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SIX SIGMA IMPLEMENTATIONS IN INDONESIA INDUSTRIES AND BUSINESSES: A SYSTEMATIC LITERATURE REVIEW

Sugiri Widjajanto [1)], Humiras Hardi Purba[1)]
Industrial Engineering Department, Universitas Mercu Buana Jakarta[1)]
Jln. Meruya Selatan No 1, Kembangan, Jakarta 11650, Indonesiaa
E-mail: (swidjajanto@gmail.com, humiras.hardi@mercubuana.ac.id)

Abstract *Understanding quality in manufacturing starts with defect identification and improvement finding. Reliability that is influenced by equipment design or working methods or environment has led to the concept of improvement with the Six Sigma method, which has been absorbed in Indonesia industries. This article discussed Six Sigma implementation in Indonesia that identifies, evaluates, and synthesizes results from various sectors and summarizes current evidence that contributes to evidence-based practice. This study reviews the research articles published between 2016-2020 with keywords DMAIC and Six Sigma. The results show that from 52 selected papers, the Six Sigma value of the observed industries is 3.68 on average, with the most negligible value 1.10 from the crude palm oil refinery. The highest is 5.10 from the bagging process of sugar refinery. However, the Six Sigma application is not always satisfying concerning its suitability function, requirement of industries, culture, local regulation, and internal business concern, especially in efficiency and cost. This study starts with finding relevant journal articles, evaluating their sources, identifying abstracts, evaluating the method and its result, and the research gaps. Future research is suggested utilizing the Industry 4.0 concept to enhance Six Sigma implementations.*

Keywords*: Six Sigma, DMAIC, Indonesia*

1. Introduction

Six Sigma is a comprehensive tool known in quality improvement methods for decades and has been recognized as a primary tool for many companies. The Six Sigma implementation in Indonesia industries has been conducted in various sectors, i.e., automotive, heavy industry, food & beverage, petrochemical, oil & gas, and small-medium enterprises (SMEs). In a common developing country like Indonesia, successful Six Sigma implementation requires top management, business infrastructure, working culture change, and training and education [1].

The cycle of define, measure, analyze, improve, control (DMAIC) in Six Sigma is famously used in Indonesia to solve quality challenges. Define is the phase to define process, activities, and components and interactions among them. The measure is a phase when Sigma is leveled by Defects Per Million Opportunities (DPMO) calculation and determine Critical to Quality (CTQ) [2]. Analyze phase proceeds with various tools: Failure Mode and Effect Analysis (FMEA) or Cause and Effect diagram or combined with other analysis methods. The cause and effect, or so-called fishbone diagram, describes the factors that cause the problem. The major problem is identified and listed-out in detail, analyze using various methods, and finally, an improvement target is achieved. Improve phase will determine suggestions based on the analysis results dan conduct all possible corrective actions. The DPMO value is calculated again to get the sigma level after improvement [2].

Based on Setiawan et al., 2020 [2], the number of Indonesian Small Medium Entreprises (SME) in 2020 is 64,199,606 with a total IDR income 14,038,598.5 billion and employed an entire workforce of 120,598,138 people in accordance to Kementrian Koperasi & UKM Indonesia database. The SMEs require good management practice to remain competitive with large

* Corresponding author. Email: swidjajanto@gmail.com
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companies, therefore a suitable management system and improvement tool to be applied in SMEs. However, SMEs cannot adopt a complete quality management system similar to the large companies due to cost constraints. Julian Syaputra et al., 2020 [1] expressed their opinion with a point of view of Indonesia SMEs with the question of whether SMEs require lean six Sigma, with samples from Indonesian small businesses that they can implement Lean Six Sigma. Furthermore, Setiawan et al., 2020 [2] also raise their research idea to question whether Six Sigma will be suitable for SME.

This paper makes a relatively small contribution to the industrial engineering literature that examines Six-Sigma implementation, particularly in Indonesia, that identifies, evaluates, and synthesizes results from observed industries. Furthermore, this study's products contribute to evidence-based practice that may be important for some student engineers' understanding of the Six-Sigma implementation in their research and practices.

