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Strategic Implementation of the PDCA and 5S Concepts to Improve the Productivity of the Informal Welding Industry in Kumasi, Ghana

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ABSTRACT

The informal welding industry is one of the major SMEs in Ghana. The industry is however confronted with a lot of challenges which, therefore, can be addressed by the use of Plan-do-check-act (PDCA) and 5S concepts. This study evaluated the benefits of the PDCA and 5S concepts as strategic tools for improving the performance of the informal welding industry in Kumasi, Ghana, by using the exploratory research technique. The PDCA and 5S concepts were implemented for a period of six months using 50 welder industries selected by the stratified random sampling procedure. The diagnosis of the current state of the industry was initially measured through performance indicators generated through questionnaires, interviews and direct observations. The design of the solution strategy was then implemented using the concepts to mitigate the challenges previously identified. This was followed by data collection to monitor the performance of the study factors. The results showed a significant (66%) general improvement in the cleanliness of the work environment, work safety and health of workers of all the study workshops. There was also a general decrease in defective products, and reduction in raw material waste and an enhanced aesthetic value of products. A total of over 17 productivity variables were evaluated out of which 11 saw between 4% and 96 % improvement, which in all translated into boosting the morale of workers and customer confidence. The study contributes to the paradigm shift of SMEs to modern management systems for enhanced performance and competitiveness.

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INTRODUCTION

The ever-increasing demands of consumers and their expectations, coupled with industrial competition and globalization are forcing organizations/industries small and large to implement various strategic and proactive market-driven strategies to continuously improve upon their products and services.[1] Continuous improvement is a key requirement for international standardization and it focuses on the idea that small, ongoing, and well-measured changes can result in a major improvement over time.[2] Continuous improvement is a process that involves planning, implementing, monitoring, and correcting any problems that may arise.

[1] Inderpreet P Singh Ahuja and Jaimal Singh Khamba, "Total Productive Maintenance: Literature Review and Directions," *International Journal of Quality & Reliability Management* 25, no. 7 (2008): 709–56.
[2] Paul W Hyland, Robert Mellor, and Terry Sloan, "Performance Measurement and Continuous Improvement: Are They Linked to Manufacturing Strategy?," *International Journal of Technology Management* 37, no. 3–4 (2007): 237–46.

A lot of obstacles have been identified that often impede the progress with the implementation of the PDCA and 5S concepts. This normally comes from the perception that the concepts are merely systems for improving housekeeping.[3] It should, however, be noted that implementation of these concepts alone is not sustainable but requires extensive leadership and follow-ups.[4]

Consequently, the PDCA and 5S models are underutilized tools in the sector. In fact, never before in the literature have these concepts been implemented by the informal welding industry in Ghana. This study therefore evaluated the benefits of the PDCA and 5S concepts as strategic tools for minimizing defects associated with the welding process and also improving the working environment, as well as the productivity of the informal welding industry in Kumasi Ghana, by using the exploratory research technique.

The 5S concept (Fig. 2) on the other hand arose after the Second World War as part of the quality assurance revolution in the manufacturing sector in Japan.[5] The term was, however, formalized by Takasshi Osada in 1980.[6] The 5S comes from five Japanese words; Seiri (sort), Seito (straighten), Seiso (sweep), Seiketso (standardize) and Shitsuke (sustain). The 5S model is considered one of the key performers' operational practices that yield significant results in the manufacturing sector.[7]

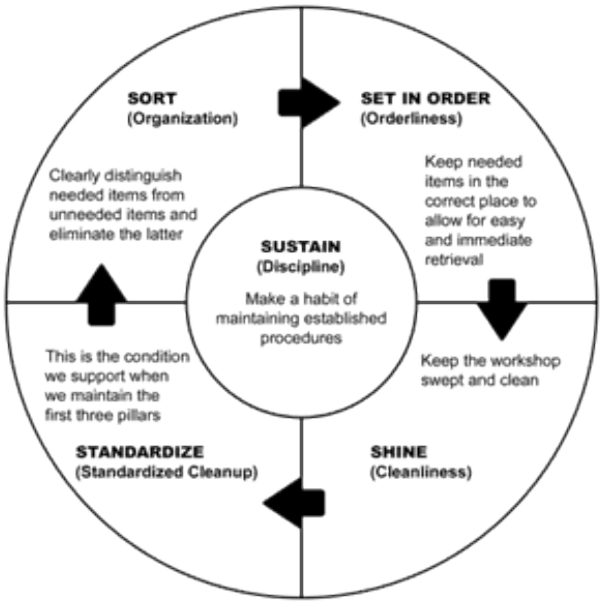

Figure 1: 5S cycle. [8]

