Assessment of costs for not implementing lean quality-improvement tools and stakeholders' cultural change adoption for operational sustainability in the case of a gold mine

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There is limited adoption of lean practices in the mining industry, particularly in Africa because of limited literature, expertise, and frameworks to support the successful implementation. This study presents a lean implementation framework for the mining sector and highlights the costs of not utilising lean practices and the effects of cultural factors related to adoption and sustainability of lean practices. Using the case of a selected gold mine in Zimbabwe, the study managed to identify the major operating costs and the respective lean tools that can be utilised to reduce them. Reduced operating costs will likely lower the cut–off grade of ore, thus increasing the life of the mine. The research study produced a framework for guiding organisations to implement lean practices and a classification of organisational cultural factors that influence lean implementation and sustainability.

INTRODUCTION

Lean manufacturing or lean production, is a systematic approach to the removal of waste from a manufacturing system (Umeda, *et al.*, 2015), predominantly developed in the automotive industry (Antony, *et al.,* 2017). The waste may be in one or more of the following forms: over–production, over–processing, transportation, re-work/corrections, inventory, waiting, and motion of personnel and equipment. Lean practices use several, systematic tools to identify and eliminate waste and facilitate the sustainability of the established practices. Such tools include value stream mapping (VSM), overall equipment effectiveness, time studies, root cause analysis, Kaizen, Poke–yoke, just in time (JIT), etc. Lean practices are referred to as quality improvement tools because their principles focus is on the continuous improvement of a production system. Lean principles have delivered significant benefits to the manufacturing industry as evidenced by their wide adoption by several sectors across the world (Anandi & Kodali, 2009), (Dhandani, *et al.*, 2004), (Parry & Turner, 2006). The benefits of lean include improved efficiency (Singh, *et al.*, 2018), streamlined production processes (Kumar & Kumar, 2012), and employee satisfaction (Curatola & Banarjee, 2015). However, there is limited adoption in the mining sector as evidenced by the limited amount of literature on the subject, especially in Africa.

The objectives of this paper were to identify the major operating costs for gold production and the respective lean tools that can be applied to curb such costs, generate a lean implementation framework to guide the organisation during the adoption of lean practices, and identification of organisational cultural factors that influence the adoption and sustainability of lean practices.

OPERATING COSTS APPLICABLE TO GOLD MINING

The mining industry, including the gold mine under consideration utilises the Wood–McKenzie guidelines for the identification, classification, and reporting of all types of costs that apply to the operations (Malensek, 2016). The costs are classified into three categories: C1, C2, and C3 cash costs. C1 costs are the direct cash costs sustained to produce the mineral resource. This includes all expenditure on activities spanning from mining, ore processing, and metal recovery to delivery to the market (Australian Mineral Research Centre, 2016). C2 costs combine C1 costs with assets amortisation costs, depreciation, and depletion. C3 costs, sometimes referred to as the fully allocated costs, combine C2 costs with other indirect costs and net interest charges on loans and other financial packages acquired by the organisation.

Based on the definitions above, C1 costs represent the combined cost of the actual activities that are carried out in a given business operation. C2 and C3 costs are mainly driven by C1 and other factors that are not directly and immediately within the span of control of the organisation. As such, we focused on identifying the contributors to the C1 cost of the organisation under consideration, given in dollars per troy ounce of gold produced i.e., US$/oz. Table 1 shows a breakdown of the C1 cost, obtained from averaging monthly costs for five years beginning April 2017 to March 2022.

Table 1. Breakdown of activities that contribute to C1 cost.

Functional Area	Major Activities/ Sub-Divisions	C1 Contribution (US$/ oz)
Mining	Mine development, drilling, blasting, loading, and hauling.	584.54
Processing Plant - Engineering	Asset maintenance activities e.g., equipment overhaul, lubrication, condition-based monitoring, etc.	167.41
Processing Plant Production	SAG milling, ball milling, crushing, leaching, gold elution, tailings management, etc.	146.11
Support Services	Human Resources, Finance, Information Technology, Employee Wellness Centre etc.	106.85
Mining - Engineering	Mobile equipment maintenance, fixed plant equipment maintenance, stay–in business projects.	99.40
Technical Services	Mine planning, geology, survey, ventilation, etc.	30.45
Total		1,134.76

We conducted a Pareto analysis and established that 80% of the total C1 cost was contributed by mining and processing plant engineering. However, to add depth to the research, we focused on establishing how lean practices can be applied to all technical functional areas identified in Table 1. We decided to leave out the Support Services functional area because it would have diverted attention from the focus on the core activities of mining.

