9th North American Conference on Industrial Engineering and Operations Management
Washington D.C., USA, June 4-6, 2024
Publisher: IEOM Society International, USA DOI: 10.46254/NA09.20240219
Published: June 4, 2024

Analysis of Operational Delays in Dumper Cycle Time in Open Pit Mines

Shafi Muhammad Pathan and Abdul Ghani Pathan
Department of Mining Engineering,
Mehran University of Engineering and Technology
Jamshoro, 76062, Sindh, Pakistan
agha.shafi@faculty.muet.edu.pk, ag.pathan@hotmail.com

Muhammad Saad Memon
Department of Industrial Engineering and Management,
Mehran University of Engineering and Technology
Jamshoro, 76062, Sindh, Pakistan
saad.memon@faculty.muet.edu.pk

Abstract

This study investigates the operational delays in dumper cycle time within open pit mines, focusing on the Thar coalfield in Pakistan. Efficient material handling processes are crucial for optimizing productivity and cost-effectiveness in mining operations. The dumper cycle time, encompassing loading, hauling, and dumping phases, directly impacts mine output and operational efficiency. This study aims to analyse these delays, identify root causes, and propose mitigation strategies to enhance material handling efficiency. Operational delays, including waiting times at loading and unloading stations, maintenance activities, and traffic congestion, are identified and analysed. Haul route interchange delays emerge as a major contributor to overall operational delays, emphasizing the importance of efficient traffic control and haul route design. The study underscores the implications of addressing operational delays for enhancing operational efficiency, reducing costs, and maximizing resource utilization in open pit mines. Overall, this research contributes to the understanding of material handling efficiency in open pit mining operations and provides valuable insights for improving operational performance and sustainability in the Thar coalfield, Pakistan.

Keywords

Open pit mining, Dumper cycle time, Operational delays, Material handling efficiency, Mining industry

1. Introduction

Open pit mining operations are complex and dynamic environments characterized by large-scale excavation activities to extract valuable minerals or resources from the earth's surface (Pathan et al. 2022). In such operations, the efficiency of material handling processes, particularly the loading, hauling, and dumping of ore or waste material, plays a critical role in overall productivity and cost-effectiveness (Shaikh et al. 2022). Among the key components of these processes, the dumper cycle time - the time taken for a dumper truck to complete a full cycle from loading to dumping - is a vital performance metric that directly impacts mine output and operational efficiency (Arputharaj 2015; Bölükbaşsi et al. 1991). Figure 1 illustrates the dumper cycle in open pit mines.

The optimization of dumper cycle time is essential for maximizing the utilization of mining equipment and resources while minimizing operational costs. However, achieving optimal cycle times can be challenging due to various factors that contribute to operational delays and inefficiencies (Afrapoli et al. 2019; Anani and Awuah-Offei 2017).

Understanding and addressing these factors is crucial for enhancing the performance and competitiveness of open pit mining operations.