The model contributes to improvement in productivity and quality,[9] safety and work environment,[10] with low implementation cost.[11] The 5S concept can be summarized briefly as nothing more than a resource in continuous improvement mechanism that presents itself as a simple and easy-to-apply tool that helps organizations to improve upon their productivity as well as guaranteeing customer satisfaction with quality products and services. Nonetheless, studies have shown that organizations have a rudimentary understanding of

[3] Rod Gapp, Fisher Ron, and Kobayashi Kaoru, "Implementing 5S with a Japanese Content. An Integrated Management System," *Management Decision* 46, no. 4 (2008): 565–79.
[4] Beata Gala and Wolniak Radoslaw, "Problems of Implementation of 5S Practices in an Industrial Company," *Management System in Production Engineering* 4, no. 12 (2013): 8–14.
[5] Paweł Falkowski and Przemysław Kitowski, "The 5S Methodology as a Tool for Improving Organization of Production," 2013.
[6] Gapp, Fisher Ron, and Kobayashi Kaoru, "Implementing 5S with a Japanese Content. An Integrated Management System."
[7] Alberto Bayo-Moriones, Alejandro Bello-Pintado, and Javier Merino-Díaz de Cerio, "5S Use in Manufacturing Plants: Contextual Factors and Impact on Operating Performance," *International Journal of Quality & Reliability Management* 27, no. 2 (2010): 217–30.
[8] Kimball Bullington, "5 S for Suppliers," *Quality Progress*, 2003, 56–59.
[9] Bayo-Moriones, Bello-Pintado, and Merino-Díaz de Cerio, "5S Use in Manufacturing Plants: Contextual Factors and Impact on Operating Performance."
[10] R Suresh Premil Kumar et al., "Performance Analysis of 5-S Teams Using Quality Circle Financial Accounting System," *The TQM Magazine* 19, no. 5 (2007): 483–96.
[11] Gapp, Fisher Ron, and Kobayashi Kaoru, "Implementing 5S with a Japanese Content. An Integrated Management System."

the principles and practices of the potential of these methodologies.[12] In another breath, organizations include some aspects of these methods in their daily routine activities unknowingly as a formalized technique.[13]

Welding is a fabrication process whereby two or more parts are fused together by means of heat, pressure or both forming a join as the parts cool. Welding is usually used on metals and thermoplastics but can also be used on wood. Welding is extensively used in Ghana for the production of agricultural machinery and implements, processing machinery, vehicle body structures and seat frames, burglary protection, balustrades and metal containers. It is also used in road construction for making bridges, buildings, staircases, billboards, railroad rolling stock, electric metal poles, telecommunication antennas etc., and in carrying out maintenance and repair work in the mining industry, refineries, and the automotive industry.[14] Welding operations in Ghana can generally, be grouped under two sectors namely the formal and the informal welding sectors. The formal welding sector comprises companies operating as medium and large enterprises (MLEs) registered in Ghana's trade register with clear-cut business objectives. The informal welding sector on the other hand comprises welding operations carried out by artisans in roadside welding shops, under trees and in local welding shops in light industrial areas. Welders in this sector engage in the repair and manufacture of car seats, aluminum containers for shops, brick/block molding machines, wagon and chassis (trucks), coal pots, oil/fluid storage tanks, iron gates, car seat frames, billboards, burglarproof windows and doors, vehicle body repairs, etc.[15]Majority of the welders use basic hand tools in their manufacturing processes including hammers, chisels, grinding tools, and drilling tools.[16] The sector mostly employs the Arc welding technique using coated welding rods.[17] Research has shown that even with the appropriate design, and technique, sometimes a series of risks appear during the welding process which can potentially result in the production of defective welds. This obviously undermines the reliability and quality of products.[18] While in recent years a series of metal welding standards such as ISO 3834 and EN 1090 have emerged for controlling the welding process, the informal welding sector in Ghana still operates with no such standard operation procedures.[19]

LITERATURE REVIEW

Theoretical Framework

Two of the most widely used tools or models for continuous improvement are the PDCA and 5S cycles. The PDCA cycle technique is a four-step process designed to help organizations identify opportunities for implementing changes and assess the results (Figure 2).

