Execution of Plan-Do-Check-Act and Lean in Manufacturing Line: A Case of Foundry Industry of South Africa

Kgashane Stephen Nyakala
Department of Mathematics & Statistics
Tshwane University of Technology
Pretoria, South Africa
nyakalaks@tut.ac.za

Mbali Yvonne Moore
Council for Scientific and Research, Pretoria
Pretoria, South Africa
mbali.hadebe1984@gmail.com

Kemlall Ramdass
Department of Mechanical Engineering
University of South Africa
ramdakr@unisa.ac.za

Abstract

Systems for refining and handling foundries have rapidly evolved in recent years. There is a constant requirement that the foundry industrial maintain its competitive stature in such a competitive environment. Absence of proper productivity measures diminishes the ability to ensure production performance. Uncontrollable and unstable processes impact profitability and sustainability of the organisation. The purpose of this study was to evaluate the current production capability with a view of enhancement. A combination of descriptive and non-parametric statistic was used to analyse data gathered. The proposed industrial engineering methodologies of improvement proved successful for the foundry industry. A quantitative cross-sectional survey research design was used for the study. This study utilised a self-developed questionnaire to identify the factors that are contributing to the low productivity of the Gauteng foundry industry. The population for this study consisted of foundry employees in the Gauteng Province of South Africa. The study selected a purposive sampling technique to provide insight into the specific study. The quantitative data obtained from the study was analysed using several statistical tools in the Statistical Package for the Social Science (SPSS) version 24.0 tool. The study was restricted to the Foundry industry, Gauteng Province. The integration of Lean methods, Plan-Do-Check-Act (PDCA) cycle method, and 5S methodology is proposed to achieve continuous improvement in the production environment of the foundry industry. This framework provides guidance on the use of productivity improvement techniques by clearly indicating steps and targets that support the achievement of cost reduction and continuous process improvement.

Keywords
Lean principles, Plan-Do-Check-Act, Manufacturing processes; Productivity improvement; South African Foundries

1. Introduction
The foundry manufacturing processes include metal castings that are equipped for making moulds, melting and handling molten metal, performing the casting process, and cleaning the finished casting. Metal castings include a large and diverse family of processes that can be categorised in many ways. For example, molten metal is cast into shapes using moulds and various patterns. Metal casting refers to the process through which the molten metal is allowed to flow by gravity or under pressure into a mould, where it solidifies in the shape of the mould cavity. The metal casting is removed from the mould after which it is machined and heat-treated. According to Cagno, Ramirez-

Portilla and Trianni (2015:4), foundries produce castings that are close to the final product shape, that is, adjacent form components. Thus, types of casting processes used differ between different foundries; the casting process depends on the quantities and the size of castings to be produced. Foundry companies are required to focus their customer business strategies in terms of quality, cycle time, cost and effectiveness. Conversely, most South African foundries are unable to meet customer requirements, and as such find themselves failing to take advantage of opportunities existing in the industry

For a foundry manufacturing industry, productivity growth improves profitability and enhances a firm's competitive position in the market. Olson (2006) discovered that productivity improvement in an enterprise could be a result of management efficiency. Araujo, Amaral and Varela (2017) state in their review that investment in both human and equipment resources will improve plant efficiency and employee improvement suggestions and the interaction of production employees with equipment engineers or specialists. An efficient productivity improvement strategy requires a systems approach which recognises the interrelationship between the elements of the system and its environment. According to Mostafa and Dumrak (2015), the main features of productivity enhancement include just-in-time practices, work-in-progress, and waste reduction (Groover 2011; Lee & Johnson 2013; Stevenson, 2015). Concerning the wastes, the literature promulgates that in the manufacturing industry these are classified into seven categories: waiting times, movements, overproduction, over processing, inventory, transport and defects. In the defined context of defects, various authors point out that defects are the main cause of damages in more advanced components. Defective products and production lines are present in the foundry manufacturing industry and requirement investigation.

2. Literature review

2.1 PDCA cycle

The PDCA cycle, also known a Deming cycle or Shewhart cycle (Saier, 2017), is a lean manufacturing methodology that was developed in 1930, when there was no more exclusive products and a more quality management focusing on competitiveness raised in the global market (Gaither & Frazier 2002). The PDCA cycle is characterised by its focus on continuous improvement; therefore, one can consider it as one of the tools that can cause improvement in the foundry industry (Maruta 2012:204). Many believe that the application of the PDCA cycle is more effective than adopting the right first-time approach (Lee & Johnson 2013: 80; Lyman 2015:101). This is because when applied correctly in any manufacturing operation, it means one is continuously looking for better systems of improvement while ensuring that senior managers or supervisors must take corrective action. Olson (2006) explains that the PDCA cycle, also known as an iterative four-step management approach is used for controlling and continuously improving processes. The PDCA method has enormous applications when developing a new or improved design of a process; when defining a repetitive work process; and when implementing any change (Groover 2011: 10; Lyons, Vidamour, Jain & Sutherland 2013: 476; Lyman 2015:103; Zeng, Phan & Matsui, 2015:216; Zokaei & Simons 2006:142). Belekoukias, Garza-Reyes & Kumar (2014:5348), for instance, conducted study relating to the impact of lean methods and tools on the operational performance of manufacturing organisations. Tahiduzzaman, Rahman, Dey & Kapuria (2018:22). PDCA has been applied in operations (Nascimento, Quelhas, Caiado, Tortorella, Garza-Reyes & Rocha-Lona, 2019:578); process engineering, procurement and ceramic (Babu, Thirugnanam & Sivam, 2016:416). A lack of their application has caused the performance of the domestic manufacturing sector to perform ineffectively in recent years as seen by weak demand conditions in local and external markets, as well as by increased competition from imported products (Lee & Johnson 2013:17; Wilson, Lindbergh & Graff, 2014:306; Ramachandran & Neelakrishnan 2017:110).

- Plan: The method pledges an improvement solution with a Plan by identifying what exactly is the problem.
- Do: The plan is executed by Do; firstly, and identifying possible solutions.
- Check: The information resulting from the experiment is checked and studied.
- Act: The final stage of Act concludes the cycle by applying actions to the outcomes for necessary improvement.