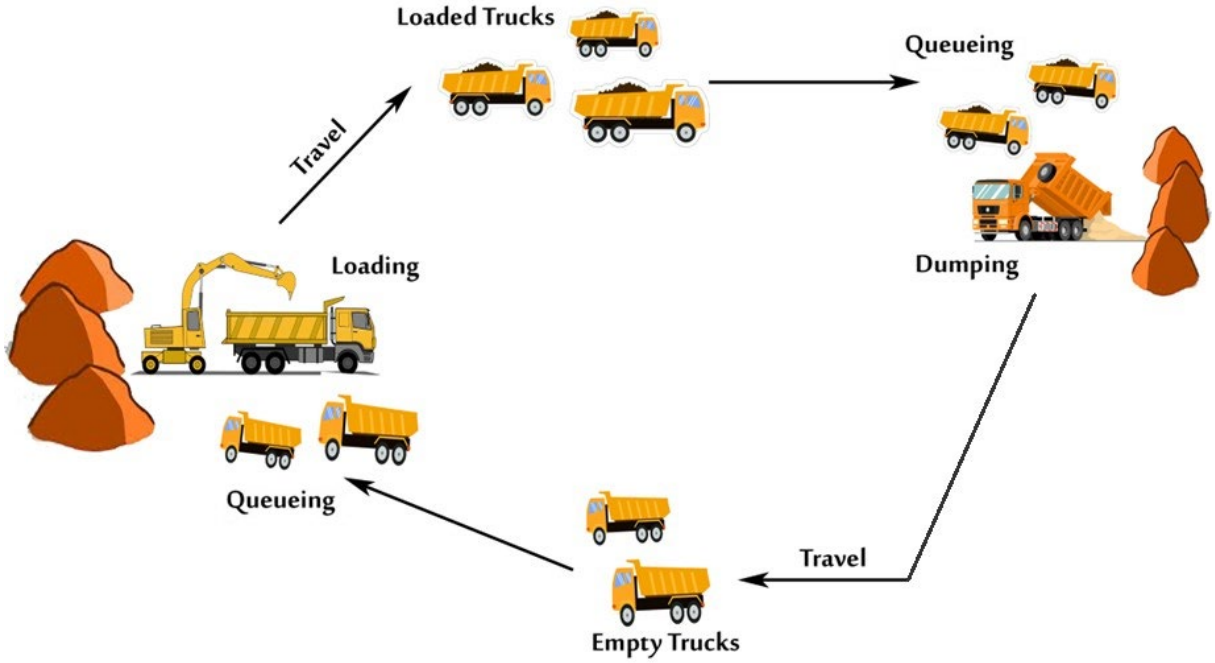

Figure 1. An illustration of dumper cycle in open pit mines

This research paper aims to analyse the operational delays affecting dumper cycle time in open pit mines at Thar coalfield, Pakistan. By investigating the root causes of delays and identifying potential mitigation strategies, this study seeks to contribute to the body of knowledge on improving material handling efficiency in the mining industry. Through a systematic examination of factors such as equipment reliability, material handling practices, environmental conditions, and operational processes, this research endeavours to provide valuable insights and practical recommendations for enhancing dumper cycle time performance.

2. Literature Review

Efficient material handling is paramount in open pit mining operations to ensure optimal utilization of resources and maximize productivity. The dumper cycle time, encompassing loading, hauling, and dumping phases, is a critical parameter influencing the overall efficiency of material transport within the mine. In this section, we explore existing research and knowledge pertinent to the analysis of operational delays in dumper cycle time in open pit mines. Several factors influence dumper cycle time in open pit mines.

A study by Smith et al. (2018) identified equipment availability and reliability, haulage distances, loading and dumping practices, as well as traffic congestion as key determinants of cycle time efficiency (Smith et al. 2020). Additionally, environmental conditions such as weather, terrain, and ambient temperatures can significantly impact operational performance (Kumar et al. 2022; Scott and McKee 1994).

Advancements in technology have enabled the implementation of various solutions to optimize dumper cycle time. Real-time monitoring systems, such as GPS tracking and fleet management software, allow for better coordination and control of mining operations, reducing idle times and improving equipment utilization (Bnouachir et al. 2020; Quigley and Dimitrakopoulos 2020). Furthermore, the integration of automation and autonomous vehicles has the potential to further enhance efficiency and safety in material transport processes (Bechtsis et al. 2018). Operational challenges such as equipment breakdowns, suboptimal loading practices, and inefficient haulage routes contribute to delays in dumper cycle time. Oluwatobi et al., (2023) highlighted the importance of proactive maintenance strategies

and operator training programs in mitigating equipment-related delays (Chernos et al. 2022; Dayo-Olupona et al. 2023). Similarly, optimizing haulage routes through advanced modelling techniques can minimize travel distances and reduce cycle times (Liu and Chai 2019; Ozdemir and Kumral 2019).

Environmental factors, including weather conditions and geological characteristics, pose significant challenges to material handling operations in open pit mines. Extreme weather events, such as heavy rain or snow, can cause delays and disruptions in mining activities, impacting dumper cycle time (Bao and Zhang 2020; Liu and Chai 2019). Moreover, geological features such as steep gradients or unstable terrain may necessitate modifications to hauling practices to ensure safe and efficient operations (D. Tannant 2001). Improving dumper cycle time not only enhances operational efficiency but also has broader implications for sustainability and economic viability in mining operations. Minimizing idle times and reducing fuel consumption through optimized cycle times contribute to lower carbon emissions and operational costs (Chang et al. 2015; Wang et al. 2024). Additionally, efficient material handling processes support timely delivery of ore to processing facilities, thereby enhancing revenue generation and overall profitability (Erkayaoglu and Demirel 2016).

The literature emphasizes the multifaceted nature of operational delays in dumper cycle time in open pit mines and underscores the importance of addressing these challenges through a comprehensive approach. By integrating technological innovations, operational best practices, and environmental considerations, mining companies can optimize material handling processes and improve overall efficiency and sustainability in their operations.