2. Research Methods

This literature review is the best method to study and analyze from basic theory, tools, experience, and lessons learned for academic or practical exercises. According to Figure 1, this study starts with the initial collection as step number one of five steps. Collecting from various publishers, i.e., Science Direct, Research Gate, ProQuest Search, MDPI, Springer Open, and Google Scholar within the year from 2016 until 2020. The keyword is "Six Sigma in Indonesia" or "DMAIC Indonesia" for manufacturing, services, and other industrial sectors as well as SMEs

Step-by-step activities of the literature review are shown in Figure 1 and described as following:

- Stage 1. The initial collection managed 120 articles.
- Stage 2. Screening; omitted numbers of papers due to irrelevant research objects and kept 85.
- Stage 3. Collate information, also removing the number of reports and selected 63 related to industrial and manufacturing.
- Stage 4. Full-text article assessed, gain more knowledge and choose 52 standing out.
- Stage 5. In-depth study for those remaining 52 articles.

The method used in this study is an exploratory case study to explore and look for factors that encourage or inhibit the Six Sigma implementation in Indonesia companies, industries, businesses, and SMEs.

3 Result and Discussion

3.1 Indonesia Industry with Six Sigma in general overview

Based on the in-depth review of 52 chosen articles, the author divided the articles into several groups of industries and made a table based on article published year as shown in Figure 2 and Table 1. Total 52 writings are containing Six Sigma implementations in Indonesia's various industries. Table 1 showed more detail with the industrial type of the research object and also their respective result.

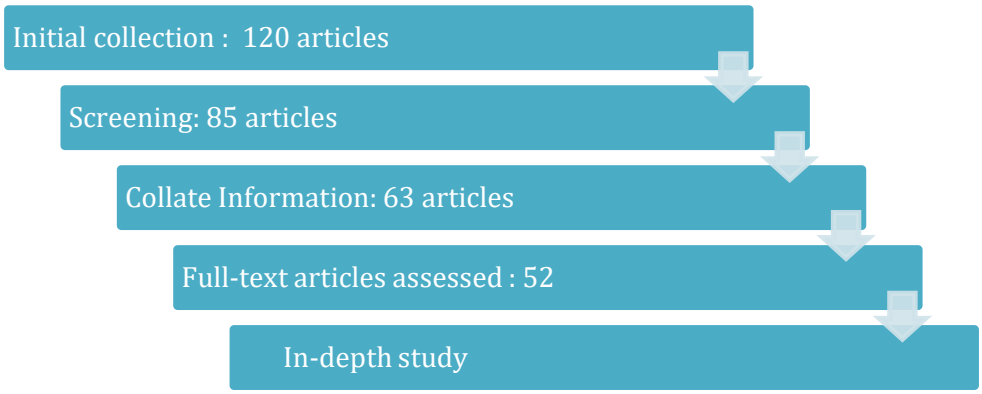

Fig 1 Literature review framework

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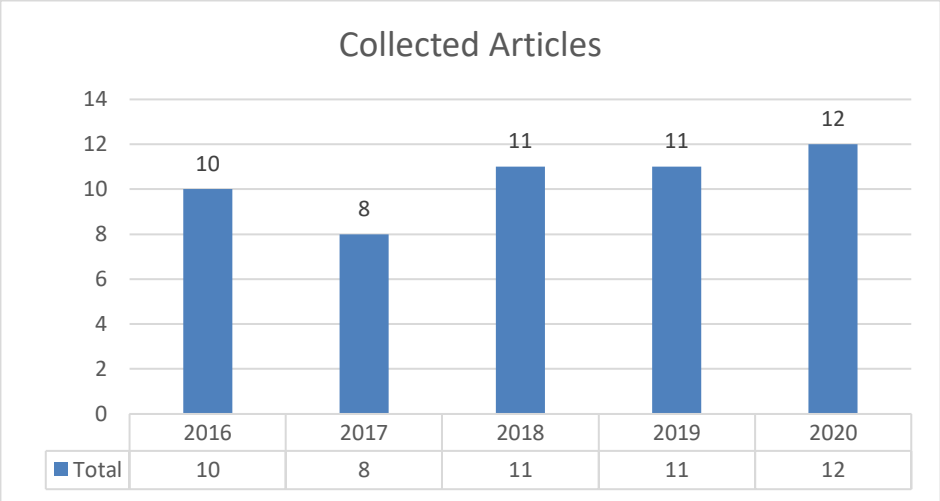