Figure 2: Plan-do-check-act (PDCA) cycle[20]

[12] Bayo-Moriones, Bello-Pintado, and Merino-Díaz de Cerio, "5S Use in Manufacturing Plants: Contextual Factors and Impact on Operating Performance."
[13] Samuel K M Ho, "5-S Practice: The First Step towards Total Quality Management," *Total Quality Management* 10, no. 3 (1999): 345–56.
[14] Michael Akpakpavi, "Weld Quality Assurance Practices in the Metal Welding Industries in Ghana," *International Journal of Science, Technology and Society* 3, no. 4 (2015): 111–19.
[15] Akpakpavi, "Weld Quality Assurance Practices in the Metal Welding Industries in Ghana."
[16] Peggy Ama Fening et al., "Safety, Practices and Associated Healthy Hazards among Informal Welders in Kumasi Workplace, Ghana," *Design Engineering* 8 (2021): 17221–35.
[17] Emmanuel Adu and Andrews Danquah, "Welding Practices in Selected Metal Welding Industries in Ghana," *International Journal of Scientific and Engineering* 7, no. 6 (2016): 462–73.
[18] J P Oliveira, T G Santos, and R M Miranda, "Revisiting Fundamental Welding Concepts to Improve Additive Manufacturing: From Theory to Practice," *Progress in Materials Science* 107 (2020): 100590.
[19] Fening et al., "Safety, Practices and Associated Healthy Hazards among Informal Welders in Kumasi Workplace, Ghana."
[20] Moen Ronald, and Norman Clifford. Circling back. Clearing up the myths about the Deming and seeing how it keeps evolving. Quality Progress, (2007) 24; 23-28.

The Plan–Do–Check–Act procedure involves the following basic steps:

Plan: Recognizing an opportunity and planning a change. In the case of metal fabrication, it could be designing a new product due to customer preference changes in market demand.

Do: Carrying out a small-scale study. Regarding metal fabrication, this could be fabricating samples of a proposed design.

Check: Analyze the outcome of the results. In this case, test the market acceptability of fabricated products.

Act: If the change does not yield the desired results, go through the process again with a different plan. In this case, construct a new design. If on the other hand, you were successful, incorporate a new design into broader fabrication and use newly acquired ideas for continuous improvement.

Continuous Improvement

The current global market environment is very dynamic and as a result, manufacturing industries are experiencing intense competition regarding products and processes, technologies, customer expectations and employee behaviour. These challenges are forcing manufacturing industries to implement various strategic and proactive market-driven programs to remain competitive.[21] Issues of concern include improving efficiency in product cost, product quality, and satisfaction of customer demands.[22] To be able to address these challenges requires improvement in the manufacturing process, which includes simplification of the manufacturing process by eliminating waste and other workplace innovation practices.[23]

Industry Productivity and Performance Improvement

The PDCA cycle is a continuous cycle of planning, doing, checking and acting. It provides a simple and effective approach to addressing challenges and managing changes in an organization. It was developed in 1930 when the global market focused on product competitiveness based on quality management systems.[24] The PDCA cycle was used as a tool for quality control of products in its beginnings. Later it became acceptable as a tool for developing improvements in processes at the organizational level.[25] PDCA in recent years has been employed in a continuous improvement approach for improving activities of organizations as well.[26] The PDCA implementation is very flexible and accommodates other tools for its effective implementation.

These tools usually help in analyzing the problem and defining the necessary actions to be taken for implementation. One of the major tools that support the effective implementation of PDCA is the 5S. The 5S approach helps to establish a disciplined, clean and well-organized work atmosphere, through planning, managing, and regulating the manufacturing process. It also makes processes easier, saves operation space, and time and produces goods with fewer defects. Chapman considers 5S as an industrial technique that makes an organization different from the rest.[27]

Implementation of the PDCA cycle has shown positive outcomes such as a reduction of costs and defects, as well as an improvement in the quality of processes and products. For instance, Nabiilah et.al., utilized the PDCA cycle approach to reduce the defects in the electrodeposition process.[28] In the service section, Chen et.al., also applied the PDCA cycle in the management of Herceptin usage in breast cancer patients and saw a significant safety of the usage of the medication.[29] The solution to the problem of quality in the production of

