

Process Improvement in Newspaper Printing through Lean Six Sigma: Waste Analysis and Defect Reduction Strategies

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ABSTRACT

This study examines the implementation of Lean Six Sigma (LSS) in a newspaper production company in Malaysia to identify and analyze sources of waste and product defects. Using the DMAIC (Define–Measure–Analyze–Improve–Control) framework—applied up to the DMAI stages—the research integrates qualitative methods (interviews and observations) with quantitative tools (control charts, Value Stream Mapping, and sigma metrics). The results revealed two dominant waste categories: waiting time and defective products. Value Stream Mapping indicated that only 55.32% of the total lead time contributed to value-added activities, while 44.68% consisted of non-value-added or necessary non-value-added processes. Over one year, the company produced 840,000 copies with 12,000 defective products (1.43%), primarily scattered ink (55%), uneven margins (25%), and ink misregistration (20%). The overall process capability achieved an average DPMO of 4,833 and a sigma level of 4.09, indicating stable yet improvable performance. Root cause analysis highlighted human factors as the most influential source of defects, followed by machine, material, and method-related issues. Improvement strategies focusing on operator training, SOP compliance, preventive maintenance, and stricter supervisory controls. This study contributes theoretically by extending the application of LSS to the printing industry and practically by offering actionable recommendations to enhance production quality and efficiency. Future research should implement these strategies and validate their effectiveness through the Control stage of DMAIC.

Keywords: Lean Six Sigma, Newspaper Production, Waste Reduction, DMAIC, Process Improvement, Quality Control



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INTRODUCTION

The newspaper industry remains a vital medium of information dissemination, particularly in Southeast Asia where printed media continues to complement digital platforms. In Malaysia, despite the rapid expansion of digital journalism, printed newspapers still maintain a significant readership base. However, newspaper production companies in the country face persistent challenges related to operational efficiency and product quality [1]. Typical issues include excessive waiting times during production and recurring defects such as scattered ink, uneven margins, and misaligned prints. These inefficiencies increase operational costs, cause material waste, and reduce customer satisfaction, thereby threatening the sustainability of the industry in a competitive media landscape [2].

In practice, production failures in newspaper printing are not uncommon. Previous studies have reported misregistration of colors due to unstable machine calibration, which leads to blurred or ghost images on printed pages [3]. Ink smearing caused by over-inking or defective rollers often results in unreadable sections of newspapers [4]. In addition, paper jams and tearing during high-speed printing runs can cause significant downtime, waste, and delivery delays [5]. Such failures not only disrupt production schedules but also reduce the reliability of printed media in meeting strict distribution deadlines, which are critical in the newspaper industry.

Lean Six Sigma (LSS), an integration of Lean manufacturing and Six Sigma, has emerged as a structured methodology for improving process performance. Lean emphasizes the elimination of non-value-added (NVA) activities, while Six Sigma focuses on reducing process variability and defects through statistical quality control tools [5]. When combined, LSS provides organizations with a systematic approach to achieving higher efficiency, reduced costs, and enhanced product quality. Globally, LSS has been applied successfully in sectors such as automotive, healthcare, logistics, and electronics, yielding measurable improvements in productivity and customer satisfaction [6], [7], [8].

The application of LSS in the printing industry, however, has received limited scholarly attention, particularly within the Malaysian context. While previous studies in Malaysian manufacturing sectors have demonstrated the effectiveness of LSS in reducing defects and enhancing efficiency [9], little is known about its implementation in newspaper production. This research gap underscores the need for empirical studies that explore how LSS can be tailored to address waste and defects specific to the printing sector, where production involves complex coordination between human, machine, material, and method-related factors [10].

The DMAIC cycle (Define–Measure–Analyze–Improve–Control) serves as the cornerstone of LSS implementation, providing a structured framework to identify problems, quantify performance, analyze root causes, implement corrective measures, and maintain process control [11], [12]. Prior research has confirmed that DMAIC effectively identifies waste sources, reduces process variability, and improves sigma levels across industries [13], [14], [15], [16]. Nevertheless, its application in Malaysian newspaper production remains underexplored.