Fig 2 Collected articles based on published year

Table 1. Recent literature and articles relevant to Six Sigma implementation in Indonesia

No	Paper Identity	Research object	Result
1	Julian Syaputra et al., 2020 [1]	SME industries in Indonesia	Some SMEs prefer simple tools such as kaizen and PDCA. Some SMEs have not been able and have not been able to implement Lean Six Sigma because it is too complicated.
2	Setiawan et al., 2020 [2]	SME industries in Indonesia	Six Sigma's application is not yet a matter of urgency or priority and cannot yet be applied. Some SMEs recommend improving kaizen. Six Sigma is not suitable for SMEs and prefers simple and straightforward tools.
3	Ompusunggu et al., 2020 [3]	Fiber Polyester Industry Indonesia Toray Synthetic	Overall DPMO value is 8,531.49, and the Six Sigma level is 3.89
4	Praharsi et al., 2020 [4]	Traditional Boat Industry in East Java Indonesia	Performance measured by sigma value is 2.84.
5	Rawendra & Puspita, 2020 [5]	Milk Industry Indonesia	Increment in sigma value from 4.58 to 4.79.
6	Lestari & Dachyar, 2020 [6]	Telecommunication Company Indonesia	Ten (10) suggestions must be improved to comply with customer satisfaction.
7	Indrawati et al., 2020 [7]	Service system in fast food restaurant Indonesia	Obtained strategies were implemented, and final time improvement is received 90% from the original.
8	Puspa Wirani et al., 2020 [8]	Boiler of thermal power plant	Sigma value improved to become five from previous value 4.1.
9	Darmawan et al., 2020 [9]	Animal feed grain industry in Makassar	Significant defects were identified with 6734.13 raw-material possibilities experiencing DPMO.
10	Saryanto et al., 2020 [10]	Heavy-duty Equipment Industry	Successful in reducing remanufacturing defective product for lift arm to 140762.5 DPMO, is at the level of 2.43 Sigma and COPQ IDR. 135,000,000.00 or decreased 78.71% from the previous condition.
11	Bakti & Kartika, 2020 [11]	Indonesia ice cream producer	The filling process is obtained value of process capability (Cp) 0.59, process capability index (Cpk) 0.32, and sigma value 2.43
12	Bustmoy et al., 2020 [12]	Roman Ceramic Indonesia	The DPMO average value of 10.670 means the sigma level is 3,803 or the same as the Indonesia industry