[21] Ahuja and Khamba, "Total Productive Maintenance: Literature Review and Directions."
[22] Hajime Yamashina, "Japanese Manufacturing Strategy and the Role of Total Productivemaintenance," *Journal of Quality in Maintenance Engineering* 1, no. 1 (1995): 27–38.
[23] Shiego Shingeo, *Non-Stock Production: The Shingo System for Continuous Improvement* (Cambridge, M.A: Productivity Press, 1998).
[24] Christina Strotmann et al., "A Participatory Approach to Minimizing Food Waste in the Food Industry—A Manual for Managers," *Sustainability* 9, no. 1 (2017): 66.
[25] Rikio Murata, "Maximizing Knowledge Work Productivity: A Fine Constrained and Activity Visualized PDCA Cycle," *Knowledge Process Management* 19 (2012): 203–14.
[26] Haibin Yang, "Research and Exploration on the Teaching Practice System in Application Oriented Universities——Research and Exploration on the Teaching Reform of Circuit Principle Course of Jilin Agricultural Science and Technology College," in *2021 4th International Conference on Information Systems and Computer Aided Education* (New York, NY, USA: ACM, 2021), 1176–79, https://doi.org/10.1145/3482632.3483109.
[27] Christopher D Chapman, "Clean House with Lean 5S," *Quality Progress* 38, no. 6 (2005): 27–32.
[28] A R Nabiilah, Z Hamedon, and M T Faiz, "Improving Quality of Light Commercial Vehicle Using PDCA Approach," *Journal of Advanced Manufacturing Technology (JAMT)* 12, no. 1 (2) (2018): 525–34, https://jamt.utem.edu.my/jamt/article/view/4310.
[29] Hong Chen, Ping Wang, and Qi Ji, "Analysis of the Application Effect of PDCA Cycle Management Combined with Risk Factor Management Nursing for Reducing Infection Rate in Operating Room," *Frontiers in Surgery* 9 (2022): 837014.

photo frames was also found by the application of the PDCA cycle where the number of non-conformant materials decreased by 60%. Furthermore, the PDCA cycle was used to minimize defects in T-shirt knitting.[30] The suitability of the joint application of PDCA and 5S in small-scale industries has been confirmed by several studies including that of Singh and Baja.[31] The implementation of the PDCA and 5S concepts does not however go without any obstacle. One of the identifiable obstacles is the changing employee perception of their jobs.[32] Another observed obstacle is the lack of resources for implementation.[33]

These obstacles notwithstanding, it can be stated that the PDCA and 5S are effective tools for continuous improvement in the workplace.

MATERIALS AND METHODS

This study was conducted in the Kumasi Metropolis where a lot of informal welding industries are located. The target population for this study was the current informal welders in the Kumasi Metropolis and the sampling frame comprised 1200 welders who are in active business. The stratified sampling method was employed in arriving at the 250 welders in the metropolis, which the researchers believe possess the experience relevant for this study and who have sufficient time and were willing to participate. The advantage here is that respondents will participate of their own volition and not be selected against their will.[34] This technique was chosen to boost the response rate because respondents in this sector were reluctant to give out information since they believed in one way or the other, information about their business may leak through to competitors and also expose them to tax authorities. The sample size for the study was calculated using the stratified sampling technique as explained by Creswell.[35] In this method the researchers first divide a population into smaller subgroups, or strata, based on shared characteristics of members and then randomly select among these groups to form the final sample. This procedure ensures that the sample size is representative of the population and reduces sampling errors leading to more accurate results.

Stratified subgroup sample size = Total sample size/entire population*population of a subgroup. The calculated sample size is shown in Table 1.

For example, Sample size for Asawase = 250/1200*30 =6.0

Table 1. Location of welding workshop, respective number of welders and stratified sample size

Location	**Number of welders**	**Sample size**
Asawase	30	6.0
Asokwa	22	4.0
Bantama	12	2.0
Kwadaso	28	6.0
Manhyia	16	3.0
Nhyiaeso	22	4.0
Oforikrom	28	6.0
Suame	32	7.0
Subin	26	5.0
Tafo	34	7.0
Total	**250**	**50.0**

Primary data obtained for this study were acquired through the use of questionnaires, personal observation and personal interviews. The design was adopted because of its appropriateness in describing the current situation of the operation of the industry. The questionnaire was designed in open and close-ended patterns and administered directly to the welders. The questionnaire was pilot tested on 10 respondents and it

[30] Md Tahiduzzaman et al., "Minimization of Sewing Defects of an Apparel Industry in Bangladesh with 5S & PDCA," *American Journal of Industrial Engineering* 5, no. 1 (2018): 17–24.