Therefore, this study presents a case analysis of a newspaper production company in Malaysia that applies Lean Six Sigma to identify and mitigate waste and product defects. Specifically, the research aims to (1) measure the extent of waiting time and defective products, (2) calculate the sigma level of the printing process, and (3) propose improvement strategies to minimize waste. The findings are expected to contribute theoretically by extending the application of Lean Six Sigma to

the printing industry and practically by providing insights for managers in Malaysia to enhance production quality and operational efficiency.

In this study, the Lean Six Sigma (LSS) methodology was applied using the DMAIC framework—Define, Measure, Analyze, Improve, and Control. However, since direct improvements were not implemented within the company, the research was limited to the DMAI stages.

At the Define stage, the work processes and sources of waste in newspaper printing were identified using the SIPOC (Supplier–Input–Process–Output–Customer) diagram and Value Stream Mapping (VSM). The Measure stage involved calculating the proportion of defects with the np-control chart, followed by defect-related indicators such as Defects Per Unit (DPU), Defects Per Opportunity (DPO), Defects Per Million Opportunities (DPMO), and sigma level. In the Analyze stage, the root causes of waste and defects were examined using Pareto analysis to identify the most dominant problems, and fishbone diagrams to classify causal factors. Finally, at the Improve stage, recommendations for corrective actions.

The purpose of adopting this methodology is to systematically identify, classify, and analyze waste and defect factors in the newspaper production process. The results are expected to serve as a reference for managerial decision-making and as a basis for future quality improvement initiatives in the printing industry.

METHOD

This study adopts the Lean Six Sigma (LSS) methodology using the DMAIC framework (Define–Measure–Analyze–Improve–Control). However, since direct improvements were not implemented within the company, the research was limited to the first four stages (DMAI) [17][18].

At the Define stage, the production process of newspaper printing was mapped to identify waste and critical-to-quality (CTQ) factors [19]. Tools used included the SIPOC (Supplier–Input–Process–Output–Customer) diagram and Value Stream Mapping (VSM), which helped to visualize workflow and highlight non-value-added (NVA) activities [20].

The Measure stage focused on quantifying defects and waste within the production line. Data were collected from one year of production records and validated through employee interviews and observations. Statistical quality control tools such as the np-control chart were applied to monitor process stability [21]. Key defect metrics, including Defects per Unit (DPU), Defects per Opportunity (DPO), Defects per Million Opportunities (DPMO), and sigma level, were computed to evaluate process capability [22].

At the Analyze stage, root causes of waste and defects were examined. Pareto analysis was employed to determine the most significant sources of defects following the 80/20 principle, while fishbone diagrams (Ishikawa) were used to classify contributing factors into categories of human, machine, material, and method [23].

Finally, at the Improve stage, improvement strategies were proposed using the 5W+1H framework (What, Why, Where, When, Who, and How). Although not directly implemented in the case company, these recommendations provide a roadmap for reducing waste and minimizing printing defects in future operations [24].

By combining qualitative insights (interviews and observations) with quantitative analysis (control charts and sigma metrics), the methodology ensures a systematic approach to diagnosing inefficiencies and proposing targeted improvements in newspaper production [25], [26], [27].

RESULTS

This study was carried out to identify and analyze waste in the newspaper production process. Data collection was conducted through direct interviews and brainstorming sessions with the head supervisor of newspaper printing. These sessions focused on capturing inefficiencies observed during daily production activities, particularly those related to waste categories defined in Lean Six Sigma. The findings are summarized in Table 1, which presents the types of waste identified and their frequency of occurrence within the production system. summarizes the assessment of waste types. From seven categories of waste commonly identified in Lean Six Sigma, only two were significant. Waiting time received an average rating of 1 (sometimes occurs), while defective products were rated 2 (frequently occurs). Other categories, such as overproduction, transportation, and unnecessary movement, were absent in the production system. This finding highlights that efficiency improvement efforts should focus primarily on reducing delays and addressing product quality issues.