FACTORS INFLUENCING ADOPTION AND SUSTAINABILITY OF LEAN PRACTICES

The adoption and sustainability of lean practice in a given organisation are subject to factors that promote such efforts and those which hinder the establishment of lean practices. According to Hines *et al.,* (2011), the adoption and sustainability of lean practices are strongly enabled by having organisational strategy and alignment, suitable behaviour change and engagement of employees, adequate leadership, advanced process management techniques, and possession of the correct technology and tools to use (Hines, *et al*., 2011).

Of equal importance are the factors that hinder the implementation and sustainability of lean practices, and it is critical to identify such factors to be fully aware of ways of dealing with such problems when they arise. Leite, *et al*., (2022) utilised a systematic literature review combined with thematic analysis to identify factors that inhibit the implementation and sustainability of lean practices, using more than 20 years of relevant literature. The inhibiting factors were classified into six groups with the respective frequencies with which they appeared in the reviewed literature as shown in Table 2.

Table 2. Inhibiting factors for lean practices implementation and sustainability (Leite, et al*., 2022).*

Major Inhibiting Factors	Frequency of appearance in literature (%)
Behavioural & Cultural Influence	22.14
Organisational Strategy & Alignment	21.84
Technical Limitation	19.18
Process Based	13.57
Leadership & Commitment	12.86
Resource Constraints	10.41

We focused on the behavioural and cultural influences as they were relevant to the scope of the study. The following sections describe how this was carried out.

RESEARCH METHODOLOGY

Research Design

We carried out the research work based on pragmatism because we believe that there is no single reality that can represent the entire picture of the state of operations in all mining environments (Saunders, *et al.*, 2019). The prevailing conditions at one mining operation will likely differ from those of any other selected mine due to differences in economic, social, environmental, political, and other factors. We carried out the research without any preset hypothesis, therefore following an inductive research approach (Kellmereit, 2015) which made use of research strategies that include grounded theory, archival research, action research, and survey.

Research Instruments

We used a systematic literature review to gather qualitative data about lean practices implementation mostly in mining environments. We then applied inductive coding, conceptual framework analysis (Jabareen, 2009), and inductive reasoning to generate a conceptual lean implementation framework aimed at reducing operating costs. The conceptual framework analysis methodology was critical in establishing cultural factors that influence the adoption and sustainability of lean practices in a given operation.

After generating the conceptual lean implementation framework derived from the systematic review of literature, we submitted it for scrutiny to a panel of lean experts by making use of the Delphi technique. After making corrections as recommended by the experts, the result was a consensus-based lean

implementation framework which we then submitted to a panel of mid-level management employees of the selected gold mine. We conducted semi-structured interviews with them so that they could qualitatively assess the applicability and relevance of the framework within the operations of the organisation, and rank the identified cultural factors in terms of importance, impact and effort required. We also utilised gathered knowledge from the reviewed literature to identify specific lean tools that could be effectively applied at each stage of the gold mining value chain to lower operating costs.

Research Participants

To get valuable insights, we selected a panel of lean experts based on their academic and professional qualifications and the number of years of experience spent implementing and/or auditing lean practices in various industries. Table 3 summarises the profiles of the experts we consulted using the Delphi technique to scrutinise the conceptual lean implementation framework.

Table 3. Profiles of individuals consulted through the Delphi technique.

Expert	**Current Occupation**	**Sectors**	**Years Active in Lean**
1	Private Consultant for Toyota Motor Corporation and other organisations	Manufacturing, Mining, Aviation	40
2	Head of Safety at a major platinum mine in South Africa	Mining	12
3	Private Consultant	Manufacturing, Finance	5
4	Industrial Engineer	Manufacturing	4
5	Mechanical Engineer	Mining	4

To validate the consensus–based lean implementation framework from the lean experts, we selected a group of mid–level managers to qualitatively assess the applicability of the framework to their operations. We selected these individuals because they are in direct interaction with the operations, have the responsibility of implementing process improvements, and are generally accountable for the daily effectiveness of the operations. They also assessed the identified cultural factors and the impact of lean practices on operating costs. Table 4 gives a summary of their respective profiles.