2.2 5S methodology

5S methodology is a reference to a list of five Japanese words (Seiri, Seiton, Seisō, Seiketsu and Shitsuke), and used for arranging, managing the workspace and work flow with the aim of improving manufacturing efficiency by eliminating waste as well as improving process flow (Gupta & Jain 2015; Magdy 2018). Abadi (2017) reveal that the 5S tool originated from the Japanese acronym for *seiri* (Sort), *seiton* (Set in order), *seiso* (shine), *seiketsu* (standardization) and *shitsuke* (sustain). It is a structural system, it can assist to organise any manufacturing operation (Gupta & Jain 2015). Card (2018) gives clarity on the logic behind the 5-S principles at the workplace as the basic requirements for high efficiency in producing better quality products and services with little or no waste. The 5S can also help both foundry managers and employees to reduce non-value adding time and improve productivity and quality of their products and services (Fore & Mbohwa 2010:315; Srinivasan *et al.* 2016:365). Nel (2014) also stated that 5S helps eliminate waste and streamline operations by closely coordinating all activities. Omogbai and Salonitis (2017) summarised the 5S technique as follows:

- Sort- To organize things in order, for easiness of storing and retrieval.
- Set- To designate and clearly label where everything should be stored.
- Shine- To keep everything clean and neat.
- Standardise- To document the work approaches and make the 5s part of the culture of the organisation.
- Sustain- To form a practice of continuous improvement procedures.

2.3 Lean principles

Mpanza *et al.* (2013: 566) identified different types of casting processes that can be utilised by individual foundry organisations, depending on the quantities and the size of castings they produce. The study conducted by the National Foundry Technology Network (NFTN) (2009) found that most used casting processes in South Africa include sand casting, die casting, investment casting, and spin casting. Ayeni *et al.* (2018:38) further explain that Lean can be simply defined as a manufacturing approach to minimizing inventory and managing operations. Lean manufacturing supplies the customer with exactly what they want when they want it, without waste through continuous improvement (Render & Heizer 2005). Neves et al. (2018) further define lean tools as a necessity to meet the demands of customers and to remain cost-effective as well as increasing competitive advantage in the market. The purpose of lean manufacturing technique is to improve lead times, quality, and customer satisfaction (Askin, Ronald, Jeffrey & Goldberg 2002). In essence, lean manufacturing in the foundry industry aims to eliminate any non-value-adding activities through continuous incremental improvements (Desai 2012).

The core of lean manufacturing can be viewed as improvement which ultimately works hand in hand with innovation. Increasing innovativeness occasionally present an important mechanism for lean manufacturing (Lyons *et al.* 2013:478). An astounding claim is made by Berente *et al*. (2013) that process improvement techniques, including lean practices, are a form of innovation. This means that lean manufacturing remains a technique that can evolve with time and can be suited for a foundry environment (De Simone 2014). This gives a deeper appreciation of the explanation by Womack *et al*. (2003) about the aims of a lean manufacturing strategy. This reviews the customer's value and restructures the manufacturing processes to maximise that value (Nortije & Snaddon 2013); Bhamu *et al*. (2014) specify that lean manufacturing is the business of making high quality products at a lower cost with speed and agility. It is a technique which touches the entire process of an organisation (Duarte & Cruz-Machado 2013).

2.4 Productivity improvement approaches

Several approaches stress the idea that structured training and organisation of should be central to improvement (Saraswat et al. 2015; Ramachandran & Neelakrishnan 2017). Gonmez et al. (2018) argues that the techniques of improvement be fully understood by everyone engaged in the process, but the business and organisational context of improvement should be understood. Productivity improvement approaches aspire to eliminate waste. Productivity improvement implies that some waste has been eliminated, where waste is any activity that does not add value (Mostafa & Dumrak 2015; Kucerova *et al.* 2018). Productivity is the value of outputs produced divided by the values of input resources used and provides the formula for calculating productivity (Gonmez et al. 2018). Productivity refers to utilisation of resources, such as material and labour (Stevenson 2015). In modest terms, productivity is the ratio of output to input (Gaither & Frazier 2002). Studies have also been reported in the literature to identify the input resources and ensuring they are used optimally to produce a highest output (Mtshali *et al.* 2018). Productivity measures are useful on a number of levels, and effectively using available capital and labour in order to turn them into the products and services that company can offer to their customers (Zokaei & Simons 2006).

Folan (2016) remarks that productivity measures serve as scorecards of the effective use of resources. Production or business managers are concerned with productivity as it relates to competitiveness. Productivity can be improved by (*a*) controlling inputs, (*b*) improving process so that the same input yields higher output, and (*c*) by improvement of technology (Gaither & Frazier 2002). Raw material availability, less adaptation and eased technology and continuous improvement are critical for competitiveness, globalization, and high productivity (Singh & Singh, 2015). Mtshali et al (2018) report on the importance of government support. Subrahmanya (2015) outlines the need for better inventory management. Summarising the literature studied, the internal and external factors playing a significant role in improving the productivity of foundry manufacturing companies involve internally human capital, material, machine, location, layout, technology, management, and external competitiveness, and government. The manufacturing process, also referred, to as the input-transformation-output model, centers on converting inputs such as raw materials into outputs (Kucerova et al. 2018) This process concerns the efficient use of resources to generate products in the shortest possible time, thus avoiding waste, with the aim of meeting or exceeding the requirements of customers (Card 2018). Foundry industries generate different types of products and deliver them to their customers to satisfy the market needs. The incoming foundry material is inspected and placed in a receiving bay, later to be transformed into the final product according to customer specifications (Deshmukh et al. 2017). Scrap and waste is generated along workstation or assembly lines (Saraswat 2015). External role players such as suppliers and customers drive manufacturing systems through order intake, placing orders, and delivery. The raw material and delivery are the final product to customers and promote competitiveness in the market compared to rivals.

4. Research design

A review of literature on productivity, continuous improvement approach, competitiveness, and manufacturing strategies related to foundry manufacturing processes was undertaken. A quantitative survey study using a random sampling strategy was then adopted for the empirical portion of the study (Creswell & Clark 2011). The survey method was considered applicable for this study because it definitely facilitates data generation procedures from large populations, making it easier to develop and administer the study questionnaire while generalizing the study findings (Creswell & Clark 2011). A self-developed questionnaire was utilized to identify the factors contributing to the low productivity of the Gauteng foundry industry (Munyai et al. 2018). This was developed using a 1-to-5 point Likert scale (where 1 represented “strongly disagree or least important” and “5 represented “strongly agree and very important”) to rate each of its items. These variables were ranked and used to identify productivity improvement indices that could enhance the productivity of the Gauteng foundry industry.