[31] B Singh Sidhu, V Kumar, and Amit Bajaj, "The" 5S" Strategy by Using PDCA Cycle for Continuous Improvement of the Manufacturing Processes in Agriculture Industry," *International Journal of Research in Industrial Engineering* 2, no. 3 (2013): 10.

[32] Bhavesh Chandrayan, Ankit Kumar Solanki, and Richa Sharma, "Study of 5S Lean Technique: A Review Paper," *International Journal of Productivity and Quality Management* 26, no. 4 (2019): 469–91.

[33] Arashdeep Singh and Inderpreet Singh Ahuja, "Review of 5S Methodology and Its Contributions towards Manufacturing Performance," *International Journal of Process Management and Benchmarking* 5, no. 4 (2015): 408–24.

[34] Janice M Morse, "Designing Funded Qualitative Research.," 1994.

[35] John W Creswell and Cheryl N Poth, *Qualitative Inquiry and Research Design: Choosing among Five Approaches* (Sage publications, 2016).

yielded a Cronbach Alpha coefficient of 0.83. This coefficient signified high internal consistency and reliability. The data collection exercise was done between January and July 2022. The questionnaires were orally administered to respondents using the local language where necessary to ensure more accurate information gathering. A total of fifty (50) respondents were used for the study who were selected by the stratified random sampling as described above. Before the commencement of the study, the selected informal welding workshops in the Kumasi metropolis were located and coded. At each identified workplace the objective of the study was explained to the welders present and their consent was sought for data collection. They were also informed that their participation was voluntary and that they could withdraw from the interview at any time without consequences.

Implementation of PDCA and 5S Technique

After the work problems identified were analyzed and discussed with the respondents, the following goals for improvement were set using the PDCA concept as described by Randhawa and Ahuja [36] and the 5S approach. The 5S is a cyclical methodology: sort, set in order, shine standardize, and sustain the cycle which is used by manufacturing organizations to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results.[37] The set goals were to:

- ensure a safe and clean working environment
- improve the morale of workers
- reduce waste
- improve equipment and tools capacity
- improve fabrication process
- improve customer satisfaction
- increase sales

A discussion session on the implementation of the 5S technique was scheduled with the respondents and each of the study workshops was asked to follow the steps described below in Table 2.

Table 2. Procedure for implementation of 5S system

5S Steps	Description of task
Sort	To sort out unneeded items from needed ones and remove unnecessary items such as broken and malfunctioning tools and equipment, scrap, broken wooden tables and chairs, unused working gear and unused utensils and dispose of them. Assign a supervisor to oversee cleaning procedures and ensure the workplace is tidy all the time. Create a regular cleaning schedule in order to maintain cleanliness. Ensure house cleaning materials such as brooms, rags, ceiling brushes mops, and rugs are occasionally stocked up.
Set in order	To organize the work environment so that items will be easy to find, arrange tools and other items properly, designate areas for specific activities such as storage, label items and make available needed tools and materials such as work benches, chairs for staff and customers, cabinets and shelves for keeping materials. This will improve work safety.
Shine	To strive to ensure the working environment is neat and clean all the time, tools are also clean and well placed, the work environment is safe, and workers are provided with PPEs to improve safety and health. Ensure availability of first aid. Take pictures of the workplace before implementing 5S and track work improvement to measure the impact of change.
Standardize	To operate with SOPs, by apportioning duties and responsibilities, providing work scheduling charts, good record keeping, ensuring daily standard practices, ensuring the workplace is tidy at the end of each day,
Sustain	Changing entrenched behavior can be difficult and the tendency is often to return to the status quo and the comfort zone of old ways of doing things. Therefore practice and repeat new operating guidelines on a daily basis until it becomes a way of life.

[36] Jugraj Singh Randhawa and Inderpreet Singh Ahuja, "5S Implementation Methodologies: Literature Review and Directions," *International Journal of Productivity and Quality Management* 20, no. 1 (2017): 48–74.
[37] Singh and Ahuja, "Review of 5S Methodology and Its Contributions towards Manufacturing Performance."