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No	Paper Identity	Research object	Result
			average.
13	Suwarni & Novembrina, 2019 [13]	Pharmacy Unit of Hospital in Semarang	Performance of prescription service value is Yield =92.98%, defect =6.54%, sigma = 2.146, many improvements is required.
14	Artadi & Syah, 2019 [14]	Purchasing Order of Motorcycle in Tangerang	Total repair time with 1280 minutes or equivalent to 79.8% is proportion to added value time which previously with 7.9 % increased to 43.1 % or equivalent with a rise in 35 %.
15	Trimarjoko et al., 2019 [15]	Tire manufacturing Indonesia	Increment of sigma value from 4.48 to 5.02 and cost reduction 88.69%.
16	Rinawati et al., 2019 [16]	Automobile brake system manufacturing Jakarta	DPMO value 54.330 with sigma value 3.103.
17	Yuliyono et al., 2019 [17]	Data processing centre (DPC) of Ditjen Pajak RI	Improve average sigma level to 2.56 from the original 0.97.
18	Ulfah et al., 2019 [18]	The largest steel industry Indonesia	Sigma value is 4.131 for the cold-rolled coil product.
19	Hernadewita et al., 2019 [19]	Magazine printing company	Sigma value is 3.6, and DPMO is 15919.64. Major defect is identified as blurred (59%), unregister (29%) and paper cut (12%).
20	Henny et al., 2019 [20]	Carded and combed yarns	Sigma level is 4 with an average DPMO of 7786.
21	Juniarti et al., 2019 [21]	Plate rolling section in Steel Plate Industry	Sigma value is 4.03, and DPMO value is 6194 tons.
22	Pangestu & Fahma, 2019 [22]	LED TV production PT. Sharp Electronic Indonesia	Sigma value 4.71 average with DPMO value 672.67 average and process capability index (Cpk) 1.07724. Cpk results in increases to 1.1, 1.11, and 1.12.
23	Adriyanti & Vanany, 2019 [23]	Green Leaf Threshing (GLT) process of tobacco industries.	Increase sigma value 3.72 to 3,97 with decreasing DPMO from 13220 to 6823 and cost benefit. 20,530,760.
24	Sari & Nugraha, 2019 [24]	Automotive - Auto2000 Setiabudhi	The results obtained after improvements were made to a reduction in processing time by 50%, reduction in waste waiting, and motion and service levels by 100%.
25	Fatma & Pradipta, 2018 [25]	Waste Water Treatment of Chemical Industry Tangerang	Cost reduction up to 360 million rupiahs for operational of Waste Water Treatment during Control phase.
26	Decky Antony & Munzir, 2018 [26]	Welding process in Oil and Gas Equipment Manufacturing in Batam	After implemented all planning and design, satisfaction result is obtained with an average sigma value of 4.10.
27	Aziza & Afandi, 2018 [27]	Writing dan printing paper recycle (WPR) process	WPR quality 3.19 sigma with defect level 45.005 (DPMO)
28	Yurim Zagloel et al., 2018 [28]	SME industries in Indonesia	Critical success factors and successful Six Sigma implementation have a strong relationship with SMEs' performance.
29	Purnama et al., 2018 [29]	Bag production	Enhancement of six sigma value from 3.61 to 3.86.
30	Nelfiyanti et al., 2018 [30]	Kiwi Paste Process Production	Before implementation, DPMO = 3497 with sigma level 4.20, and after implementation, DPMO 568 with 4.75 sigma level.
31	Putri et al., 2018 [31]	Front-line section of banking business.	Sigma value of teller 3.01, customer service 2.91, and security person is 3.89.

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No	Paper Identity	Research object	Result
32	Syahputri et al., 2018 [32]	Cigarette paper industry	DPMO 119869 and sigma value 2.676, with decrement total production time by 165.92 min. and increment 12.64% of cycle efficiency process.
33	Wijaya et al., 2018 [33]	Rubber-based product for shoe industry in Bandung	DPMO of vulcanization was 89411.76 with the sigma value of 2.84 and pressing processes 10359.96 with the sigma value of 3.81
34	Kristanto & Wiguna, 2018 [34]	Building construction works in Surabaya	Eight recommendations were implemented, and the sigma level increase to 3.63.
35	Kusumawati & Fitriyeni, 2017 [35]	Bagging Process in Sugar Refinery	DPMO 162,4532 and sigma value 5.1.
36	Nurcahyo et al., 2017 [36]	Motorcycle part manufacturing	Initially, the sigma level was 3.8 sigma and became 4.8 with 0.51% defect ratio.
37	Syafwiratama et al., 2017 [37]	Polyester short cut fiber in a textile industry	Improved sigma value from 2.2 to 3.1 and saved USD 18,394.2 per month.
38	Dino Rimantho et al., 2017 [38]	Raw water quality of Pharmaceutical Industry	Capability Process Index increased to 1.07, The possibility of defective production decreased by 712 ppm and the sigma level increased from 2.30 to 4.69.
39	Kurniawan et al., 2017 [39]	Crude Palm Oil Processing in Indonesia	Based on calculation, obtained Cpk as 0.37 and converted it to sigma value as 1.10.
40	D. Rimantho & Hanantya, 2017 [40]	Noises in the workplace of machinery and automotive division	Results showed DPMO is 115,260.6, equal to sigma value 2.70.
41	Sirine & Kurniawati, 2017 [41]	Furniture and Craft	Product defect average is 0.34%, with cost less than 1% of sales due to poor quality.
42	Jihan Shofa & Gunawan, 2017 [42]	Nickel Pig Iron Product in Steel Mining Indonesia	Meager sigma value average at 1.6 of annual pig-iron processing, with problem caused by Silica (Si) and phosphor (P) value. Suggested actions are elaborated on in the article.
43	Tejaningrum, 2016 [43]	SMEs industry of cassava chips, soy chips, meatballs, and chips	Average value of capability internal process of quality culture is 3.5662 at downstream and 3.360 at upstream, and in supply is 3.626.
44	Dino Rimantho & Cahyadi, 2016 [44]	Solid waste collector Jakarta under Sanitary Office Pemkot Jakarta Selatan	Results: 0.22 DPU, DPMO 220000 and sigma value is 3.554.
45	Widyanesti & Fadhlillah, 2016 [45]	Pt. Garuda Indonesia SBU Cargo	Sigma level is 4.8 with 5 major known problems.
46	Sanny et al., 2016 [46]	SME Tofu Production Indonesia	Average 3.393 of sigma value with 29,764 defect possibility in one million trays.
47	Kusnadi & Yudoko, 2016 [47]	Oil and Gas Contractor Indonesia	It was improved by 59.3 minutes on average for the available work time.
48	Hakim et al., 2016 [48]	Piston Assembly Line in Manufacturing Laboratory UI	DPMO decreased to 700,000 from the previous 900,000. Increased labor productivity level 0.0041 to 0.00742. Decreased idle time to 12.1 seconds from previous