The current study selected a purposive sampling technique to provide insight into the specific fields of interest (Bless et al. 2018). Data analysis investigates variables, as well as their effects, relationships, and patterns of involvement with the world (Welman *et al.* 2005). Creswell (2014) explained descriptive statistics as the brief descriptive coefficients which summarise a given data set, which can be either a representation of the entire population or a sample of a population. Furthermore, Tabachnick and Fidell (2007) suggested that data analysis should be such that study questions are well addressed and the study objectives are achieved. For this research, the data analysis used the SPSS (version 24) and Microsoft Excel 2013 statistical package to produce a combination of descriptive and non-parametric statistics (Field 2013). The analysis included descriptive statistics and the results were presented in the form of frequencies, pie charts, and graphs. Descriptive statistics were used to determine the relative importance of the critical factors for the effective productivity measurement of the foundry industry. The sample for the current study comprised 143 managers/supervisors and employees of foundry manufacturing organizations in Gauteng Province of South Africa. The rule of thumb prescribes that no less than 50 participants are appropriate for a correlation with the number increasing with larger numbers of independent variables employed as the nominal anchor in determining the sample size (Tabachnick & Fidell 2007). The answers to the questions were coded, and the coding process permitted researchers to speedily retrieve and collect together all the text and other data that they had connected with the specific thematic idea of sorting sections or patterns that can be studied (Welman et al. 2012).

5. Results

Understanding productivity

This statement attempts to determine the understanding of productivity, and if there are any practices within the foundry relating to the achievement of productivity improvement. Figure 1 shows that less than 4% of the 147 participants say that their foundries do not apply any productivity improvements or measure productivity by either material or labor, while 24%%, 56%, and 15% of the participants strongly agree, agree, and are neutral respectively. An important observation is that more than 43% of the participants believe that management must educate employees about productivity.

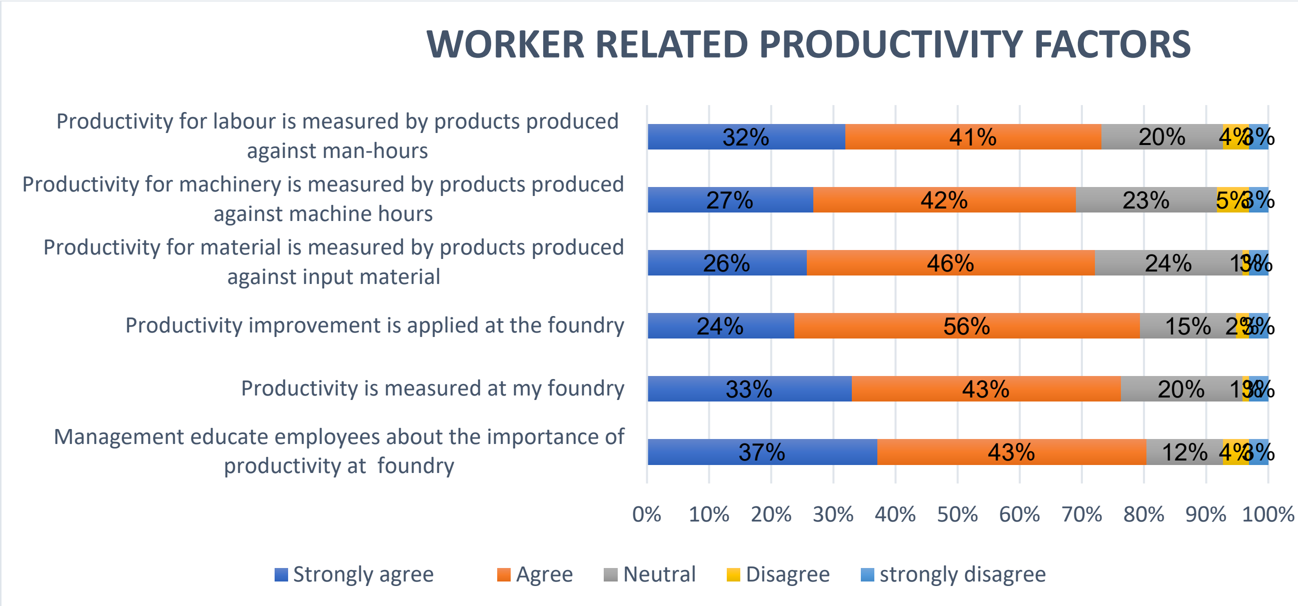

Figure 1. Understanding Productivity

i. Employee related factors

The statements attempt to determine factors that lead to low productivity improvements in the foundry, these factors are segmented into three (3) segments.

Figure 2 illustrates the results for statement 2, where less than 6 % and less that 15% of the participants either strongly disagree or disagree with the need for workers to be involved in productivity improvement initiatives or targets. This indicates that there is significant agreement about workers being part of the productivity improvement initiatives either through their experience or through training received. This is shown by the responses that are almost equally split between the three categories: neutral, agree and strongly agree.