The results of the implication plan were checked for a period of 6 months after which a comparative evaluation was carried out to assess the success of the implementation concept. The statistical package for social sciences (SPSS) software, version 21.0 was used to process data, whilst descriptive statistical tools such as frequency and percentage were used to present facts sought from respondents.

RESULTS AND DISCUSSION

Sociodemographic Characteristics of Respondents

All the welders interviewed were Ghanaians and full-time practitioners who were in active practice. Twenty percent (20%) of them were below 20 years of age. The majority (75%) were between the ages of 25 and 35 years. The remaining 5% were 40 years and above. Most of the workshops visited have a workforce of between three and eight. All the welders interviewed had some level of education, spanning from basic education (4%), secondary (68%) and tertiary which comprise graduates from technical colleges, polytechnics, diploma awarding institutions and universities (28%). Ninety-four (94%) of the welders were males and 6% were females. Majority (56%) of the respondents were married. The number of years of practiced ranged from 2 – 28 years. A large proportion of the welders (76%) did not possess the necessary technical qualifications related to welding. Instead, the apprenticeship system provides effective informal training for the welders. About 60 % of the welders visited had an average of three apprentices whilst the rest had between four (4) to eight (8) apprentices each who worked with the master craftsman.

Majority of the welders encountered (68%) practiced manufacturing welding involving metal gates and building accessories such as burglar-proof and balustrades, sheet metal containers, and tanks. The rest (30%) were involved in repair and maintenance welding, whilst a few (2%) practiced constructional welding. The practice of shield welding accounted for 72.8% of the welding types of the respondents, followed by those who practice both shield arc welding and gas metal arc welding (27.2%).

Comparative Evaluation of the Implementation of PDCA and 5S

The Working Environment

The working environment is defined by Sergio et.al., as the totality of the systems, conditions and situations in which an employee performs his/her tasks.[38] Nitsemito also defined the work environment as anything that exists around the employee at the workplace.[39] McGuire and McLaren on the other hand, defined it as the physical layout and design of the workplace including cleanliness, water, security, lighting, and, space.[40] The work environment impacts greatly on the performance of employees both positively and negatively. There are two types of work environments, conducive and toxic. A conducive work environment gives a satisfying experience to employees and enables them to actualize their abilities and potential. A toxic environment on the other hand brings about unpleasant experiences and at the same time reinforces low actualizing behaviours and levels to the development of negative traits of employees.[41] The work environment of the workshops in this study is presented in Table 3. Most of the workshops visited (68%) were small in size. The welding operations were observed to be mostly carried out in structures along the roadside and sometimes in miniature workshops and under trees with others using any available public space (popularly referred to as 'no man's land). The working environment was therefore observed to be generally poor in about 88% of the respondents. There were very limited numbers (8%) of storage facilities including racks or shelves to stock steel bars, sheet metals, and finished products. These items were seen lying haphazardly on the workshop floor. Most (78%) of the workshops also had no welding benches, as a result, most of the welding activities are done on the floor. There were basically no places of convenience at all the workshops visited. These observations confirm the findings of Fening et.al.[42] Such an environment is a significant detriment to employee motivation and engagement, which results in low productivity.

Enhanced performance of employees can therefore be realized only when the proper work environment is provided. A healthy workplace is the first and foremost requirement of any employee.[43] Such an environment nurtures job satisfaction and contributes to the quality of services.[44] Implementation of the PDCA and 5S

[38] Manzetti Sergio et al., "Fullerenes Toxicity and Electronic Properties," *Environmental Chemistry Letters* 11 (2013): 105–18.
[39] Alek Nitsemito, *Personnel Management, Human Resources Management*, 3rd Edition (Ghalia, Indonesia: Jakarta, 2001).
[40] David McGuire and Lauren McLaren, "The Impact of Physical Environment on Employee Commitment in Call Centres: The Mediating Role of Employee Well-being," *Team Performance Management: An International Journal* 15, no. 1/2 (2009): 35–48.
[41] O C Kyko, "Instrumentation: Know Yourself and Others" (New York: Longman, 2005).
[42] Fening et al., "Safety, Practices and Associated Healthy Hazards among Informal Welders in Kumasi Workplace, Ghana."
[43] John Kerke, "Literature Review on Improving the Workplace Environment," ukdiss.com, 2010.
[44] Jinbing Bai, "Does Job Satisfaction Mediate the Relationship between Healthy Work Environment and Care Quality?," *Nursing in Critical Care* 21, no. 1 (2016): 18–27.