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No	Paper Identity	Research object	Result
			121.3 seconds. Increased output 3 piston/5 min from 1 piston/5 min.
49	Parhusip et al., 2016 [49]	Gold Mining PT. Freeport Indonesia	Cost reduction: Construction employee support: 14% Steelworks: 33% Concrete works: 31% Site equipment hours: 7%
50	Mastur & Aji, 2016 [50]	Car Wheel Accessories	Based on all defect causes, obtained DPMO 34.126 with sigma value is 3.32.
51	Ilyasa et al., 2016 [51]	SME producing shoes in Bandung	Sigma value is obtained 3.274 and 38758.87 DPMO with six causes of defective products,
52	Fatkhurrohman et al., 2016 [52]	Brigdestone Tire Indonesia, Bekasi	Reduced production cost by IDR 180 million per month with reducing loss energy, reducing scrap material and reducing lost time production.

Most of the research coming from automotive industries with nine articles, including automobile brake system manufacturing [16]. Others are motorcycle seller [14], tire manufacturing [15] and [52], disc brake[24], frame-arm for motorcycle [36], car wheel accessories [50], noises [40] and piston assembly line [48].

The second most articles are derived from research in the food and beverage industry, i.e., milk processing plant, fast food restaurant, ice cream factory, Makassar feed grain processing, [5], [7], [9], [11], [35] and this include palm oil processing [39] and tobacco & cigarette [23], [32]. Sigma value in milk processing increased to 4.79 [5], Ice cream producer has 2.43 [11], feed grain has DPMO 6734.13 [9], Tobacco industry got increment 3.72 to 3.97 [23], the cigarette industry has 2.676 [32], bagging process of sugar refinery got 5.1 sigma [35] and Crude Palm Oil (CPO) obtained Cpk 0.37 with 1.10 sigma value [39].

Table 2. The Object research and article published year

Type of Industry	Year					Total
	2016	2017	2018	2019	2020	
Automotive	3	2		4		9
Chemical & pharmacy		1	1			2
Electronic			1			1
Food		2		1	4	7
Government	2			1	1	4
Home App.			1		1	2
Home Care		1				1
Mining	1					1
Paper & printing			2	1		3
Service	1		2	1	1	5
Ship Mfg					1	1
SME	2		1		2	5
Steel & Heavy equipment		1	1	2	1	5
Textile	1	1	2	1	1	6
Total	**10**	**8**	**11**	**11**	**12**	**52**