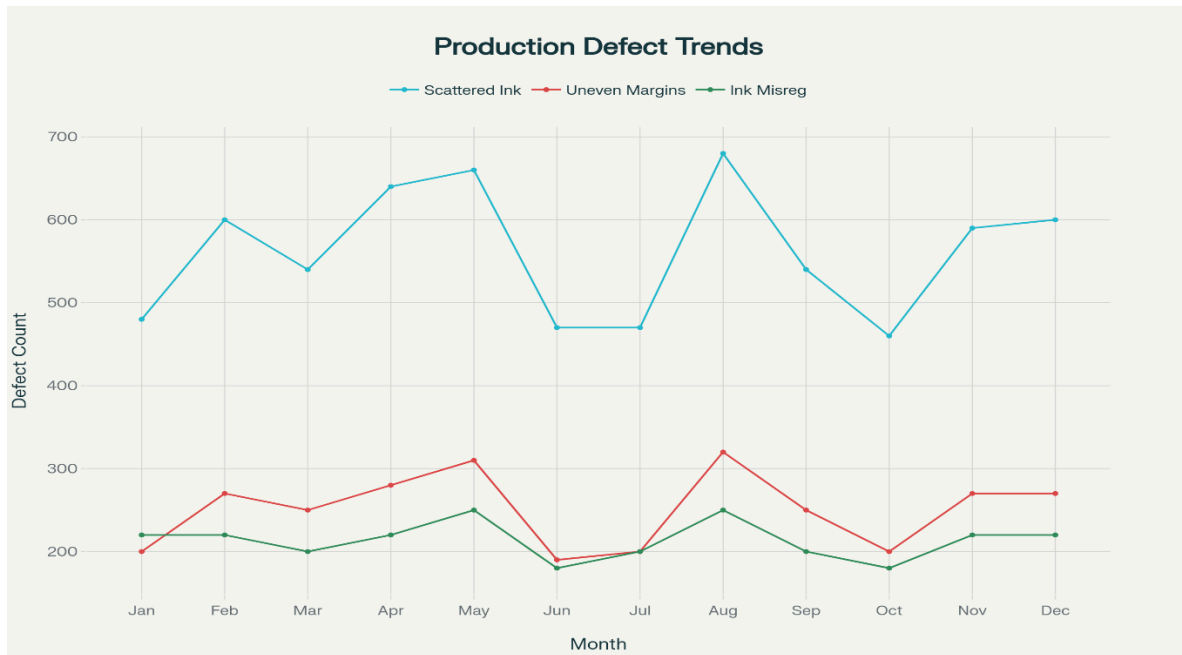


Figure 1. Defect of Newspaper Production

The monthly production defect analysis reveals significant temporal variations in quality control performance across three primary defect categories throughout a 12-month observation period. Scattered ink defects demonstrated the highest frequency, ranging from 460 to 680 units per month, with peak occurrences observed in August (680 units) and May (660 units), while minimum levels were recorded in October (460 units) and June-July (470 units each). Uneven margins exhibited moderate variability between 190-320 units monthly, showing pronounced peaks in August (320 units) and May (310 units), corresponding to periods of maximum scattered ink defects,

suggesting potential correlations between these defect mechanisms. Ink misregistration maintained relatively stable patterns with lower amplitude fluctuations (180-250 units), indicating superior process control compared to other defect categories, though notable increases occurred during May and August production cycles. The synchronized occurrence of multiple defect peaks during specific months suggests systemic quality control challenges requiring comprehensive root cause analysis and implementation of statistical process control methodologies to achieve sustainable defect reduction and enhanced manufacturing performance.

VSM (Value Stream Mapping)

Value Stream Mapping (VSM) diagrams are widely employed to systematically map, visualize, and analyze both value-adding and non-value-adding activities within a process, thereby facilitating the identification of inefficiencies and the optimization of material and information flows across the production system.