approaches resulted in improving the general cleanliness of all the workshops by over 66 % of respondents (Table 3). Items such as scraps, unused clothing, and other sharp objects that used to lie on the ground unattended to were all dealt with. This provided better work safety which significantly helped to reduce the chances of injury incidents. The results collaborate with the findings of Fernandes [et.al]., who observed a significantly different score in favour of cleanliness, neatness and orderliness at a manufacturing workplace when the 5S approach was implemented. [45]

In certain instances, a workplace might seem full not because there is much to house, but rather due to poor arrangement of items and unnecessary items that need to be discarded. Compliance with the PDCA and 5S principles resulted in the creation of more space for needed items. The study also observed an improvement in the storage arrangement of the study workshops, as 20% had provided wooden cupboards for storage of tools and other items. In a small number (2%) of other workshops there were innovations where wooden shelves of small compartments were made to keep personal items of workers and not left scattered and hanging around the workplace as previously. A greater number (34%) of the workshops had provided workbenches which were a great achievement of the implementation process. Tools and equipment in almost all the workshops were cleaned and kept properly than previously to make them quickly accessible for use. This helped to avoid derailing the welding process because employees knew where to get what tool they needed in the shortest time possible. This agrees with the findings of Indah et.al., who observed 18.7% and 11.2% effectiveness in minimizing the search activity and space occupancy in a welding workshop when the 5S technique was implemented.[46] A sizeable number of workshops (34%) unfortunately did not improve in their storage of tools and other materials status solely because those workshops operated along the streets and had no proper housing units with poor security.

Table 3. Implementation of PDCA and 5S on The Work Environment

Factor	Description	Percentage occurrence before	Percentage occurrence after
Type of workshop	Small miniature workshops situated under trees and along the road.	68	68
Work floor	Poor unconcreted work floors.	86	80
Condition of work environment	Poor working conditions, items lying haphazardly, generally untidy.	88	22
Workbenches, chairs	Availability	22	56
Arrangement of tools and equipment	Grouping and arrangement of tools properly for easy reach	16	56
Storage facility	Availability of items for keeping tools and other work items	8	58
Presence of unwanted materials	Scraps, unused clothing and other sharp objects are scattered around	68	6
Place of convenience	Availability of changing and washrooms	4	4
Supervisor	Designated person responsible for workshop cleanliness	15	100
Cleaning of workshop	Regular cleanup schedule	4	100

The Welding Processes

The main task of welders is to assemble raw materials to obtain finished products without defects for their customers. Defects are considered one type of waste in the welding process that negatively affects the quality aesthetic value and cost of products. Studies have shown that even after proper selection and handling of raw

[45] Joana P R Fernandes, Radu Godina, and João C O Matias, "Evaluating the Impact of 5S Implementation on Occupational Safety in an Automotive Industrial Unit," in *Industrial Engineering and Operations Management II: XXIV IJCIEOM, Lisbon, Portugal, July 18–20 24* (Springer, 2019), 139–48.

[46] I Rizkya et al., "5S Implementation in Welding Workshop–a Lean Tool in Waste Minimization," in *IOP Conference Series: Materials Science and Engineering*, vol. 505 (IOP Publishing, 2019), 012018.

materials and the welding process, defective parts still persist.[47] This assertion was confirmed by this study as some defects including insufficient or excessive welds and welder bridges were commonly observed on most of the products on display at all the workshops visited. All the workshops also lack Metal Active Gas (MAG) welding machines, as a result long welded seams are produced manually by the arc welding method using coated welding rods (Table 4). Furthermore majority (94%) also lacked sheet metal processing equipment, hence sheets are mostly cut and molded manually which results in poor quality finishing. The artisans practiced visual inspection as the mode to ascertain quality. Correcting these defects when a product is already assembled is always a difficult task. A closer look at the equipment and tools at the workshops revealed negligence of maintenance. Tools and equipment were often dusty and were not well arranged. It was observed that there is practically no periodic equipment and tools maintenance culture. Some of the apprentices even shared tools. Implementation of the PDCA and 5S techniques improved the welding process and reduced welding defects by 20% (Table 4).

