A CONCEPTUAL METRICS FRAMEWORK FOR MONITORING & TRACKING OF LEAN IMPLEMENTATION IN MINING ORGANIZATIONS

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Abstract:
To lower costs and increase productivity, compliance & safety in mines, organizations are implementing innovative process systems/frameworks and methods. Lean is a commonly used framework for process improvement and helped many organizations across the globe. It's also being applied in the mining industry and has offered many benefits. However, an organized & methodical measurement framework is lacking to evaluate the quantitative benefits linked to the organization's goals. As with any other industry, mining also expects a metrics system for monitoring & tracking and assessing lean implementation. This paper explores the opportunity of using a conceptual framework for lean in the mining. The authors will explore the available and proven structures used in other industries and propose a conceptual, quantitative design to support and ensure sustainable mining operations. In the future, a more innovative framework shall be integrated with the proposed measurement system, providing a clear direction for lean practitioners and management.

Keywords: Lean, Metrics, Productivity, Mining

1. Introduction
One of the main commercial sectors in India is the mining industry, which has undergone a rapid growth in recent years. India has huge mineral deposits, but its mining industry is nevertheless plagued by old problems (Panwar et al., 2018). The assessment states that a 1% increase in the mining industry causes an increase in industrial production growth of 1.4% to 1.6%. The environment, capital investment, technology & modernization, and quality are a few of the most significant issues facing the Indian mining industry. The mining sector is capital-intensive, and to meet production targets, there must be a constant rise in the demand for minerals and ore. Most mines must develop checklists, modify systems, enhance processes, improve training, and introduce new safety, sustainability, and quality programs (Sarkar, 2012). One of the most widely used quality programs & framework is Lean, which is implemented across industries of varied domains, including mining (Dadhich & Kant, 2022; Kaswan & Rathi, 2020). However, there is a lack of a practical/usable metrics framework to assess the benefits of lean, which are linked to organizational vision, mission and targets. As with any other industry, mining also needs a metrics measurement framework for monitoring & tracking and evaluating lean implementation (Manish et al., 2022; Raut RD, Mangla SK, Narwane VS, Dora M, 2021; Timans et al., 2016). Few trustworthy metrics frameworks are used in IT industry, and they have assisted hugely to companies. This paper discovers the probability of utilizing those frameworks to determine the level of lean implementation in Mining.

2. Literature survey
2.1 Challenges faced by mining industry
The main concern for mining and metals leaders in 2023 will be rising asks for ESG, climate change, sustainability, license to operate, and a more unstable geopolitical atmosphere. The issue is: How can mining and metals companies push forward with their makeover into purpose-led, low-carbon, digitally enabled organizations while navigating urgent difficulties like growing costs and supply chain disruption? (Sharma & Dadhich, 2014; Singh, M., Kumar, P., Rathi, 2019). One appropriate tool for transformation in mining companies can be Lean implementation. Lean has been implemented by mining and allied industries and has given good benefits to the organization. It can help mining companies also to ensure optimal operations.

2.2 Lean and its usage in mining industry

In the present aggressive macro-economic conditions in which corporation functions, key assets handling is becoming increasingly more significant. Lean techniques intend to eliminate waste from systems. Taiichi Ohno developed the original seven wastes (Muda), the Chief Engineer at Toyota (Dadhich, Hiran, Rao, & Sharma, 2022; Kaswan & Rathi, 2020; Sarkar, 2012). Lean has been used and practiced in the mining sector for a few years. The mining industry has benefited from it through cost savings, increased productivity and quality, and improved safety. The mining industries have used a lean context based on company background and external environments. It is assisting businesses in reaping certain benefits, but more may be done by pursuing additional advancements to fulfill the organizations' and businesses' ever-changing needs (Carberry et al., 2019; Dadhich et al., 2021). However, several difficulties to implementing lean in the mining sector must be overcome for the good of the sector (Biswas et al., 2018; Manish Dadhich, Kamal Kant Hiran, Shalendra Singh Rao, 2022; Singh et al., 2021).