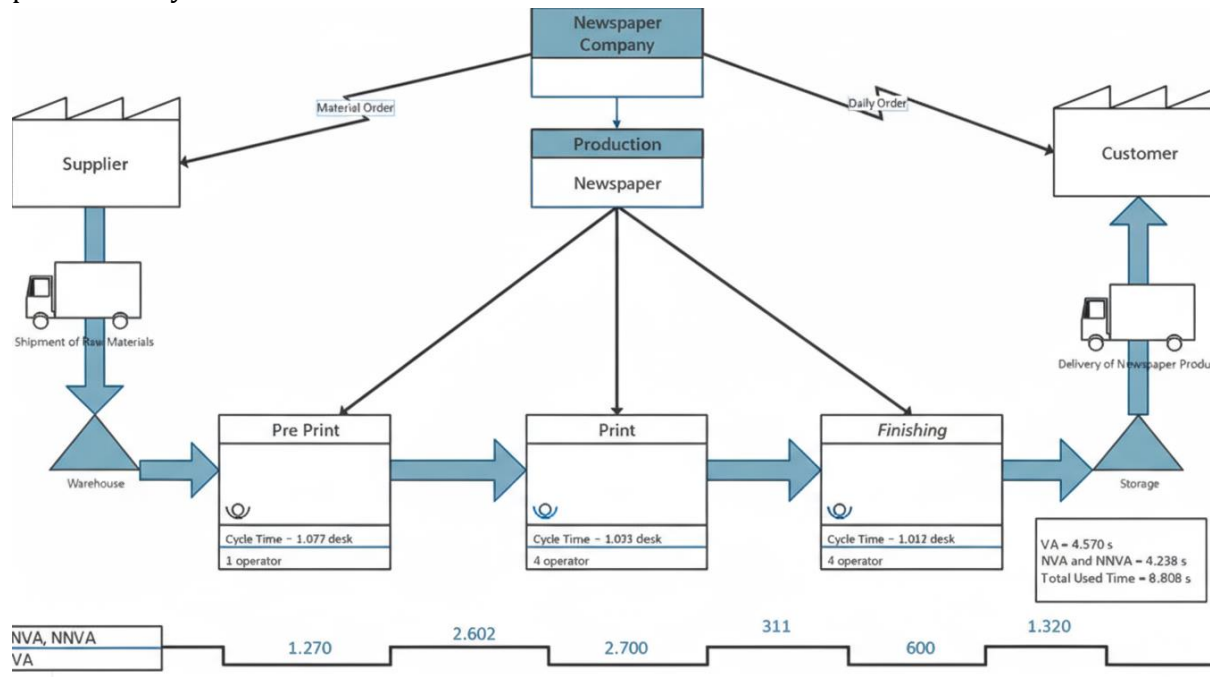


Figure 2. Value Stream Mapping of Newspaper Production

The figure 2 shows Value Stream Mapping (VSM) in the newspaper production process, which consists of the Pre-Print, Print, and Finishing stages, with the flow of materials and information from suppliers to customers. The mapping results show that the total process lead time reaches 8,828 seconds, with a Value Added (VA) proportion of 4.52% and Non-Value Added (NVA) of 95.48%, which indicates a high potential for waste in the production flow. This condition indicates the need for improvement in reducing non-value-added activities, particularly in waiting time in warehouses and distribution processes, to improve supply chain efficiency. Thus, the application of lean manufacturing through VSM can be a relevant strategy to minimize waste, accelerate cycle time, and increase the company's competitiveness in responding more responsively to customer demand.

Cycle time overall production is the total value of the VA value from all stations in the production process carried out. The calculation results obtained are huge 4570 seconds. VA is the time to do a process that adds value to the product, while NVA is the opposite of VA, which is the time to do a process that doesn't add value to the product, and finally NNVA is the time to do a process that doesn't add value, it's hard to get rid of but can be made more efficient. The calculation results obtained are huge 4.233 seconds.

Lead Time

Lead time refers to the total duration required from the initiation of a process until its completion. Based on the calculation results, the observed lead time reached 8.803 seconds, which indicates a considerable processing duration relative to the expected efficiency of the system.