Table 5. Profiles of mine employees consulted.

Participant	Title	Patterson Grade	Years spent with the mine
1	Resident Engineer	D3	9
2	Processing Plant Superintendent	D3	10
3	Projects Engineer	D2	5
4	Projects Metallurgist	D2	6
5	Plant Metallurgist	D2	6

FINDINGS

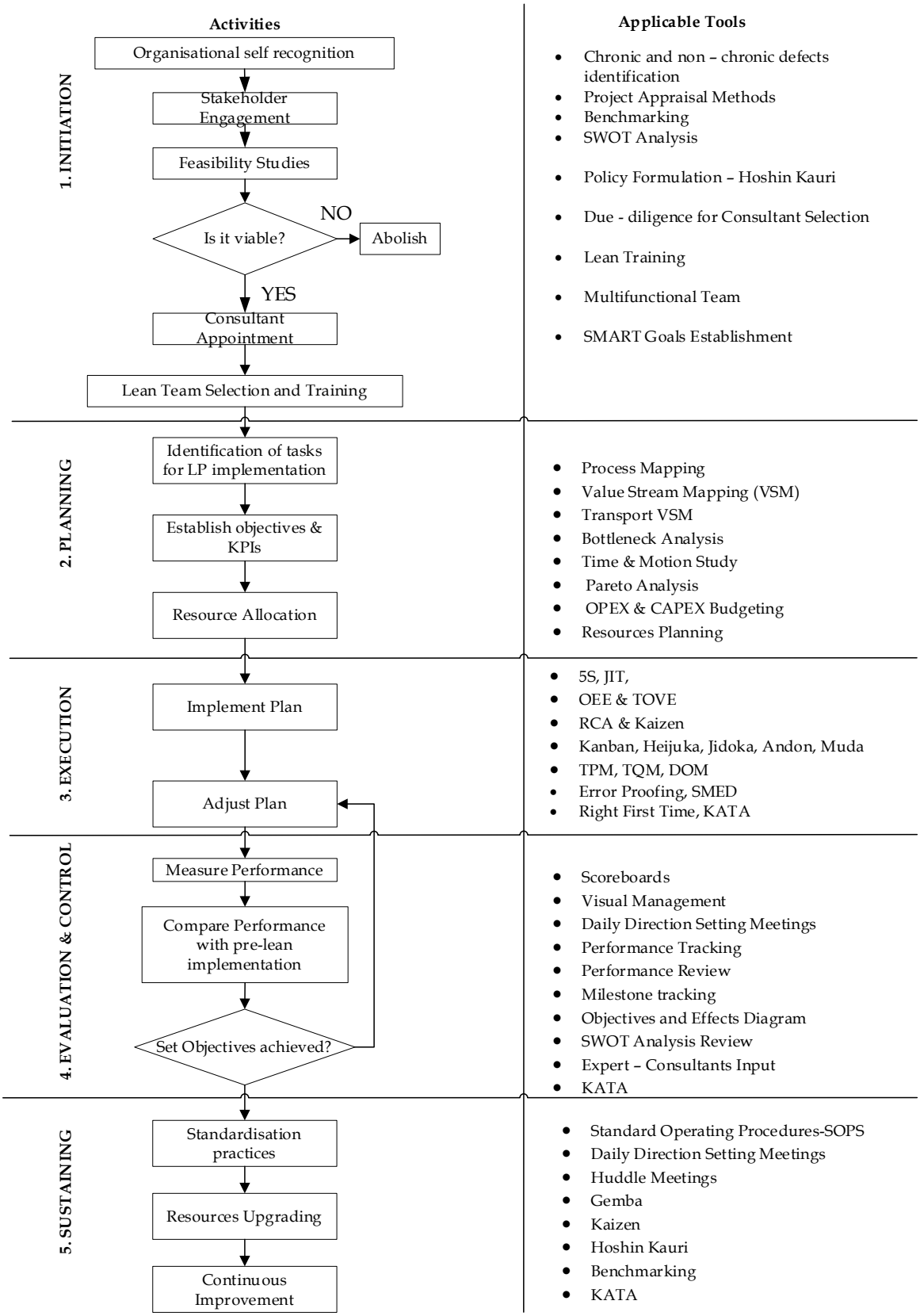
We managed to establish several findings after conducting the research. Firstly, we generated an implementation framework for lean practices at the organisation, then a quadrant–based ranking of the cultural factors that influence the adoption and sustainability of lean practices. The other finding

was the significant potential of gaining savings on C1 operating costs, which could lead to an extension of the effective life of the mine. In addition to this, we also managed to establish that the gold mine under consideration has minimal application of lean practices as confirmed by the respondents during the interviews conducted. The following subsections present the findings.

