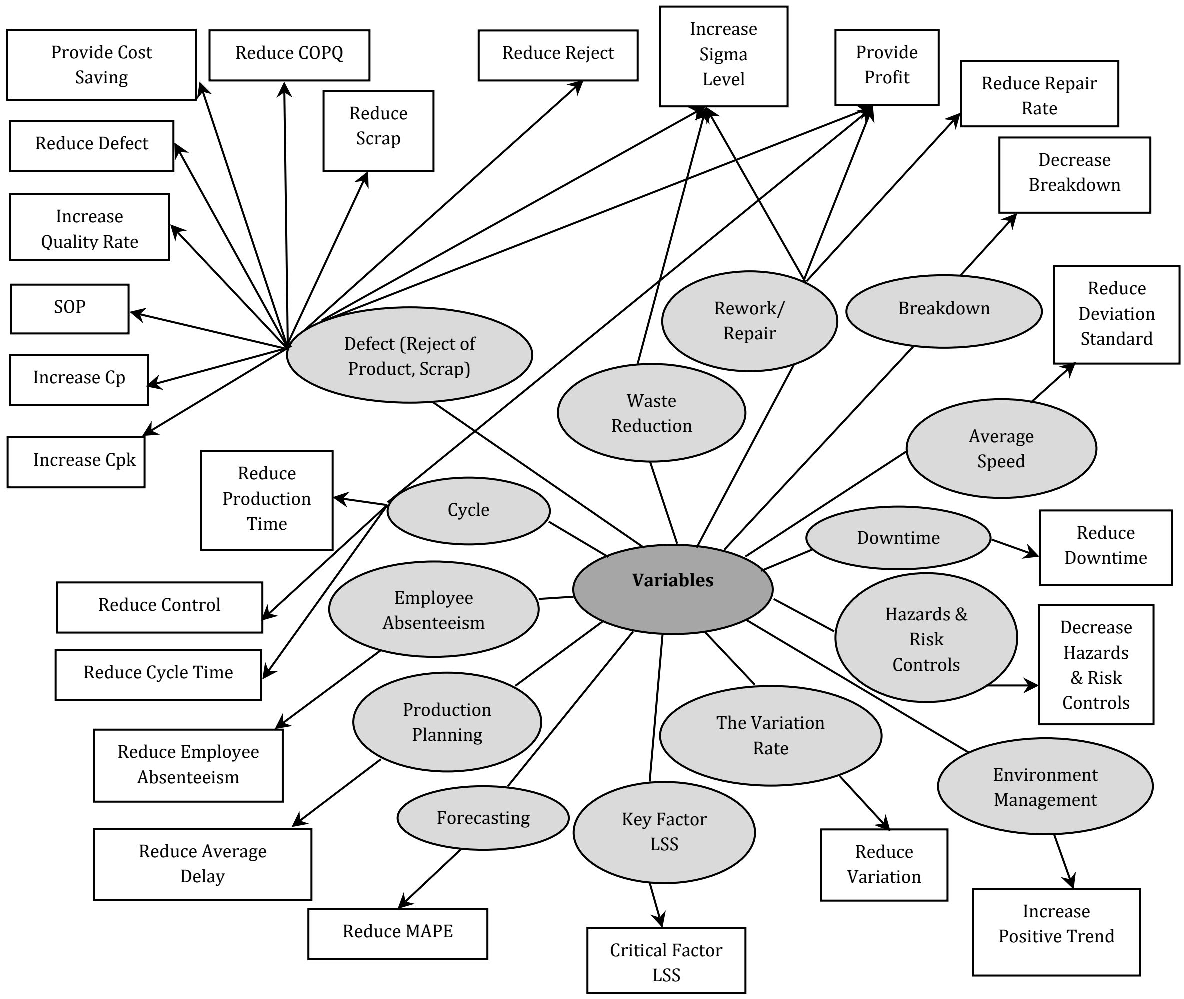

Fig. 3 The research result and variables

4.2 Objective value of the study

Systematic DMAIC phase

According to the literature used in this study, the Six Sigma phase can be synthesized with the tools used and the expected goals in implementing the DMAIC phase, as presented in Table 3.

Table 3 Systematic DMAIC phase

Phase	Description activity	Tools	Main of Goals
Define	• Define the problem • Determine CTQ • Determine improvement targets • Create a charter project	VOC/VOB, SIPOC diagram/ process map, Historical data, Pareto diagram, Questionnaire, Brainstorming.	• Obtain the CTQ • Build a team of improvement • Obtain improvement targets
Measure	• Collect data and facts • Mapping to represent data • Measurement of the condition base on data and facts obtained	Gage R &R, Pareto diagram, Control chart, Cp (sigma level) measurement, four-block diagram, descriptive dan non-descriptive statistic analysis.	• Obtain a process capability (sigma level) that represents the condition before improvement.
Analyze	• Perform analysis base on data and fact • Vital factor testing • Planning improvements	Brainstorming, CED, CE Metrik, RCA analysis, Comparison WOW vs. BOB, Scatter diagram, linear regression, Anova, why-why analysis, three possible analysis, FMEA, gaps analysis.	• Know the potential causes of the problem • Know the main causes (vital factors) of the problem • Develop an effective improvement plan.