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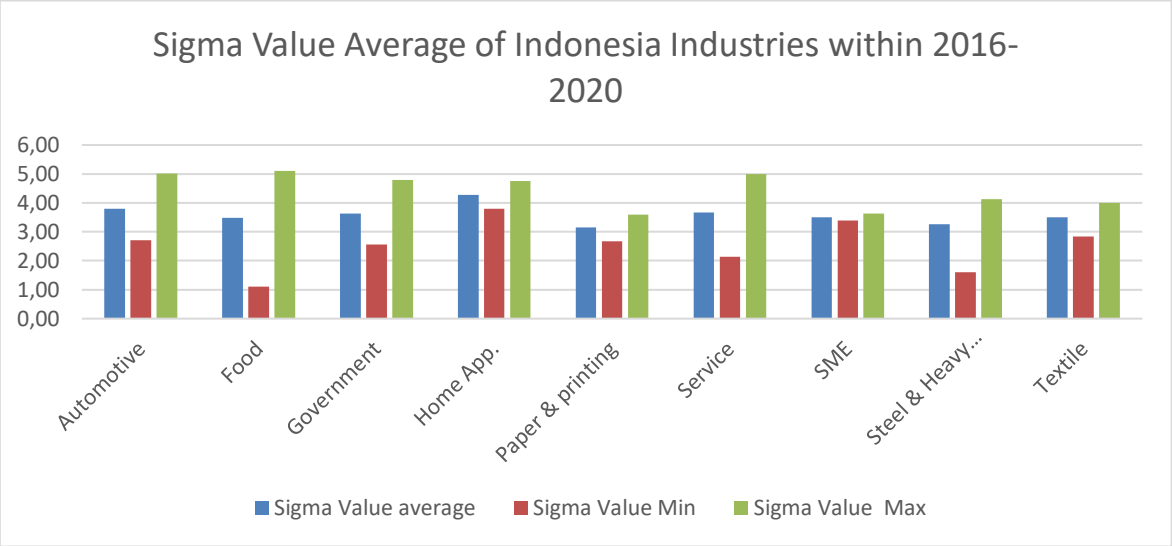

Fig 3 Sigma value of Indonesia industries 2016-2020

The third most research is textile with 6 (six) articles containing research in carded combed yarns [20], bag factory [29], fiber [37], shoe industry [51], [33] and polyester [3]. Carded and combed yarns factory got sigma level at 4 and 7786 DPMO [20], bag factory gained sigma level from 3.61 to 3.86 [29], fiber producer improve Sigma 2.2 to 3.1 [37], shoe industry in Bandung achieved sigma level 3.274 with DPMO 38758.87 [51], shoe pressing processing with sigma value 3.81 [33], a polyester industry with a DPMO value of 233 and a six-sigma level of 5 [3].

After summarizing all collected articles from various industries with all sigma values and segregation of average value within the industry type, those are represented in Figure 3. There are also shown the least and the highest sigma value in a respective grouping of industry types. Obtained average of sigma value from all Indonesia industries within the year 2016 to 2020 is about 3.68, with the most negligible value is 1.10 from Crude Palm Oil (CPO) refinery with Cpk 0.37 [39]and the highest sigma value is 5.10 belong to bagging process of sugar refinery [35]. The electronic industry with recent technology implementation has a 4.71 sigma level, and boat fabrication is traditionally assembled with 2.48 sigma [4]. Another industry that uses high technology is chemical and pharmacy, which obtained sigma value of about 4.69 [49].

3.2 Indonesia SMEs

There are several studies related to Six Sigma in Indonesia SME, i.e., Yurim et al. (2018) [28] and Setiawan et al. (2020) [2], and Lean Six Sigma by Julian et al. (2020) [1]. Julian (2020) studies the advantages and obstacles of implementing six Sigma and Lean Six Sigma in Indonesia's SMEs during the pandemic period. The method applied in this study is a qualitative exploratory study of cases, which explores and looks for factors that influence the impulse or motivation to implement Lean Six Sigma in SMEs and factors that inhibit the implementation of Six Sigma. Some SMEs prefer simple tools such as Kaizen and Plan-Do-Check-Action (PDCA). Some SMEs have not been able to implement Lean Six Sigma because it is too complicated. Thus they recommend improvement with kaizen. This research's novelty is the first research in Indonesia that analyzes the advantages and obstacles of implementing lean six Sigma in SMEs during the Covid-19 Pandemic [1]. Another study was in 2018 because critical success factors for Indonesia SMEs are top management commitment, working culture changes, and training & education [28].