2.3 Challenges of lean implementation in mining

Lean implementation in mines is more complicated than in most industrial plants. In controlled factories, it is simpler to use methods like 5S and the visual workspace to increase cleanliness and order. Though it demands methods to implement and sustain lean projects successfully, operational excellence is still attainable. Businesses may make sure they are making the most significant profit by using their time and resources as efficiently as possible by using lean six sigma (Kaswan & Rathi, 2020). In areas where losses are greatest, mines can make significant operational improvements. For instance, waiting times and waste can be reduced by regulating material areas that may be replenished frequently. The environment assistances when process flow enhancements result in smaller operating footprints and less energy squandered (Dadhich, Doshi, Rao, & Sharma, 2022; Singh et al., 2021). Additional potential exists with new mining-related technologies, such as autonomous operations, including AI-ML-drilling and virtual reality apparatuses, which would facilitate a reduction in the number of personnel needed inside mines. Instead of creating additional waste and unused potential, embracing this novel knowhow from a lean viewpoint may augment the paybacks (Purohit et al., 2022; Singh, M., Kumar, P., Rathi, 2019). Implementing lean principles in mining can be challenging due to the nature of the industry, which involves complex operations and heavy equipment. Here are some of the challenges that can arise during the implementation of lean in mining:

- Safety concerns: Safety is a critical issue in mining, and any changes to work processes must prioritize safety. Lean implementation can change how employees work, impacting safety if not adequately managed.
- Large capital investments: The mining industry requires significant capital investments in equipment and infrastructure. Changing processes to implement lean principles can require additional investment, which can hinder adoption.
- Complex supply chains: Mining operations involve many suppliers and contractors, making implementing lean principles throughout the supply chain challenging. Coordination and communication between different stakeholders are essential to achieving success.
- Reliance on experienced personnel: Mining requires skilled and experienced personnel to operate heavy equipment and manage complex processes. Implementing lean principles may require a shift in roles and responsibilities, which can be challenging for experienced personnel to adapt to.
- Limited visibility and data: Mining operations can be located in remote areas, making accessing real-time data on equipment and processes difficult. This limited visibility can make it challenging to identify areas for improvement and implement lean principles effectively.
- Resistance to change: Resistance to change can be a significant barrier to implementing lean principles in mining. Employees may be comfortable with existing processes and resistant to change, making it challenging to achieve buy-in for new ways of working.

Overall, implementing lean principles in mining requires careful planning and coordination to ensure that changes are implemented safely, efficiently, and effectively.

3. Research gap and necessity of new framework

Many businesses implement lean initiatives and programs to increase productivity, customer satisfaction, processes, quality, and sustainability. Lean project/program planning, implementation, and monitoring involve numerous stakeholders and departments. There are numerous problems and restrictions with the implementation of programs. The lack of structured, systematic monitoring during the implementation of the lean initiative may be one of the reasons why the success rate of lean implementation is not very high. Till today, there is no management & metrics framework for lean adoption in mining (Manvinder Singh Pahwa, Manish Dadhich, Jaskaran Singh Saini, 2021). Lean and other frameworks aren't used very often, and this industry lacks conceptual models that are coherent enough to direct the creation of new systems. Innovative frameworks and processes are required to improve outcomes in sustainable mining operations (Dadhich, Manish, Shalendra Singh Rao, Renu Sharma, 2021). Lean may produce greater results if it is used in conjunction with other frameworks for improvement for monitoring and tracking purposes since it will give management and practitioners more visibility. So, it's imperative to propose a framework, which can be used to ensure that organizational-level lean projects/programs are implemented successfully, and practices are sustained for a more extended period.

4. Objectives of the study

This report aims to propose a new metrics framework for lean implementation.