Lean Practices Implementation Framework

The framework was developed to guide the gold mine in adopting and sustaining lean practices for all the technical functional areas identified in Table 1. The implementation flows with five major steps: Initiation, Planning, Execution, Evaluation and Control, and Sustaining. Table 5 shows the implementation framework and its respective stages.

Table 5. Lean practices implementation framework



Stage	Major Activities	Success Factors	Barriers to Success
Initiation	• Stakeholders' engagement to get their buy-in. • Feasibility studies. • Identification of chronic and non-chronic defects as part of feasibility studies. • Generating a management plan for the identified defects; the plan needs constant updating as the implementation progresses. • Motivating for adoption of lean practices. • Approval of the implementation exercise. • Generation of policies that support lean practice across the organisation. • Selection and appointment of suitable consultants. • Selection of lean team members from the organisation's departments. • Training of lean lead team by the consultants. • Holding kick-off meeting.	• Utilisation of standard project appraisal methods and feasibility studies before commencing the implementation exercise. • Commitment and willingness by shareholders and senior management to use lean practices. • Pre-existing conditions e.g., organisation already using methodologies like Six Sigma that integrate easily with lean practices. • Selection of lean team members from various departments of the organisation brings diversity and depth to the lead team. • Selection of a consultant with a track record of successful implementation of lean practices in mining environments. • Effective communication explains what stakeholders stand to gain from the exercise, thereby getting their support buy-in. • Generating lean policies that bar retrenchment of staff that may become redundant due to gains achieved as a result of lean implementation. • Training of leaders and subsequent change of culture to promote psychological safety — a key environmental factor for lean success.	• Lack of interest and commitment by shareholders and senior managers to have lean practices implemented. • Failure to utilise standard project appraisal methods to decide the feasibility of carrying out the implementation exercise. • Failure to select the correct consultant to assist with the implementation exercise may lead to dismal results. • A combination of members from various backgrounds also brings about social and cultural barriers into the dynamics of the exercise. • Level of literacy, particularly for the shopfloor team members may result in certain limitations during training. • General resistance to change by employees.
Planning	• Profiling stakeholders. • Defining VALUE.	• Generating individual profiles presented to them to adopt lean practices as required by the organisation, thereby addressing each stakeholder according to their characteristics.	• Failure to comprehensively identify key areas that need lean implementation.
	• Identification of processes/ stages that need lean implementation. • Ranking processes/stages according to impact • Budgeting and resource allocation. • Generating implementation plans for identified processes/stages. • Identification of metrics to measure performance. • Setting SMART goals that need to be achieved.	• Utilising experienced consultants to assist in generating plans that are more likely to be effective. • Ranking of tasks according to impact ensures that significant value is earned from the investment made. • Well-trained lead team members will assist with valuable organisation information during the planning phase. • Planning with set SMART goals is key during the performance tracking phase.	• Failure to put in place measures that neutralise social and cultural barriers amongst the planning team members. • Lack of management systems that cater to the interactions of the planning team according to Tuckman's Ladder. • Poor resource allocation. • Failure to identify applicable key performance measurement indicators for each process/ stage identified. • Lack of adequate support from senior management.
Implementation	• Implementing the plan. • Resource provision. • Communicating with employees and stakeholders.	• Presence of policies that support employee involvement, flexibility, and empowerment when implementing lean practices. • Visible support by senior management e.g., attending implementation sessions and being available on the shopfloor or in the processing plant. • Making use of competent consultants to lead the process. • Allowing employees to express themselves by asking questions and making suggestions. • Availability of adequate resources. • Implementing planned lean practices according to schedule, budget, and scope. • Having patient leadership that understands that results may take time to reflect in metrics selected to monitor progress.	• Inadequate provision of resources. • Inadequate training of employees and lead team members. • Resistance to change by employees. • Failure to put in place measures that neutralise social and cultural barriers amongst the consultants, lean team members, and other employees. • Lack of buy-in from employees because of the absence of information on what they stand to gain from lean implementation.
Evaluation & Control	• Analysis of the several plans and their compatibility with the target processes. • Adjusting such plans and/or the processes to obtain compatibility. • Assessing if the adjustments made meet expectations. • Assessing performance improvement using established metrics. • Checking for adequacy of the identified metrics and adjusting accordingly.	• Ability to analyse the plans, the effect on waste elimination, and adjusting the plan as required. • Presence of organisational policies that empower employees and the lean team to make adjustments. • Established metrics for measuring performance improvement indicate the level of progress achieved. • Having patient leadership that understands that results may take time to reflect in metrics selected to monitor progress. • Allowing employees from the organisation's lead team to lead the stage of implementing corrections, thus allowing them to gain confidence and exposure while being guided by the consultants. • Effective use of lean tools that promote interaction between management and shopfloor employees. These include gemba, huddle meetings, daily directional setting meetings, etc.	• Failure to objectively compare accomplishments against set objectives which will be misleading to all stakeholders concerned. • Lack of interest and commitment by all parties involved, when evaluating the compatibility of the plans and the target processes/stages. • Failure to put employees at the forefront of implementation of identified improvements so that they gain exposure and confidence.
Sustaining	• Incorporating the implemented practices into Standard Operating Procedures • Recommending opportunities for further improvement. • Establishment of policies that promote continuous improvements. • Establishment of policies that reward employees accordingly.	• Nurturing the relationship between employees and management such that constructive interactions can be achieved. • Visible commitment by senior management to maintain and improve the established methodology of operation. • Acknowledging positive employee contributions publicly. • Provision of resources required for continuous improvement initiatives. • Continued use of lean tools that promote further improvements. These are Kaizen, KATA, benchmarking, etc.	• Slipping back to old ways of doing things. • Resistance to change is mostly influenced by attitude and organisational culture. • Lack of discipline and motivation by employees and managers to uphold the newly established ways of operating. • Lack of resources to make improvements in processes as required by the recommendations. • Failure by management to support continuous improvement efforts like benchmarking.