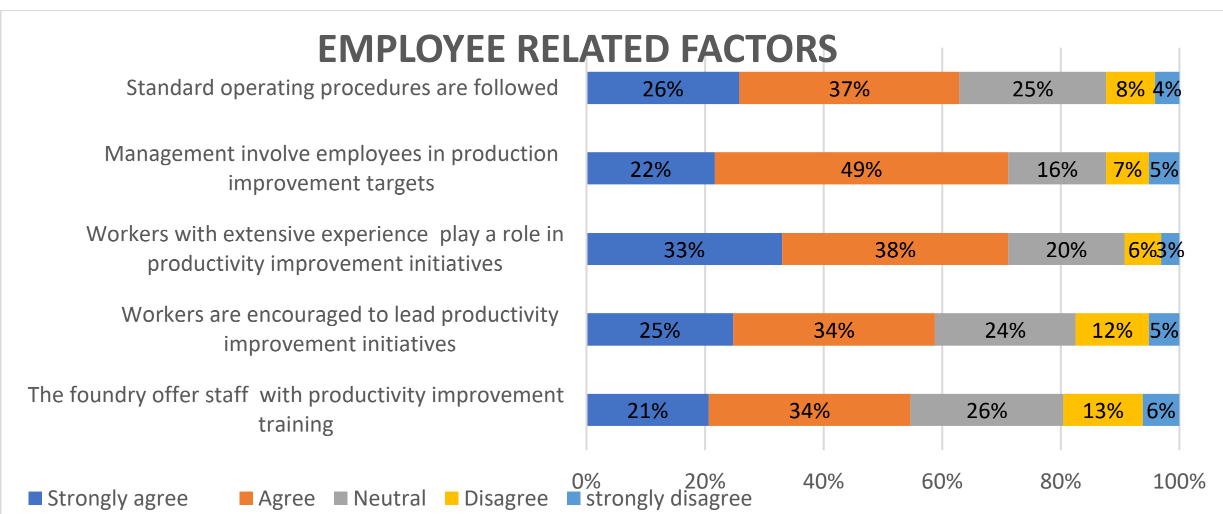

Figure 2. Employee related factors

Equipment or machinery technology-related factors

This statement attempts to determine how the foundries operate and use their machines and equipment efficiently and in ensuring that productivity is improved. Figure 3 shows that less than 6% of the 147 participants say that machine maintenance is a high priority and that machines are never left idling. More than 31% of the participants strongly agree or agree, that in their foundries set up times are tracked and that downtime is minimized at all times. An important observation is that for more than 39% of the foundries each machine has a process instruction for maintenance.

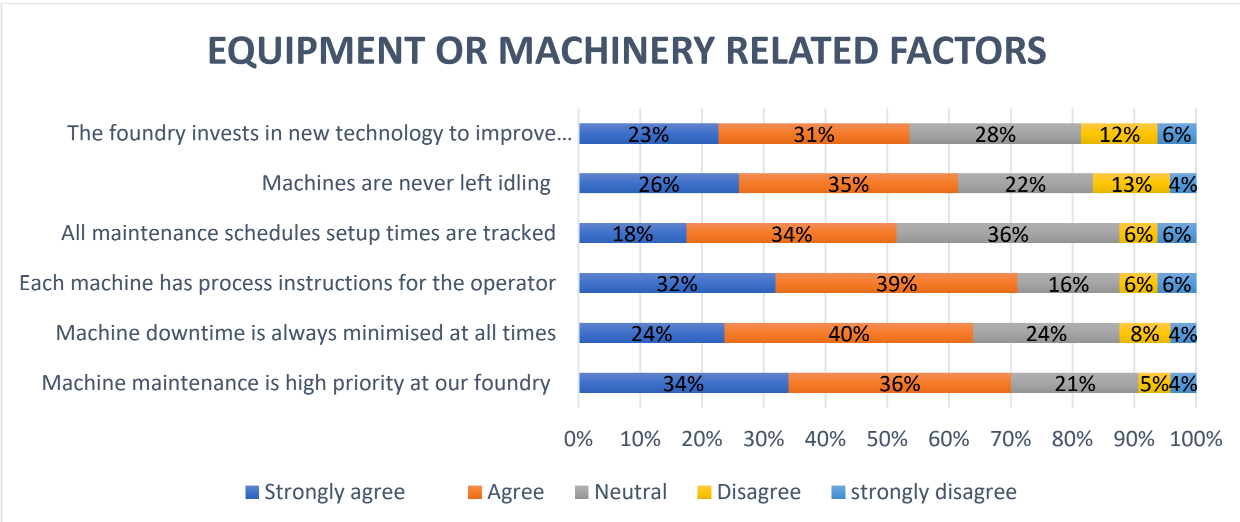

Figure 3. Equipment or machinery-related factors

Foundry management-related factors

This statement determines how foundry management and leadership communicate, encourage, and involves workers in ensuring that they are involved in activities relating to productivity improvement. Figure 4. shows that less than 6% and less that 15% of the 147 participants strongly disagree or disagree that management encourages or involves workers in implementing productivity improvement techniques. An important observation is that more than 47% of the foundries monitor targets, and more that 32% of participants strongly agree or agree that management encourages teamwork and workers in their foundry.

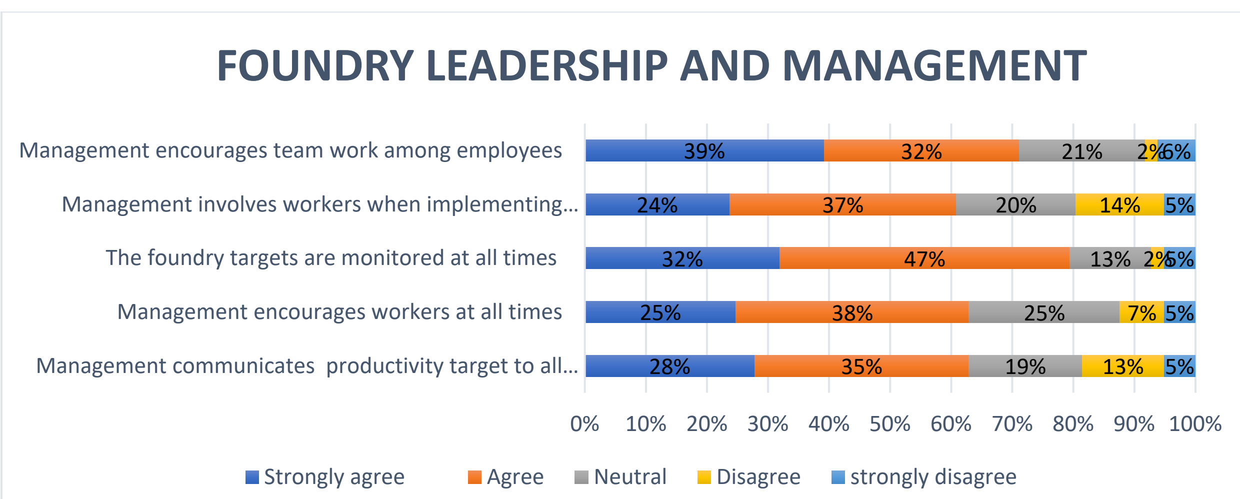

Figure 4. Foundry leadership and management-related factors

Tools or techniques that can improve productivity

This statement was an attempt to determine if the foundry believes that productivity improvement tools or techniques can improve the sector. From the analysis below, it was encouraging that 78% of the respondents believed that productivity improvement techniques can be integrated into their current production process systems and that adopting productivity improvement techniques is vital for the foundry industry. Less than 10% of the respondents said no, while less than 13% said they did not know. It was quite a concern that 44% of the respondents indicated that not all employees know about the productivity of their foundry. However, 49% responded that their foundries are planning to use productivity improvement techniques in the near future (Figure 5).