Analysis results for the SMEs in cassava chips production are determined to value CP, CPU, CPL, and CPK. Cultural influences on process quality can raise the coefficient determinant significantly in upstream 88.3% downstream 84% and internal supply 61% [43].

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Another example is coming from SME who produce tofu, that able to identify defects that can be targeted for improvement, i.e., tofu thickness defect (53.62%) and the tofu texture (39.27%) [46]. Another SME, for example, is an Indonesian furniture and craft company that has done excellent quality control. The results showed an average of product defect is 0.34%, and finally, cost due to the poor quality becomes less than 1% of sales [41].

3.3 Research Gap and Industry 4.0 Concept for Six Sigma Enhancement

The research gaps are identified mainly in the organization, cost constraint, and Six Sigma tools. Poor coordination and commitment among management levels and the organization's working culture had become critical factors in the successful Six Sigma projects. Different approaching and leadership styles may be required in other industry types and different sizes of organizations. SMEs will need different local regulation approaches, while the big company has a more rigid organizational structure for Six Sigma planning and implementation.

The challenge in the future is the implementation of six Sigma in industries and businesses to utilize the Industry 4.0 concept [53], [54], [55] or even with minor changes by poka-yoke or fault-proof [56]. Table 3 below shows the concept of Industry 4.0, which can support the implementation while categorizing it into Autonomous Operation Maintenance (a) and Early Management of Equipment and Products Design (b).

Table 3 also shows the criteria in Industry 4.0 which will enhance and enabler the Six Sigma implementation. Operation activities usually involve specific and sensitive sections, so interaction with the experts is essential. Thus, virtual representation technologies such as virtual reality (VR), either augmented reality (AR), and head-mounted-displays for remote training will enhance operator and maintenance knowledge and lead for improvement. Furthermore, other intelligent technologies and the Condition Monitoring system allow machine loads indication, warning sign, and defects measurement to be monitored at the office in real-time during operation. Early warning dan potential failure detection will result in less downtime and more excellent prevention [53].

In the example of early product design and equipment management, digitalization can remove the boundaries between the planning and design phases on the one hand and the production phases on the other [55]. Another benefit of digitalization is a shorter product lifecycle, a wider variety of products, and increased product complexity, which will provide a platform for an increase in production rates. As a result, equipment management must initiate new products from the start, which ultimately results in a short ramp-up period [54].

Table 3. Industry 4.0 concept to enhance six sigma implementation [53], [54], [55].

Industry 4.0 Concept	Application
Additive manufacturing (AM)	(a)
Plug and play	(b)
Human-computer interaction (HCI)	(a)
Virtual representation (e.g., Virtual Reality, Augmented Reality)	(a)
Auto-identification	(a)
Digital object memory	(a)
Digital twin / /simulation	(a), (b)
Cloud computing	(a)
Real-time computing	(a), (b)
Big data & Data analytics	(a)
Machine learning	(a)

(a) = autonomous and planned operation & maintenance
(b) = early product & equipment management (design)

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4. Conclusion and Summary

This literature study obtained an average 3.68 sigma value of Indonesia industries within year 2016-2020 with the most negligible value of 1.10 from a crude palm oil refinery. The highest is 5.10 from the bagging process of sugar refinery. Based on the observed articles, the advantages of applying Six Sigma are very good for improvements in operations, quality, productivity, cost reduction, and safety. Six Sigma can be applied in all types of companies, organizations, and SMEs in Indonesia. However, the application of Six Sigma for Indonesia SMEs has obstacles, i.e., cost limitations. The cost of Six Sigma consultants will burden SMEs. Another challenge for SMEs is the limited skills of personnel to run Six Sigma, and the last challenge is about the time consuming of the Six Sigma project. Thus, Indonesia SMEs prefer simple tools such as kaizen and PDCA. Future research is suggested utilizing the Industry 4.0 concept that can enhance Six Sigma implementations.

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