Table 3 Systematic DMAIC phase (continuation)

Phase	Description activity	Tools	Main of Goals
Improve	• Discussion to determine alternative improvements that can be implemented • Carry out improvements according to the results of the discussion • Verification of key variables in the implementation process	DOE, FMEA, Gage R &R, Pareto diagram, Control chart, Cp (sigma level) measurement, four-block diagram, Descriptive and non-Descriptive statistic analysis, Three possible solutions, Corrective action.	• Carry out improvement • Strive for the effectiveness of improvements by looking at the comparison of the results of improvements with conditions before improvement
Control	• Control process variations according to customers' requirements • Design monitoring and controlling strategies for improvement results • Verification of objective and standardized projects, sharing new standards and determining the further project	SPC/Control chart, Control plan, SOP, Historical data, Questionnaire, Brainstorming.	• Obtain a controlled process. • Obtain new standards / documentation from the improvement process • Ensuring new standards are known and implemented throughout the entire organization. • Make further improvement plans.

Increase of Sigma Levels, Productivity Improvement and Industrial Sustainability Using the Six Sigma Method

The consistency of the DMAIC phase in Six Sigma implementation has been proven and has succeeded in increasing quality, reducing unnecessary production costs, and increasing productivity. Khawale *et al.* [5] in his study, stated that the DMAIC (Six Sigma Methodology) approach could be used to reduce defects and increase productivity. Six Sigma is a method that results in business excellence with a focus on the needs and expectations of customers. It is the key to the success of this method, based on facts and analysis with measurable statistical methods so that the results can be accounted for in managing businesses currently both manufacturing and services. The Six Sigma implementation is directly related to the company's finances, resulting in customer satisfaction being the target of this method and with innovative ways to exceed the expectations / desires and satisfaction of the customers. Jacob and Jenson [67] in their study of the tire industry in India using the VSM and Six Sigma methods, succeeded in increasing speed calendering machines and reducing cycle time from 17 hours 37 minutes to 16 hours 15 minutes. This study explains that by running the entire DMAIC phase combined with the Value Stream Mapping (VSM) method, it can reduce the cycle time of the calendering process, which means that the productivity of the calendering process can be improved.

Soković, Pavletić, and Krulčić [57] in their research on the Automotive industry explained that Six Sigma with the help of tools of analysis is proven to be able to reduce product and process variability and be able to improve process capability through reducing defects and reducing cycle times so as to reduce production costs and certainly will increase company profits. In general, increases obtained through reduced production time and control time can provide an annual profit of $ 72,000. The expected annual profit from implementing this system is $ 100.

Based on several research findings using the Six Sigma method as explained earlier, it is proved that the consistency of the implementation of the structured phases in Six Sigma, namely DMAIC phase, may provide positive results in solving problems. It may improve process capability / sigma levels and productivity as indicated by decreasing variations, defects, cycle time, customer complaints, non-value-added, and production cost, as well as increasing product quality, customer satisfaction, cost-saving / profit, competitiveness and maintaining industrial sustainability. Fig. 4 illustrates the relationship between the consistency of the DMAIC phase with increasing sigma levels, productivity, and industrial sustainability.