Cultural Factors

We used the conceptual framework analysis method as proposed by Jabareen (2009), to establish the cultural factors that influence lean adoption and sustainability. Table 6 shows the identified factors and their respective descriptions.

Table 6. Description of identified cultural factors.

Cultural Factor	Description
Human centricity	Adoption and sustainability of lean practices significantly rely on the the employees'motivation, attitudes, resistance to change, negative perceptions about lean and its impact on their work.
Universal integration	Lean adoption affects all stakeholders linked to the organisation. The factor considers how the organisation identifies such stakeholders, trains them, ascertains their roles in adoptiong lean, and how they should interact with the organisation. It further covers how they all fit into one cohesive structure governed by lean methodologies.
Organisational awareness	It refers to the ability to objectively define the current state of operations, desired state in the future, how to get there and how to measure progress made towards attaining the desired future state. It also covers the ability to identify strengths and weaknesses of the organisation and accepting all changes resulting from adopting and sustaining lean practices.
Universal commitment	This refers to the need for full commitment from all stakeholders. It can be demonstrated by fulfillment of assigned tasks as guided by the adopted lean practices. Universal commitment is expected from key stakeholders such as employees, senior managers, contractors and material suppliers among others.
Performance	The adoption and sustainability of lean practices requires a systematic way of measuring progress made. This factor focuses on the correct selection of what to measure, how to measure it, units of measure and quantifying good and bad performance. It also covers how good perfomance can be emulated elsewhere and suppression of poor performance.
Sustainability paradox	This relates to the cultural behaviour of the organisation in terms of resources allocation. Adoption of lean practices requires resources and so does the daily operation of the business. Depending on the demands of either facets, there is a possibility of failing to allocate resources to the lean adoption exercise because operations require the same resources or are chanelling resources to sustain lean adoption exercises, leaving the daily operations without resources to fully function.

During the semi-structured interviews, we asked the participants to rank the importance, impact and effort required to adopt and sustain lean, concerning the factors described in Table 5. The ranking ranged from 1 to 5 with 1 being the least possible mark, indicating lowest importance, impact, or effort required while 5 was the highest possible mark indicating the highest importance, impact, or effort required. The results obtained were tabulated and plotted into radar and quadrant charts as shown in the following sections.