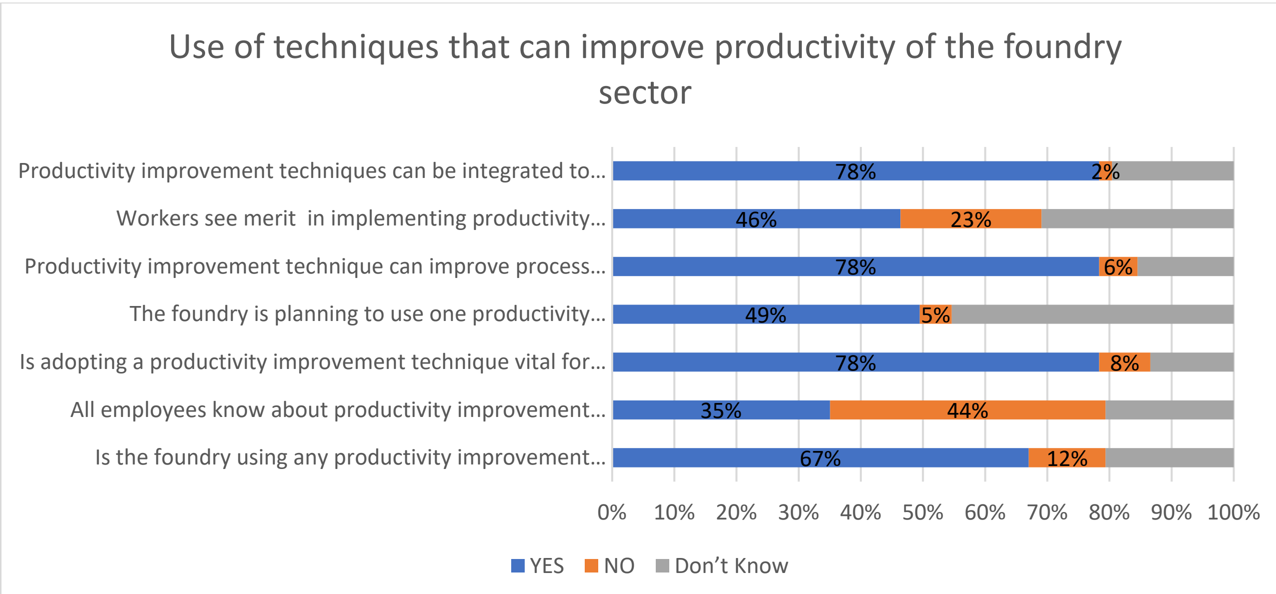

Figure 5. Can productivity improvement tools or techniques improve productivity in the sector

Productivity tools or techniques currently being used in the foundry

The statement determined what productivity improvement tools or techniques were being currently used by the foundries. Figure 6 gives a concerning analysis, where 42% of the participants stated that their foundries are not using any productivity improvement techniques. It is encouraging that 14% of the participants stated that they are using continuous improvement techniques, and 10 % of the participants declared that their foundries are using new software and new machines. This is an indication that the industry is slowly moving with change and adopting new technologies.

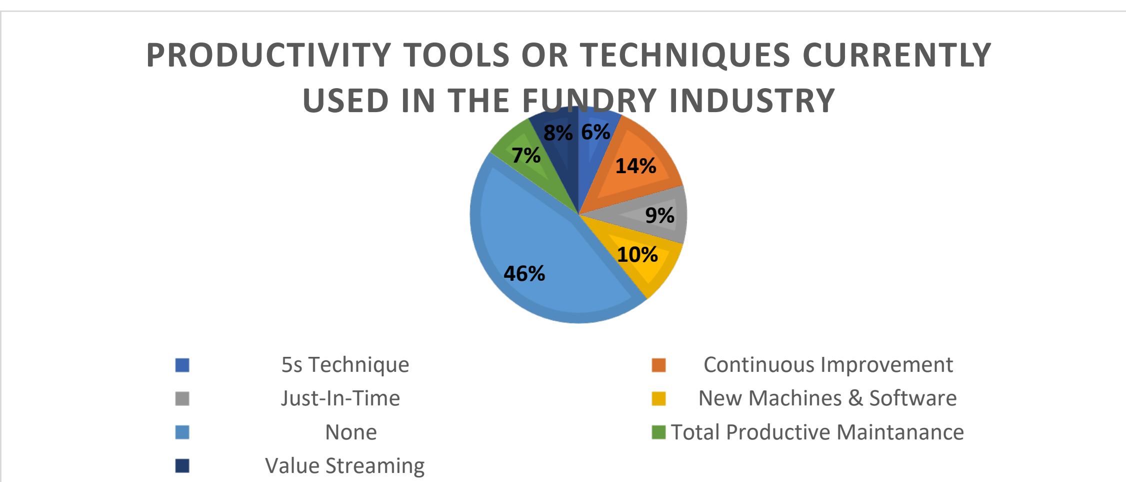

Figure 6. Productivity improvement tools or techniques currently used in the foundries

6. Recommendation and conclusion

The proposed productivity improvement framework for the Gauteng foundry industry

The proposed framework encompasses key productivity improvement indicators which must be applied in order to improve productivity in the Gauteng Foundry sector. This framework is anchored on three key factors that must be addressed in order to improve productivity in the Gauteng foundry industry. These are further supported by tools that are implementable and sustainable in order to improve productivity. Productivity improvement is a journey that requires continuous implementation; the proposed framework gives further direction on how it must be implemented, monitored and sustained by the Gauteng foundry industry. The positive attribute of the proposed framework is that it is centred on continuity and sustainability while ensuring that all stakeholders from the foundry industry are involved and play a meaningful role in the implementation of the framework. This was done to minimise the risk of resistance and lack of support for the proposed framework.

Figure 7 .below presents the proposed framework, which is further discussed in sections 5.3 to 5.3.3.3.