The paper suggests the usage of a customized framework that can be used to measure the status of lean application in mining. This framework will help in planning, monitoring & tracking lean improvement initiatives/programs across the organization. There are improvement frameworks like CMMI, PCMM, PMP-PMI, GQM, KPI, etc., which can be used to build a Lean measurement system to quantify the level of implementation of lean practices in the organization and the benefits achieved through it.

5. Methodology

For building the new framework, the researcher relied upon the secondary data available from lean implementation in different industries. The researcher also studied the existing project management processes & frameworks and their usage by IT organizations. The researcher decided to use the GQM, SMART, and CMMI-based practices and sub-practices to define a new framework for managing lean implementation in mining. The new framework will have processes, practices, and sub-practices which must be followed while executing a lean project/program.

6. Discussions / Results: New Framework for Sustainable Mining Operations

There are few measurement frameworks used by ICT concern for precise supervision of complex projects & process improvement initiatives. The following sections of the paper describe 3 key frameworks namely, GQM, SMART, and CMMI-based systems:

6.1 Goal Question Metrics (GQM) Framework

For lean practitioners in the mining sector who require a formal methodology to assess the success of the organization's deployment of lean across all departments, the GQM-based measurement framework will be helpful (Gaurav Kumar Singh, 2022; Timans et al., 2016). A GQM model can be created by defining a set of quality and/or productivity objectives at the corporate, divisional, or project level, such as increased performance, on-time delivery, and customer satisfaction. The Goal Question Metrics (GQM) framework is a structured approach used to define, measure, and improve a software development project's quality. The framework consists of the following steps:

- Establish goals: Identify the goals you want to achieve in the software development project. For example, improving the software's reliability, enhancing its usability, or reducing its development time.
- Define questions: Develop a set of questions that will help you evaluate the achievement of the established goals. The questions should be specific, measurable, and relevant to the goal. For

example, "What percentage of users reported an error in the software?" or "How long does it take to fix a software defect?"

- Define metrics: Identify the metrics that will be used to measure the answers to the questions. Metrics should be objective, quantitative, and directly related to the question. For example, the metric for the question "What percentage of users reported an error in the software?" could be the number of error reports per 1000 software usage hours.
- Collect data: Collect the data necessary to answer the questions and calculate the metrics.
- Analyze results: Analyze the data collected and compare it against the established goals. This analysis can identify areas where improvements can be made to achieve the goals.
- Take action: Use the results of the analysis to take action to improve the software development project. This action could involve modifying the development process or changing the software's design.

By using the GQM framework, software development projects can establish clear goals, measure progress towards those goals, and take action to improve the quality of the software continuously. The GQM framework can be used at different stages of the software development lifecycle, from requirements gathering to testing and deployment.

6.2 SMART measurement framework

It tracks the recital and progression toward a firm's aims at a specific time. Organizations function in environments determined by their primary stakeholders and tracked by key parameters established by management with goals and objectives in mind (Dadhich, Hiran, Rao, Sharma, et al., 2022). It also supports teams as they attempt to achieve specific results and address impediments. Projects, processes, and strategic changes can all be tracked using KPIs (Jorquera Valero et al., 2022). A SMART system is also helpful for cross-departmental collaboration because it makes it easy to know at a glance what other teams are working toward. It let businesses know if their assumptions are correct and whether what they are doing is effective. It's a message and a tale that rapidly assesses whether the group is making progress toward the objectives they have set together. Metrics can assist in turning abstract concepts into attainable aims and helping to keep high-level goals top of mind. Strong SMART framework save time, vital information gathering, managerial supervision, and perspectives of an organization. Lean adoption in the mining industry can be measured a set of metrics. The management will benefit from continuously assessing how well the organization's lean procedures are working. Such a system will increase business value by enabling strategic process linkage monitoring and decision-making[1].