Table 1. Lead Time of Newspaper Production

Process	Description of activities	Processing (second)	VA (second)	NVA (second)	NNVA (second)
Pre Print	Perform inspection of tools and printing materials	600			600
	Waiting for news to come in	1.800		1.800	
	Incoming news	900	900		
	Plate taking	10			10
	Printing news on plates	370	370		
	Inspect plate moulds	30			30
	Take plate molds to plate bending parts production station	22			22
	Bending the plate	120			120
	inspection	20			20
Print	Take the plate that has been bent into the newspaper printing machine	11			11
	Perform machine settings	900	900		
	Do the printing process	1.800	1.800		
	Print process inspection	300			300
Finishing	Bringing the printout in the finishing section	420			420
	Do packaging/finishing	900	900		
	Take the newspaper to the delivery car	600			600
Total		8,803	4,870	1,800	2,133
Average		100 %	55.32%	20.45%	24.23%

Table 1 shows the lead time analysis in the newspaper production process, which is divided into three main categories: Pre-Print, Print, and Finishing. The total process time reached 8,803 seconds, with a Value Added (VA) proportion of 4,870 seconds (55.32%), Non-Value Added (NVA) of 1,800 seconds (20.45%), and Necessary but Non-Value Added (NNVA) of 2,133 seconds (24.23%). These results show that more than half of the total production time was used for activities that provided direct added value, particularly in the activities of printing news on plates (370 seconds), the

printing process (1,800 seconds), and setting up the printing machine (900 seconds). However, there is a significant portion of non-value-added activities, such as waiting for news to arrive (1,800 seconds) and the inspection process (350 seconds in total), which collectively contribute to delays in the production cycle. On the other hand, activities categorized as NNVA, such as equipment inspection, plate collection, and final product delivery, account for nearly a quarter of the total lead time. This high proportion of NNVA indicates the need to evaluate the production support system to make it more efficient. Thus, the results of this analysis confirm that optimizing waiting times and inspection activities can be a key strategy in reducing lead time and improving the efficiency of the newspaper production process flow.

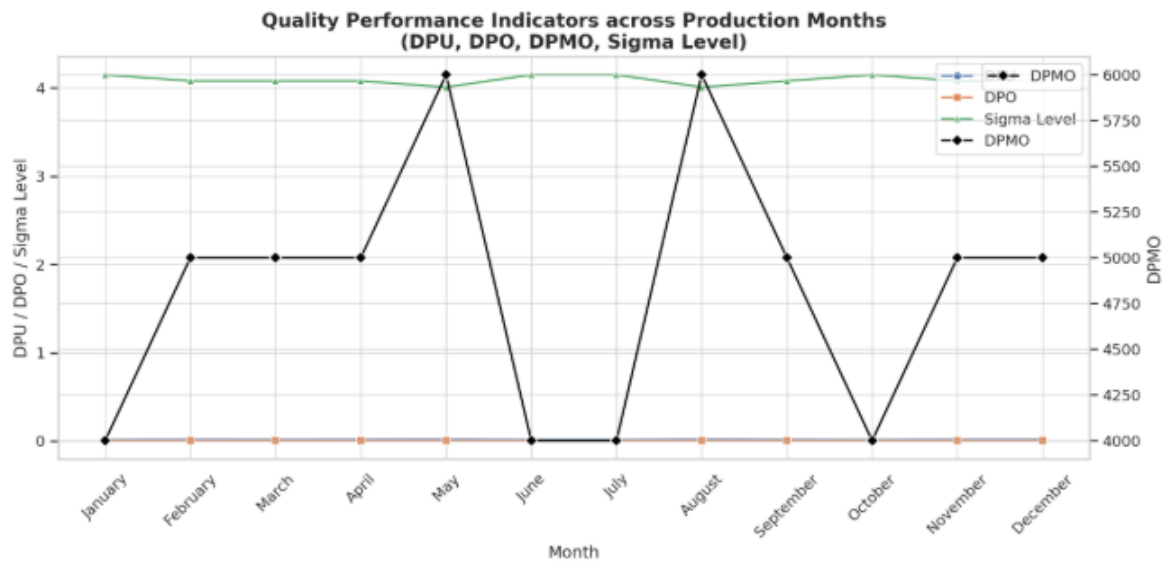


Figure 3. Quality Performance Indicators across Production

Based on the visualization results in the Quality Performance Indicators across Production Months (DPU, DPO, DPMO, Sigma Level) figure, it can be seen that the variation in quality indicators throughout the period from January to December shows significant fluctuations in the DPMO (Defects Per Million Opportunities) value, while the Sigma Level value is relatively stable at around 4.2–4.3. The DPU (Defects per Unit) and DPO (Defects per Opportunity) values tend to be constant at low levels, indicating that the defect rate per unit and per opportunity is relatively under control. However, the spike in DPMO in May and August indicates an anomaly in the production process that drastically increased the number of defects, although conditions returned to normal afterwards.