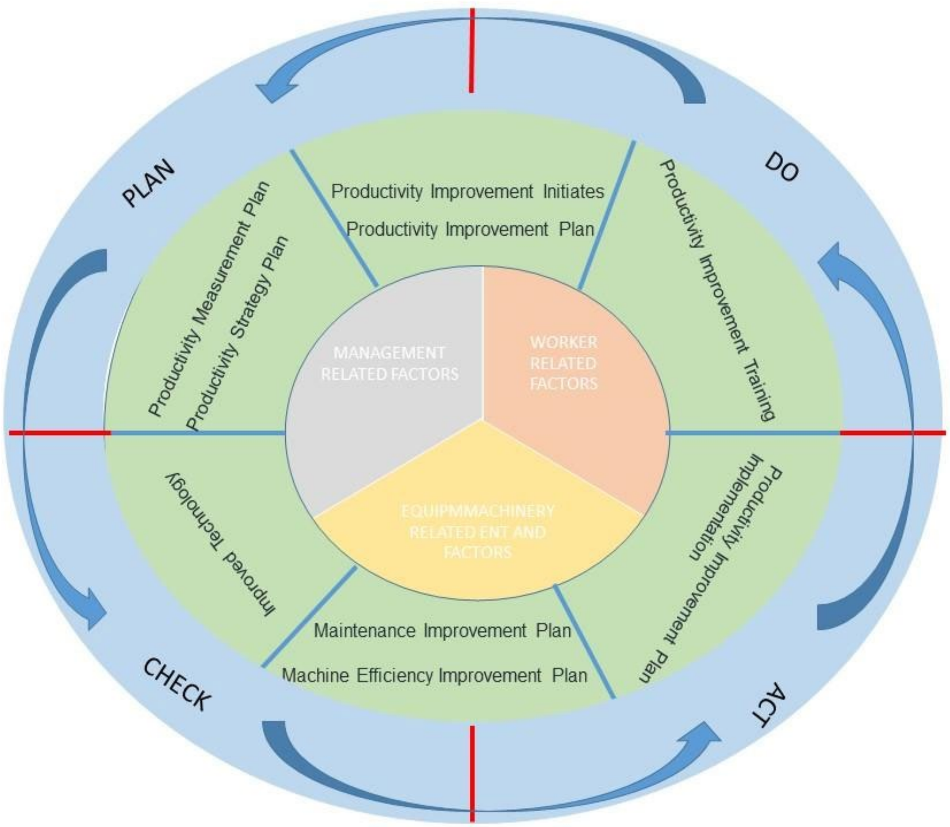

Figure 7. Productivity Improvement Framework for the Gauteng Foundry Industry

How the proposed framework addresses the problem statement

The problem statement for this study was that the Gauteng foundry industry has become less efficient and is faced with a number of challenges. These include a lack of access to markets, a rise in input costs like energy and labor while having limited access to capital; minimal technology advancement and use is being implemented. This has led to the industry losing their global competitiveness and productivity. The proposed framework, used key improvement factors to address the problem of low productivity in the Gauteng foundry industry. These factors are grouped into three key productivity improvement factors that were recommended by this research as key focus factors to improve productivity. These three factors are discussed in detail below:

1.

2. Management and leadership related factors

The proposed framework addressed five key factors that the foundry management and leadership should implement. These are listed as follows:

3. Development of a productivity strategy and measurement plan

It is imperative for management to ensure that they are leaders in driving productivity within their foundries. The important initial step is for the foundry management to develop a productivity strategy that is aligned to their foundry operation and that has a clear measurement plan. This will assist the foundry to not only to meet targets but also to have a clearly defined vision and mission. The productivity strategy must be a driving force in all departments of the foundry; the proposed framework must encourage foundry management to involve employees even at this stage. Based on the outcome of the questionnaire, it was noted that more than 85% of the respondents wanted management to involve workers in the planning and setting targets for productivity. In the proposed framework, the productivity strategy and measurement plan must involve both the management and the workers to ensure effectiveness and ownership from all parties.

5.3.3 Lead productivity improvement initiatives and communicate them to all employees

It is fundamental that management ensures that employees are aware of and educated about the importance of productivity. Communication is vital for the implementation of productivity improvement. According to the outcome of the questionnaire, more than 63% of the respondents agree that productivity levels should be communicated at all times, while 57% agree that foundry workers should be encouraged to lead productivity improvement plans. The proposed framework ensures that communication takes throughout the Plan – Do – Act – Check circle, and foundry workers are part of the planning of productivity improvement plans in the foundry.

5.3.4 Offer productivity improvement training to employees

Training and upskilling of the foundry workforce have to take center space in order to ensure not only the survival of the foundry sector but for it to remain competitive in the global arena. According to the questionnaire respondents, only 51% of the foundries offer training to their employees, and this is a fundamental issue that the foundry sector must address in order to remain productive. The proposed framework emphasizes the training of foundry workers for them to be able to understand the productivity improvement strategy, be able to implement it, and also to be able to contribute to the overall productivity of the foundry sector.

5.3.5 Involve workers in the implementation of the productivity improvement plan

The involvement of foundry workers in the implementation of the productivity improvement plan will ensure that implementation is not forced on them, but it is part of their daily duties. Although targets and plans are set by foundry management; they must be efficiently communicated to the entire organization. The outcome of the questionnaire revealed that more than 70% of the respondents believe that management must involve employees when setting productivity targets. The proposed framework ensures that both the foundry management and the workers are involved in the productivity improvement planning and productivity strategy setting. This will ensure the sustainability of the framework and cooperation amongst all the parties.

5.3.6 Invest in new industry-related technologies and innovation

Management needs to ensure that the productivity improvement framework must be revisited and updated based on the economic, industry, and technology changes, to ensure relevance and effectiveness. The respondents strongly agreed more than 50% that foundries should invest in new technologies, although this is currently not happening. Technology advancement will not only improve productivity but will also ensure that the foundry remains competitive. The proposed framework ensures that updated technology is always checked and integrated into the productivity improvement plans and strategy.

5.4 Labour or worker-related factors

The labor force or workers are the backbone for the success of any productivity improvement framework. Therefore, it is important that workers know about productivity and how it is measured and monitored in their respective foundries. Workers are key in ensuring that all inputs are efficiently converted into productive outputs. Communication and implementation must be done in order to increase productivity. All workers must know the different steps of the productivity framework and understand what the Plan is, what to Do When to Act and when to check.

The proposed framework addressed five key factors that the foundry management and leadership should implement. These are listed as follows:

4.