Table 7. Ranking of cultural factors that influence lean practices adoption and sustainability

Factors	Importance	Impact	Effort Required
Human centricity	4.6	4.2	4.2
Universal commitment	3.4	3.6	3.0
Organisational awareness	3.8	4.0	3.4
Universal integration	4.2	4.6	2.8
Performance	4.4	4.4	3.8
Sustainability paradox	3.4	4.2	3.6

Quadrant Chart 1

The data in Table 7 was then plotted on quadrant charts. The importance and impact were plotted and produced the quadrant chart below.

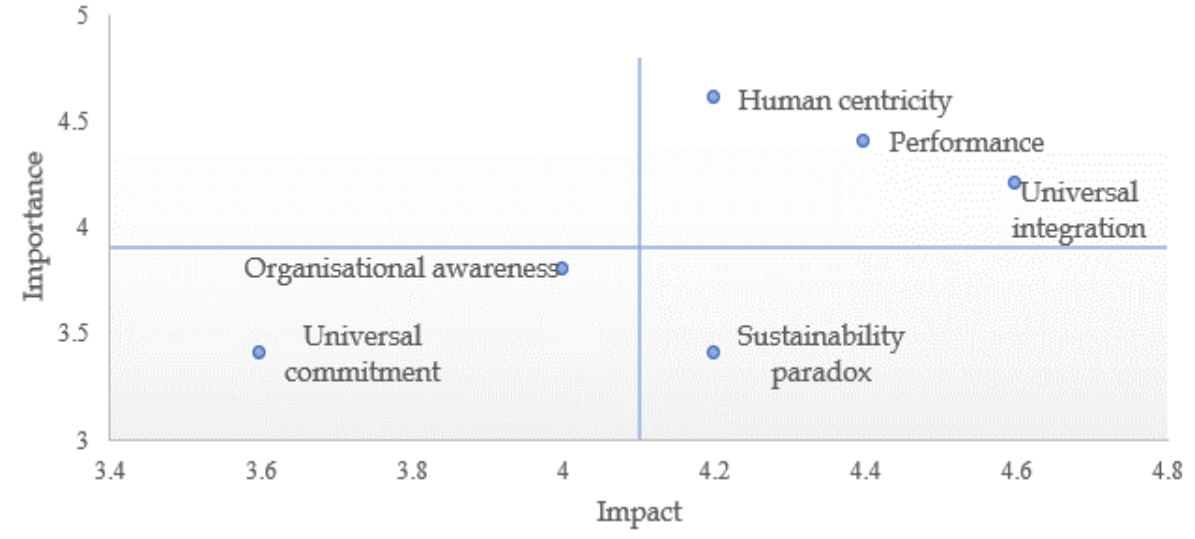


Figure 2. Quadrant chart showing the distribution of cultural factors when importance is plotted against impact.

From the chart above, it follows that at the organisation in question, human centricity, performance, and universal integration have high importance and high impact in terms of influencing lean adoption and sustainability. Organisational awareness and universal commitment were classified as low importance and low impact factors probably because the interviewed employees are responsible for specific departments within the organisation. As such, their ability to perceive the influence of factors at organisational level will be limited. Sustainability paradox was ranked as a high impact, low importance factor showing that if resources are limited during adoption and sustainability stages, the impact of failing to sustain the lean practices will be significant.

Quadrant Chart 2

Human centricity, performance, and sustainability paradox were classified as high impact, high effort required factors in as far as lean adoption and sustainability is concerned. Organisational awareness universal commitment factors were ranked low, and this could be influenced by the seniority level of the employees interviewed who are mostly concerned about the sections and departments they manage. Universal integration was ranked as a high impact factor with lower effort required to manage

compared to other factors like performance and human centricity which covers issues like employee motivation and attitudes. The diagram below shows the distribution of the factors as described above.