6.3 CMMI METRICS PROCESS AREA-BASED FRAMEWORK

The first maturity framework spanning many domains was created in 1986 by Carnegie Mellon University's Software Engineering Institute. The oldest maturity model to direct software development is the Capability and Maturity Model (CMM). It was originally published in 1995. It was created primarily to offer a systematic, structured framework to handle problems with software management and engineering process. Later, CMM evolved into the Capability Maturity Model Integration (CMMI), which offers a means of displaying and evaluating organizational practices and activities concerning predetermined standards[2]. The CMMI model was initially developed for the U.S. Department of Defense to evaluate the quality and capabilities of their software contractors, but it has since been applied to organizations worldwide, in every industry, to help them understand their current level of performance and capability and provide a roadmap to improve business outcomes. CMMI's Metrics Process Area (PA) system enables enterprises to easily assess their present performance and help plan future improvements. CMMI's Metrics PA combined with GQM & SMART measures with some customization can be used to determine the level of lean application in the mining business. For sustainable mining operations, it's prudent to combine the best practices of

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[1] https://ficci.in/sector-details.asp?sectorid=81

[2] CMMI Reference: https://www.wibas.com/cmmi/project-management-cmmi-dev

multiple models and use the best of the available processes. Below is the conceptual model for lean measurements & management based on the three frameworks:
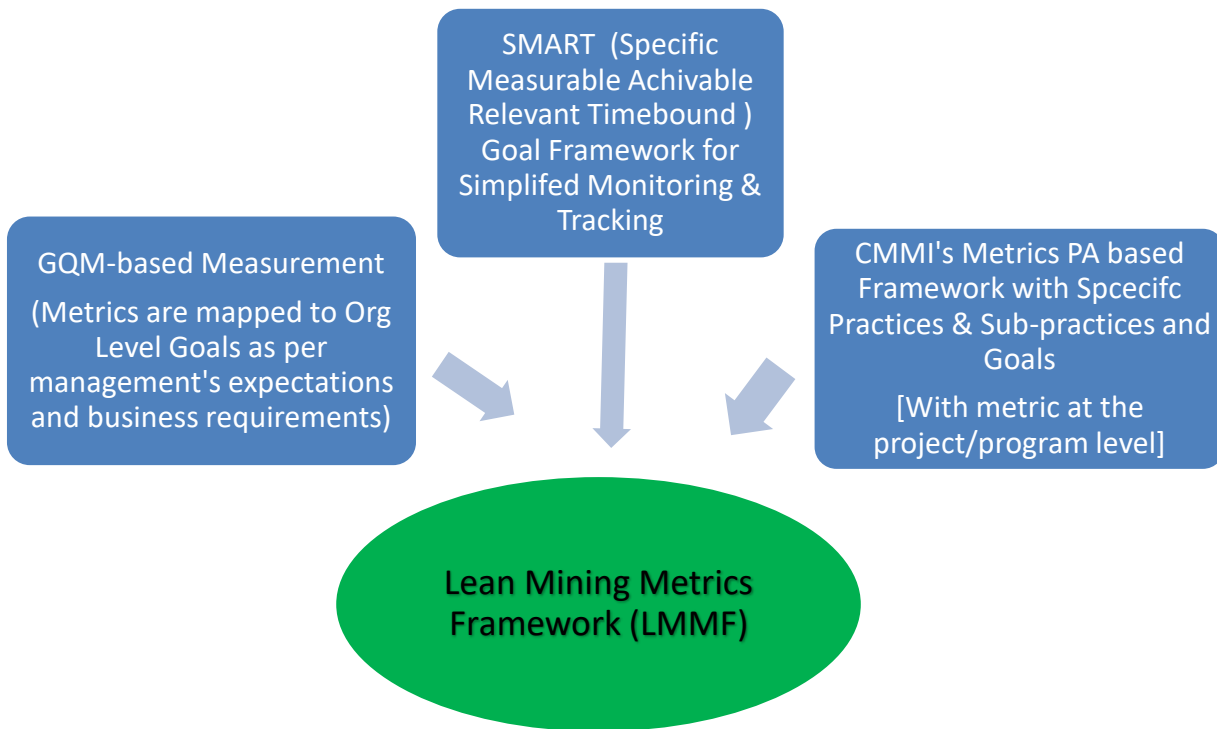