5.5 Training of workers in productivity improvement skills

The labor force is the backbone of the success of any productivity improvement framework, and skills development is central to improving productivity. Based on the outcome of the study, 41% of the respondents have only matric or lower than matric qualification, with only 22% having some form of apprenticeship training. The proposed framework addresses this challenge by enforcing productivity improvement training to improve the skills and productivity of the foundry employees. This can be done by implementing an effective skills development system that focuses on technical training, technology advancement training, and industry-related skills training. This can help the Gauteng foundry sector to sustain productivity growth and translate that into more and better jobs. The proposed framework also enforces and encourages the coordination of skills development with the adoption of new technologies; this is done to improve the foundry sector's global competitiveness.

The proposed framework will ensure that the investment in human capital can increase the number of skilled workers. On the other hand, increasing new technology will require appropriately trained workers and managers in order to sustain local job growth and productivity. Productivity improvement can only be achieved when all affected parties take ownership and become leaders of the adopted strategy. This is a team effort that involves all employees in the foundry. The proposed framework encourages workers to be part of the focus of productivity improvement in the foundry. It enforces taking ownership and leadership of the product strategy and the actual implementation. Just less than 20% of the employees disagreed with the suggestion that foundry workers must be encouraged to lead productivity improvement initiatives.

References

Abadi, S.G. The application of Kaizen and 5s in the manufacturing field to improve and measure the work environment and increase benefit to owners and customers (case study sun military and civil clothing factory). M.Sc. thesis, Sudan University of Science & Technology. 2017.

Allfred, C.R., Fawett, S.E., Wallin, C. & Magnan, G.M. A dynamic collaboration capability as a source of competitive advantage. *Decision Sciences*, vol. 42, no.1, pp. 129-161, 2011.

Araujo, N., Aramal, G. & Varela, L. Improving productivity and standard time updating in an industrial company- A case study. *International Journal of Mechatronics & Applied Mechanics,* (1):139-144. 2017.

Babu, K., Thirugnanam, A. & Sivam, S.P. Lean process management implementation in Ceramic industry. *International Journal of Chemical Sciences*, 14(52): 415-430. 2016.

Beeley, P. *Foundry technology*. Second Edition, Butterworth-Heinemann. New York: Wiley. 2001.

Belekoukias, C., Garza-Reyes, J.A. & Kumar, V. The effect of lean methods and tools on the environmental performance of manufacturing organizations. *International Journal of Production Research*, 52(18):170-180. 2014.

Berente, N. & Lee, J. How process improvement efforts can drive organizational innovativeness. *Technology Analysis & Strategic Management*, vol. 26, no.4, pp. 417-433, 2014.

Bless, C., Higson-Smith, C. & Sithole, S, L, *Fundamentals of social research methods: An African perspective.* Fifth edition. Juta & Company Ltd, Cape Town, South Africa. . 2018.

Cagno, E.& Trianni, A. Analysis of the most effective energy efficiency opportunities in manufacturing primary metals, plastics, and textiles small-and medium-sized enterprises. *Journal of Energy Resources Technology* 134, 1-9. 2012.,

Cagno, E., Ramirez-Portilla, A. & TRIANNI, A. Linking energy efficiency and innovation practices: Empirical evidence from the foundry sector. *Energy Policy* 8, 240-256. 2015.

Card, A.J. The problem with "5 whys". *BMJ Quality & Safety Journals*, vol. 26, no.9, pp. 671-677, 2018.

Caskey, K.R. Competitive strategies for small manufacturers in high labor cost countries. *Competitiveness Review*, vol. 25, no.1, pp . 25-49, 2015.

Coka, B. Annual Report 2013-2014. Midrand, Republic of South Africa: Productivity SA. 2014.

Conroy, E. Lean manufacturing to survive a lean economy. *Rubber World*, vol. 249, no.3, pp.18-27, 2013.

Cooper, D.R. & Schindler, P.S. *Business research methods*. Twelfth edition. New York, NY: McGraw-Hill. 2014.

Creswell, S. *Research design: Qualitative and quantitative approach.* London: Sage Publishers. 2014.

Davies, J. South African Institute of Foundrymen. Presented to the Portfolio Committee on Trade and Industry. The impact of IPAP on the Foundry Industry. 11th August 2015. SAIF CEO. 2015.

De Simone, R. *International Foundry Forum*, Venice Lido, 26th -27th September 2014. 2014.

Deshmukh, G., Patil, C.R. & Deshmukh, M.G. Manufacturing industry performance based on lean production principles. *Proceedings of International Conference on Nascent Technologies in Engineering, ICNTE,* 2017, 1-6. 2017.

Emanuele, P., Konstantinos, S. & Mark, J. Energy and material efficiency metrics in foundries, *Procedia Manufacturing*, vol. 21, pp. 421-428, 2018.

Fore, S. & Mbohwa, C. Cleaner production for environment conscious manufacturing in the Foundry industry*: Journal of Engineering, Design, and Technology,* 8 (3): 314-333. 2010.

Gaither, N, & Frazier, G. *Operations management*. Ninth edition. Southern-Western Thomson Learning. Cincinnati, Ohio. 2002.

Garza-Reyes, J.A., Kumar, V., Chaikittisilp, S. & Tan, K.M. The effect of lean methods and tools on the environmental performance of manufacturing organizations. *International Journal of Production Economics,* vol. 200, no.6, pp. 170-180. 2018.

Groover, M.P. Introduction to manufacturing processes. *Materials, Processes, and Systems. Hoboken, NJ: J. Wiley & Sons.* 2011.

Gupta, S. & Jain, K.S. An application of 5S concept to organise the workplace at a scientific instruments manufacturing company. *International Journal of Lean Six-Sigma*,vol. 6, no.1, pp. 73-88. 2015.

Jacobs, F.R. & Chase, R.B., *Operations and supply chain management*. Second edition. New York: McGraw-Hill. 2012.

Kothari, C.R. *Research methodology: Method and techniques.* Second edition. New Delhi: New Age International. 2004.

Kumar, S. A. & Suresg N. *Operations management.* New Dehli: NEW AGE International Publisher. 2009.

Krajewski, L.J., Maholtra, M.K. & Ritzman, L., P*Operations management: Processes and supply chains,* eleven edition. UK, Harlow: Pearson. . 2016.

Kruger, D., Ramphal, R. & Maritz, M. Operations Management. 3rd ed. Oxford University Press Southern Africa. 2014.