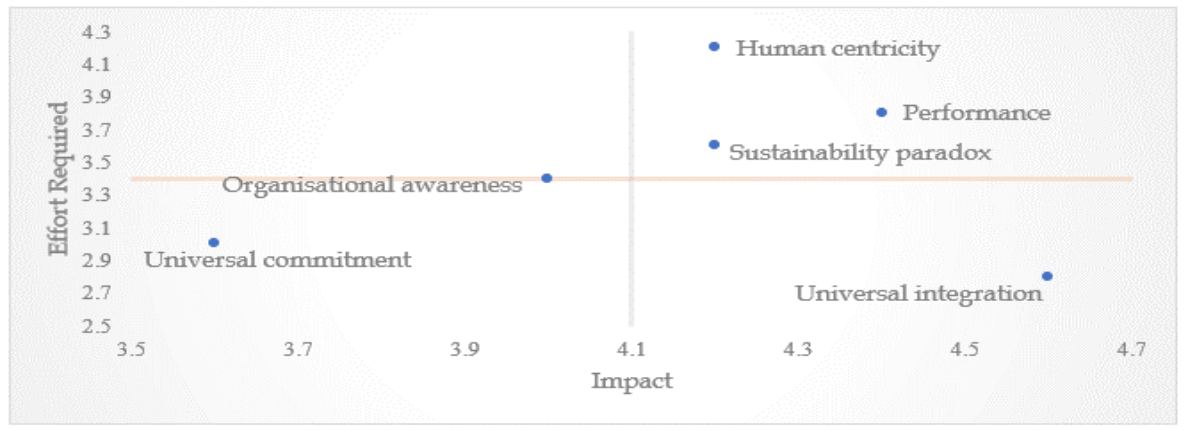


Figure 3. Quadrant chart showing the distribution of cultural factors when effort required is plotted against impact.

Costs Assessment

From Table 1, the total C1 cash cost from 2017 to 2022 for the organisation under considertation was US$ 1134.76 per oz. During that same period, the average gold price was at US$ 1549.53 per oz (Macrotrends, 2023). This gives a difference of US$ 414.76 per oz, indicating a significantly minimal profit margin considering that C2 and C3 costs were not factored in, primarily due to confidentiality considerations by the organisation under consideration. The current C1 costs stand at US$1081.31 following a change in personnel in senior management positions. The new executives focused on cost containment and cutting measures that had less to do with lean practices but more to do with cancelling contracts for non-performing contracting companies. In the literature, there are gold mines which operate with C1 costs in the range of US$ 800 – 950 per oz (Evolution Mining, 2013), (Metallon Corporation, 2014), (Yapo & Camm, 2017), (Norton Gold Fields Limited, 2012) which show that this particular organisation is losing a considerable amount of money due to non–implementation of lean practices that may result in significant cost reductions.

During the semi-structured interviews we conducted with the selected employees, they separately agreed that lean practices will definitely reduce waste which contributes to high operating costs. The life-of- mine for this operation stands at eight years with a cut off grade of 1.58 grams of gold per ton of processed ore (g/ton), operating with C1 costs of +/- US$ 1100. The employees interviewed also agreed that with lean practices correctly implemented, the operating costs will likely reduce and one of the major benefits is that with lower operating costs, the mine can afford to lower the cut-off grade, thus extending the effective life of mine at a profit margin influenced by the positive gains on cost reduction and other external factors.

Limited Knowledge of Lean Practices

The semi-structured interviews we conducted also revealed that the participants had limited knowledge of lean practices and their use. Of all the tools used to practice lean, only 5S, JIT, Bottleneck Analysis, and VSM were identified as the lean tools interviewees were aware of. This indicates a lack of in-depth knowledge about lean practices, a gap which can be closed through raising awareness, conducting training, and promoting implementation efforts in various organisations.

CONCLUSION

In this study, we proposed a framework to guide a gold mining operation in implementing and sustaining lean practices. We also identified the cultural factors that need to be considered when adopting and sustaining lean practices. The operating costs can be minimised by application of lean methodologies, resulting in a possible extension of the life-of-mine. These findings are based on

qualitative assessments, and we recommend that future studies should focus on implementing the framework, validating it, improving on it and reporting on the outcomes of such exercises.

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I am a Mechanical Engineer with experience in the Manufacturing and Mining industry and have been exposed to maintenance, engineering, and project management environments. I am a member of the South African Institution of Mechanical Engineers, Zimbabwe Institution of Engineers, and the Engineering Council of South Africa. My initial experience in the manufacturing sector has driven me to note and apply process improvements within the mining sector, particularly the application of lean methodologies which aim to improve business management processes.