Fig 1: Conceptual lean mining metrics framework

The framework can be used to design a Metrics Program to monitor and track Lean implementation in the organization. The proposed framework can include the following Lean related Metrics (indicative list) for tracking/ensuring sustainable mining operations:

- % Compliance with Lean processes/practices in the operations department
- % Improvement in Cycle Time of key mining operations
- % Improvement in Productivity at mine site/plant
- % Improvement in Equipment Availability
- % Improvements in Mean Time Between Failure (MTBF) of major equipment
- % Reduction in Mean Time to Repair (MTTR) of major equipment
- % Reduction in cost per 1000 tons of mineral extracted
- % Reduction in accidents per 1000 tons of mineral extracted
- % Reduction in Fuel Usage in Heavy Machines
- % Reduction in Empty Travel Distance of Machines / Vehicles
- % Reduction in Waiting Time
- % Improvement in Machine Uptime
- % Improvement in Waste Recycling
- Number of Days of Training Conducted per Employee per Calendar Year
- % Improvement in employees involved in Lean improvement initiatives

The above metrics should be monitored & tracked using a real-time dashboard/ tool, which the management can use for decision-making. To establish sustainable mining operations, a new framework should incorporate the following elements:

- Environmental Stewardship: The framework should prioritize environmental protection, including reducing greenhouse gas emissions, minimizing waste generation and implementing environmental management systems.

- Social Responsibility: The framework should also consider the social impacts of mining, including local employment opportunities, community engagement, and support for indigenous communities.
- Economic Viability: Mining operations must be financially viable to remain sustainable over the long term. The framework should consider financial aspects such as capital investments, operating costs, and risk management.
- Innovation and Technology: Innovative technologies can help reduce the environmental impacts of mining and improve productivity. The framework should prioritize the adoption of new technologies and continuous innovation.
- Collaboration and Transparency: Collaboration with stakeholders such as local communities, suppliers, and regulators is essential for sustainable mining. The framework should prioritize transparent communication and collaboration with stakeholders.
- Health and Safety: Mining operations involve many hazards, and prioritizing worker safety is critical for sustainability. The framework should consider health and safety measures and training for workers.
- Life Cycle Thinking: The framework should take a life cycle approach, considering the full life cycle of mining operations, from exploration and development to closure and reclamation.

By incorporating these elements, the framework can establish a holistic approach to sustainable mining that considers environmental, social, and economic factors. This approach can help ensure that mining operations are sustainable over the long term and provide benefits to all stakeholders involved.

7. Limitations and future direction

The proposed framework is based on the available literature related to CMMI & lean implementation. This conceptual framework needs to be validated by mining companies and lean practitioners. Future best practices and frameworks like PMP-PMI, PCMM, BSC, and Value Engineering related processes can be added to make the proposed framework more practical, acceptable, and robust. The rating system for each practice can also be included to make it more quantitative and measurable. Additionally, the framework has only been evaluated in the manufacturing industry; future studies may assess the framework's application in service industries. Finally, researchers and practitioners may look at introducing new tools and approaches into the model for better people management, better process resistance, and observing employee health and safety.

8. Conclusion

The best practices of available frameworks are integrated to define a metrics framework, which mining organizations can use to monitor & track the level of lean implementation. The framework should be customized as per the organizational context and management requirements. The framework's pieces and components were created to produce deliverables more successfully when used in the mining sectors. Additionally, the proposed framework can be regarded as appropriate to adapt its use in other industrial sectors where similar activities occur, with some modification to its existing phases and the addition of other tools. A company that manufactures fastening components was considered to validate the suggested framework. It takes a lot of time to deploy and analyze different metrics because it is an implementation framework. Since the framework is general, it might be used by other mining automotive firms with comparable operational environments to achieve Optimized Mining Operations.

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