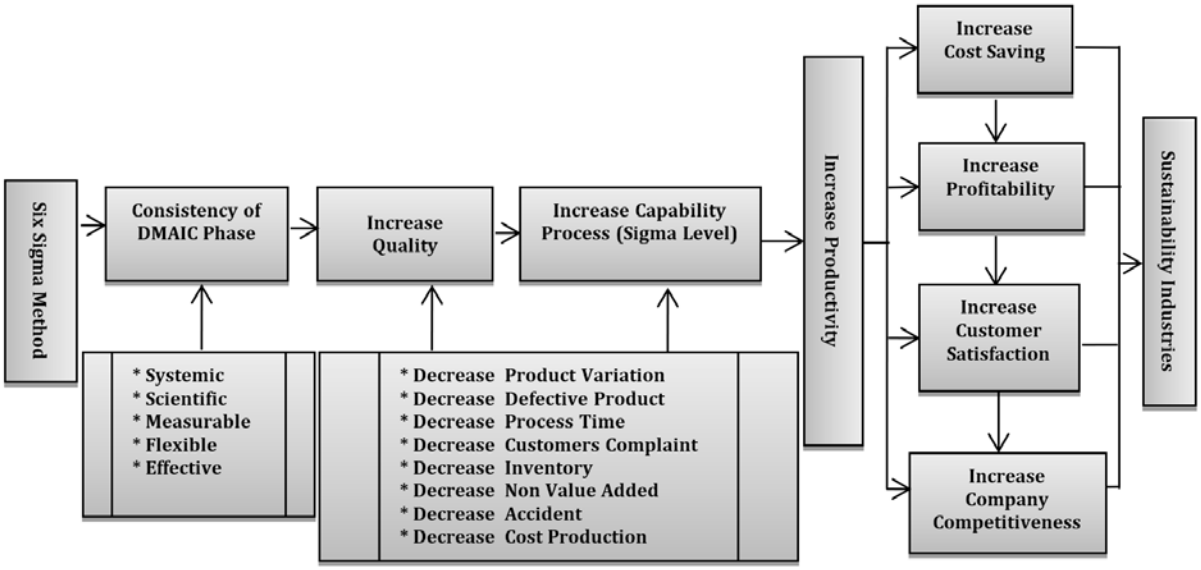

Fig. 4 Relationship/effects of Six Sigma method on increasing Sigma levels, productivity and industrial sustainability

According to the literature review on the consistency of DMAIC in the implementation of Six Sigma based on the literature that has been obtained and after going through analysis and synthesis based on the rules of systematic literature review (SLR), it can be concluded that the objective values obtained from this study are as follows:

1. Process capability (sigma levels) is an indicator of process stability or capability to produce a quality product. The higher the value of process capability (sigma levels), the process will be able to produce products with better quality, vice versa.
2. Productivity is an indicator of the success of an organization / company that has the concept of how to produce or increase the production of goods and services optimally by utilizing resources in the form of tangible and intangible assets effectively and efficiently.
3. Implementation of Six Sigma in a business organization system is a systemic approach (has definite stages), *Scientific* (based on data and facts), *Measurable* (has definite measurement standards with statistical methods), *Flexible* (can be combined with methods and other tools of quality) and *Effective* (is able to increase productivity at a low cost by reducing defects) to revolutionize the scope and use of quality systems in the business currently.
4. Six Sigma is a complex and flexible method / system for achieving, maintaining, and maximizing business achievement that is characterized by understanding customer needs by using facts, data, and statistical analysis and is based on organized management to perform continuous improvement.
5. Six Sigma implementation has varying results depending on the level of readiness of the organization/company, operating system, measurement system, information integration system, employee involvement, the concept of continuous improvement, environmental support, and top management commitment.
6. There are two main benefits of implementing Six Sigma to the effectiveness of the company. (1) Direct benefits: these benefits are in the form of financial side obtained from the Six Sigma implementation which is characterized by increasing quality and productivity which will definitely provide cost savings and increase the profit of the company / organization; (2) Indirect benefits: these benefits are in the form of the non-financial side including increased teamwork, increased sense of belonging among employees, increased employee competence, increased employee initiative, increased quality, increased trust in business relationships, which will further increase competitiveness in maintaining the continuity of the company / organization.
7. Quality, process capability (sigma levels), and productivity are attributes of customer satisfaction to maintain competitiveness and industrial sustainability and have a positive relationship and are directly proportional between these attributes.

Recommendation

Referring to the literature that has been reviewed, various previous studies show that the implementation of Six Sigma is more likely to provide tangible / direct benefits such as; reduce defects, reduce downtime, reduce cycle time, forecast accuracy and others that will all provide financial benefits, yet very rarely research that discusses the hidden/indirect benefits of Six Sigma that will provide non-financial benefits. It is recommended that more subsequent studies discuss research methodology that will provide results in terms of hidden / indirect benefits so that research on Six Sigma is more varied.

5. Conclusion

This paper is a systematic literature review on the consistency of DMAIC using the Six Sigma method from various previous studies in the manufacturing industry of 2006 to 2019 from 14 countries with 27 types of industries and involving 14 research variables and 30 publishers. According to the literature reviews, it shows different results from each research that indicate differences in the level of analysis ability of researchers and the level of readiness of the company / organization in implementing Six Sigma, however, overall the Six Sigma approach has been successful in reducing product variation, reducing defects, reducing cycle time, reducing production costs and increasing customer satisfaction, providing cost savings, increasing profits and increasing competitiveness in order to maintain the sustainability of the company / industry. The study also succeeded in obtaining seven objective values , which are the main results of this study and managed to find a consistent relationship between the DMAIC phase of increasing sigma levels, increasing productivity, and industrial sustainability as the research questions in this study.

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