A lot of studies have indicated that most organizations are able to attain significant improvements from 5S implementation in the quantity of items manufactured through various influences not limited to increased availability of equipment, a reduction in set-up time and overall improvements in production time.[48] This study on the contrary, however, found this improvement to be minimal and this could be related to other factors including high cost of raw materials, customer priority change, and prevailing economic situation (Table 4). Indah et.al. also obtained similar minimal improvement in productivity in their study. [49]

Table 4. Implementation of PDCA and 5S on The Welding Process

Factor	**Description**	**Percentage occurrence before**	**Percentage occurrence after**
MAG machine	Availability	0	0
Sheet metal processing equipment	Availability	6	6
Welding method employed	Shield Arc Gas metal arc	88 12	88 12
Equipment maintenance culture	Periodic maintenance	0	4
The mechanism for assessing the quality of products	Visual	100	100
Items produced and timely delivery	Quantity	52	74
Maintenance cost	Provision of necessary tools and items	2	58
PPEs	Use of complete PPEs by workers	4	12

Implementation of the PDCA and 5S program effectively improved welding quality and rate of delivery in all the study workshops by 22%. This 22% improved welding quality finding collaborates with that of Ablanedo-Rosas et.al., who observed that application of the 5S practice improved quality products and the competitive advantage of manufacturing industries in Mexico.[50] The maintenance cost of the implementation process was observed to be high in the majority (72%) of the workshops due to factors including the provision of workshop items for cleaning, making of wooden cupboards for storage, provision of shade canopies and acquisition of new basic tools.

This study has explored a window of opportunity for improving the competitiveness and profitability of the informal welding industry. Some of the ergonomic practices that were identified to be debilitating to the market competitiveness and profitability of the industry included defective or poor finished products, absence of

[47] Sergio et al., "Fullerenes Toxicity and Electronic Properties."
[48] Randhawa and Ahuja, "5S Implementation Methodologies: Literature Review and Directions."
[49] Rizkya et al., "5S Implementation in Welding Workshop–a Lean Tool in Waste Minimization."
[50] José H Ablanedo-Rosas et al., "Quality Improvement Supported by the 5S, an Empirical Case Study of Mexican Organisations," *International Journal of Production Research* 48, no. 23 (2010): 7063–87.

standard operating procedures, absence of maintenance culture, poor workshop arrangement and poor record keeping.Based on the evaluation results after a six (6) month period of implementation of the PDCA and 5S concepts, there was a remarkable improvement in the work practices and a better work environment that had an impact on improving workplace safety and workers' confidence.This implies that the implementation of the PDCA and 5S concepts provided a positive impact on the informal welding industry both in terms of workers' safety and market competitiveness, thereby improving their profitability.

RECOMMENDATION

The informal manufacturing industry in Ghana has fewer capital resources to invest and usually operates on limited profit margins. The operators of these industries also have the perception that quality implies procuring state-of-the-art equipment and employing modern technologies. This study on the contrary has demonstrated that when the investment and profit margins are modest, it is better and appropriate to implement the PDCA and 5S approaches to enhance performance and productivity. This study, therefore, recommends that the PDCA and 5S concepts be replicated in other formal and informal manufacturing industries in other to meet quality and customer expectations.

CONCLUSION

This study has evaluated the benefits of the implementation of the principles and practice of the PDCA 5S concepts on the productivity of the informal welding industry in Ghana. The findings showed that PDCA is a tool that facilitates the detection of improvement opportunities and their development and implementation in an organization. The benefits of the PDCA cycle are further simplified and enhanced by the 5S supportive tool as documented in this study and others. The application of these combined tools improved the general workplace environment and reduced welding defects. A total of over 17 productivity variables were evaluated out of which 11 saw between 4% and 96 % improvement. Altogether, the morale of workers was enhanced which translated to improved productivity. Another development achievement of this study is the provision of a competitive advantage to the workshops that partook in the study over their counterparts who did not take part in the study. To sustain this observed improvement will, however, require organizational cultural changes which will influence the daily attitude behavior of all workers in the informal welding industry. The empirical nature of the study provides practicing welders who wish to implement the PDCA and 5S concepts the evidence of the benefits. It also provides a starting point avenue for further scientific interrogation into the subject matter. The findings of the study also contribute to the scarce knowledge on the subject matter in Ghana.

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