A Sigma Level above 4 indicates that the production process is still in the category of good process capability, in accordance with Six Sigma standards, where level 4 is equivalent to a quality level that can minimize defects to around 6,210 DPMO. However, the variation in DPMO shows that the production system still faces challenges in the consistent implementation of quality control. This condition emphasizes the need for more adaptive quality management interventions, such as through the implementation of Statistical Process Control (SPC) and root cause analysis for months with high anomalies.

Overall, the data shows that the company was able to maintain quality stability for most of the period, but still needs a continuous improvement strategy to reduce DPMO variability. These efforts will support the achievement of more consistent process capabilities, thereby driving the process towards a higher Six Sigma target level (>4.5 sigma) in line with world-class manufacturing industry standards.

The Improve stage represents the next step in implementing quality enhancement after identifying the root causes of defects. In this study, improvement strategies were developed but not directly implemented, as the research was limited to the diagnostic and analytical stages of DMAIC. Nevertheless, corrective measures were formulated to provide practical guidance for managers.

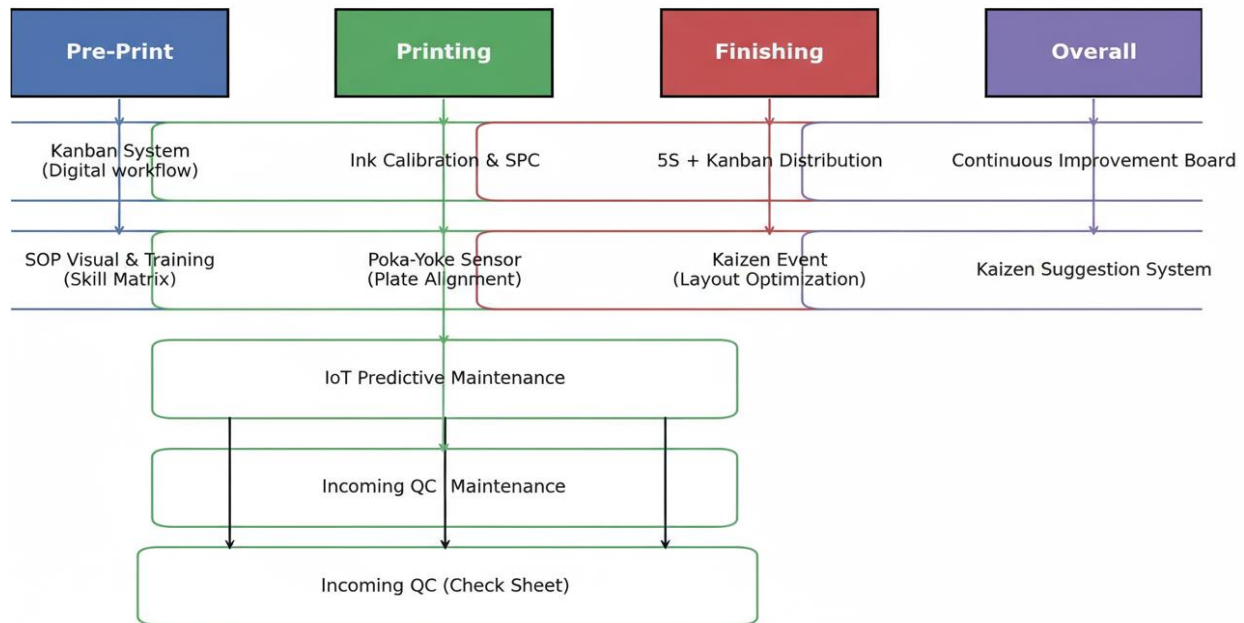


Figure 4. Proposed Improvement Roadmap

DISCUSSION

The findings of this study indicate that the major sources of inefficiency in newspaper production are waiting times and defective products, with scattered ink defects accounting for 55% of total errors. The process capability analysis yielded an average DPMO of 4,833 and a sigma level of 4.09, suggesting relatively strong but still improvable quality performance. Similar results have been reported in recent Lean Six Sigma (LSS) studies across manufacturing and service sectors.