Kucerova, M., Mlkva, M., Sablik, J. & Gejgus, J, Eliminating waste in the production process using engineering. *Production Engineering Archives*,vol. 9, no. 4, pp. 30-34, 2018.

Lee, C.Y. & Johnson, A.C. *Operational efficiency*. Handbook of Industrial and Systems Engineering, 17-44. 2013.

Leedy, P.D. & Ormrod, J.E. *Practical research: Planning and design.* Tenth edition. UK: Pearson. 2014.

Lyons, A.C., Vidamour, K., Jain, R., & Sutherland, M. *Developing an understanding of lean thinking in process industries***.** *Production Planning and Control*, 24(6): 475-494. 2013.

Magdy, E.A.E. The Application of 5S's workplace organisation at an Egyptian Flexible Packaging Factory. *International Design Journal,* 7(3):99-107. 2018.

Maruta, R, Maximizing knowledge work productivity: A time constrained and activity visualized PDCA cycle. *Knowledge and Process Management* 19: 203–214. . 2012.

McTavish, R., Gunasekaran, A., Goyal, S. & Yli-Olli, P. Establishing a strategic framework for improving productivity. *Integrated manufacturing systems*, vol. 7, no.4, pp. 12-21, 1996.

Mostafa, S. & Dumrak, H. Waste elimination for manufacturing sustainability. *Procedia Manufacturing*, 2, 11-16. 2015.

Mpanza, Z., Nyembwe, D., & Nel, H. Investigating the Impact of Poor Utilisation of Quality Management System in a South African Foundry. Stellenbosch, South Africa, *SAIIE25 Proceedings*, 9th – 11th of July 2013, 566 – 567. 2013.

Mtshali, E.P., Nyakala, K.S., Munyai, T.T. & Ramdass, K.R. Identifying causes of low productivity in the printing industry. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, 933-944. 2018.

Munyai, T., Nyakala, S. & Mbohwa, C. Knowledge transfer model for the productivity of the cable manufacturing industry: A South African perspective. *African Journal of Science, Technology, Innovation and Development, vol.* 9, no.6, pp. 749-759, 2017.

Nyembwe, D.K. Technologies for the base metal casting industry in Southern Africa: The impact of rapid prototyping. *Proceedings of the Southern African institute of mining and metallurgy*, 305-312. 2010.

Olson, W. *Systems thinking, sustainability science and engineering: Defining principles.* Elsevier: Technology & Engineering, USA. 2006.

Omogbai, O. & Salonitis, K. The implementation of 5S lean tool using system dynamics approach. *Procedia CIRP*, vol. 60, pp. 380-385, 2017.

Ozigbo, N.C. The dynamics of technological innovation capability on new product development and industry's performance: A study of Nigerian Iron and Steel Industry. *Journal of Business Management and Economics*, 3: 1-8. 2015.
Pfeiffer, A., Gyulaia, D., Kadar, B. & Monostori, L, Manufacturing Lead times estimation with the combination of simulation and statistical learning Methods. *Procedia CIRP*, 41: 75-80. . 2016.
Prasad, K.D., Jha, S.K. & Prakash, A. Quality, productivity and business performance in home-based brassware manufacturing units. *International Journal of Productivity and Performance Management,* 64(2): 270-287. 2015.
Ramachandran, G.M. & Neelakrishnan, S, An approach to improving customer on-time delivery against the original promise date. *South African Journal of Industrial Engineering*, 28(4):109-119. . 2017.
Saraswat, P., Kumar, D. & Sain, M.K. Reduction of work in process inventory and production lead-time in a bearing industry using value stream-mapping tool. *International Journal of Managing Value and Supply Chains*, 6(2):27-35. 2015.
Sari, M.F. & Darestani, S.A. Fuzzy overall equipment effectiveness and line performance measurement using artificial neural network. *Journal of Quality in Maintenance Engineering*, 25(2), pp.340-354. 2019.
Swanson, L. Linking maintenance strategies to performance. *International Journal of Production Economics, vol.* 70, no.3, pp. 237-244. 2001.
Tabachnik, B. G. & Fidell, L.S. *Using multivariate statistics*. Fifth edition. Boston: Pearson Education. 2007.
Welman, J.C., Kruger, S.J. & Mitchell, B.. *Research methodology,* Third edition, Cape Town: Oxford University Press. 2012
Wilson, J.D. *How to implement lean manufacturing,* New York: McGraw-Hill. 2017.
Zokaei, A. K. & Simons, D.W. Value chain analysis in consumer focus improvement: A case study of the UK red meat industry. *The International Journal of Logistics Management, Vol.* 17, pp. 141-162, 2006.

Biography

Dr. Kgashane Stephen Nyakala is currently a Senior Lecturer in the Department of Mathematics and Statistics at the Tshwane University of Technology. Dr Nyakala is a graduate in DPhil in Engineering Management at the University of Johannesburg and his research focused on the development of a model to empower small businesses to improve construction quality processes, optimising construction process design, implementing lean construction and implementing lean manufacturing in South Africa. He is a quality, process, performance and operations specialist with a driving passion for improving production, reliability, scheduling, lean and competitiveness. His professional memberships include the South African Production and Inventory Control Society (SAPICS) and Industrial Engineering and Operations Management (IEOM). Dr. Nyakala combines over 15 years of international experience with exemplary academic record in the areas of strategic improvement and quality management, as a researcher, and academician.

Mbali Yvonne Moore is a Project Manager at the Project Manager at the Council for Scientific and Industrial Research, Pretoria. Mrs. Moore completed Master's Degree in Operations Management at the Tshwane University of Technology, South Africa. Her interests are Optimisation, process mapping modelling, lean manufacturing, productivity improvement and operations management. She has 15 years' experience in the manufacturing and foundry industry, as a production manager, product and project manager.

Prof Kemlall Ramdass has worked as a work-study officer, industrial engineer, production/ operations manager and skills development facilitator in the clothing and textile industries between 1981 and 1999. He joined the academic profession in 1999 as a lecturer with Technikon South Africa. He later moved to UNISA's Department of Business Management in 2006 lecturing in Operations Management, Industrial Engineering and Quality Management. He is currently employed at the University of Johannesburg. He has vast experience with regards to continuous improvement methodologies from an industrial engineering, quality and operations management perspective. He has presented papers both nationally and internationally and is a peer reviewer for numerous publications. He is a member of SAIIE, SAIMS and SAIMS which are internationally recognised in industrial engineering and management.