Applied DMAIC to an aluminum extrusion process and reported a significant reduction in surface defects, coupled with an increase in sigma level. Their results align with the present study, where DMAIC effectively identified major defects; however, unlike their work, this study halted at the DMAI stages, leaving improvement strategies untested [28], [29]. Highlighted the role of LSS in maintenance systems, showing that preventive machine maintenance stabilized process variation and reduced product defects. This finding supports the present result that machine instability, such as plate shifting and unstable temperature, is a critical driver of defects [30].

Other case studies in filter manufacturing and bottleneck analysis [31], [32], [33] confirm that Value Stream Mapping (VSM) is effective in quantifying waiting and non-value-added activities, much like the 44.68% of non-value-adding time identified in this research. Automotive component suppliers applying DMAIC [34] achieved substantial reductions in DPMO and highlighted human and machine factors as the most influential causes of defects, consistent with the dominance of operator-related errors observed in the newspaper case.

Service-sector applications further reinforce these findings. In outpatient clinics, LSS projects significantly reduced patient waiting times and improved throughput [35], validating the emphasis on waiting as a critical waste category in the present study. Similarly, LSS applications in healthcare and pharmaceuticals have demonstrated that operator training and strict adherence to standardized work instructions are decisive in lowering defect rates [36]. These parallels strengthen the recommendation in this study to prioritize human-factor interventions through clearer SOPs, operator checklists, and supervisory control [37], [38], [39].

The importance of statistical process control is further confirmed in railcar assembly studies, where DMAIC-based monitoring detected special cause variations similar to the out-of-control points identified in this study's np-chart [25]. More recent works integrating LSS with Industry 4.0 suggest that real-time monitoring of machine conditions and predictive maintenance can reduce variability and stabilize defect levels [24], which is highly relevant to the recurring scattered ink issue documented here.

Finally, systematic reviews of LSS applications emphasize that Pareto analysis consistently identifies two or three defect categories responsible for the majority of failures [14]. This finding parallels the present result, where scattered ink and uneven margins together contributed 80% of total defects. In addition, several studies on food and packaging industries reported sigma levels improving from 3.0–3.5 to 4.0–5.0 after completing the Improve and Control phases [10], suggesting that the sigma level of 4.09 observed here could be further increased if the proposed improvement strategies were implemented and monitored.

In summary, the results of this study are consistent with recent evidence across industries: (1) human and machine factors dominate defect occurrence; (2) waiting time is among the most common wastes; (3) Pareto prioritization ensures efficient allocation of improvement resources; and (4) preventive maintenance and SOP compliance are critical enablers of sustained quality. The theoretical contribution lies in extending LSS applications to the printing sector, while the practical implication is the provision of evidence-based recommendations that can be tested in future work. However, unlike many Scopus-indexed case studies [15][4], this research remains diagnostic due to the absence of Control-phase validation, which should be addressed in subsequent studies.

CONCLUSION

This study demonstrated the application of Lean Six Sigma in diagnosing waste and defects in a Malaysian newspaper production company. The findings identified waiting time and defective products as the most critical forms of waste. Among the 12,000 defective copies recorded over one year, scattered ink (55%) and uneven margins (25%) emerged as the dominant defect types, collectively accounting for 80% of total defects. The process capability analysis yielded an average sigma level of 4.09, reflecting relatively stable performance but still below the Six Sigma benchmark. Value Stream Mapping further revealed that nearly half of production time was spent on non-value-adding

or necessary non-value-adding activities, underscoring the potential for efficiency gains. Root cause analysis showed that human factors, such as operator carelessness and non-compliance with SOPs, were the primary contributors to defects, alongside machine instability, material inconsistencies, and unclear methods. Based on these insights, the study proposed improvement strategies using the 5W+1H framework, emphasizing operator training, preventive maintenance, and stronger managerial supervision.

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