3. Methodology

The study aims to provide valuable insights into operational delays in dumper cycle time in open pit mines, informing strategies for improving efficiency and productivity in mining operations. This study employs a mixed-methods approach to analyse operational delays in dumper cycle time in open pit mines. The research design integrates quantitative data collection and analysis with qualitative insights from key stakeholders in the mining industry.

Data was collected through direct observation of mining equipment operations on the site. This includes recording timestamps for the start and end of each dumper cycle, as well as tracking equipment status, haulage distances, and other relevant parameters. This research focused the open pit mines across diverse geographical locations of Thar Coalfield Pakistan, to capture a range of operational contexts and challenges. The data collected on dumper cycle times and operational parameters will be analysed using statistical techniques. This analysis will identify trends, patterns, and correlations related to operational delays. The results of analysis will provide a comprehensive understanding of operational delays in dumper cycle time.

Ethical considerations were paramount throughout the research process. Informed consent was obtained from participants prior to data collection, and their confidentiality and anonymity will be ensured. The research will adhere to ethical guidelines outlined by relevant institutional review boards and regulatory bodies.

4. Results and Discussion

The cycle time data was collected for 300 dumpers for one day, i.e., 3 shifts. Two dumper destinations were situated, which are referred to as ‘Waste Dump’ and ‘Coal Crusher’ in this study. Out of 300 dumpers, 73 were unloading the coal at the coal crushing plant, remaining 227 were transporting overburden to the waste dump.

The cycle time components were determined and analysis was performed. Figure 2 presents the summarized results of cycle time analysis during a working shift of 8 hours. It can be observed that the waiting time at loading is greater than the loading time at unloading. This is due to the reason that empty travel time of dumper is less than the loaded travel time. Additionally, the haul road factors such as super elevation, rolling resistance, driver expertise etc., affect the travel time of loaded truck as compared to the unloaded truck.

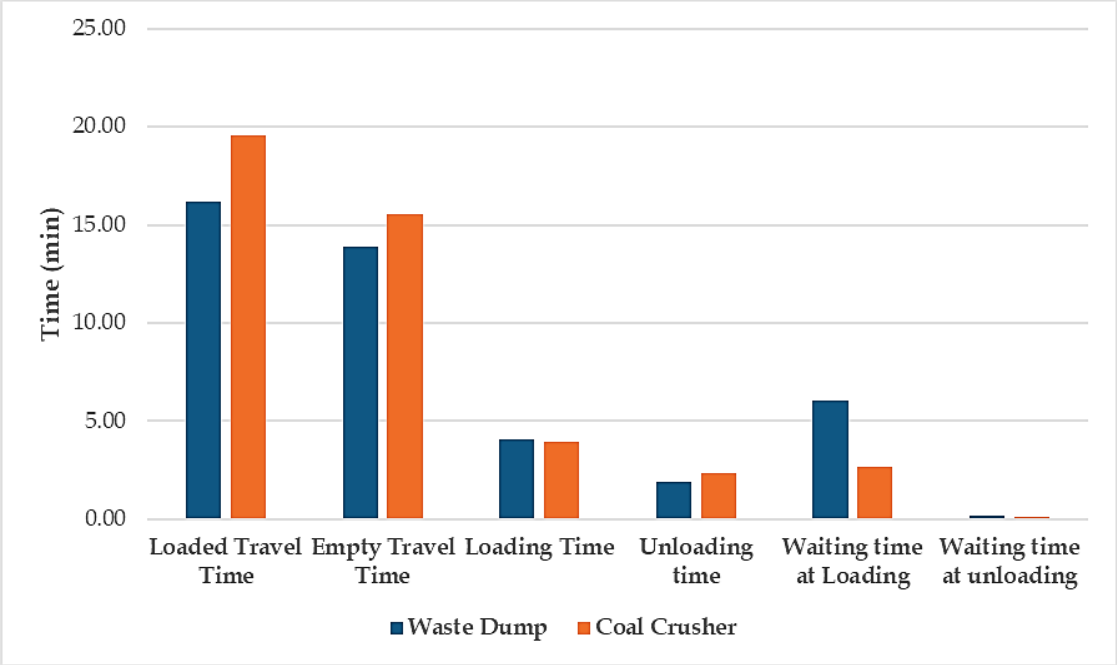

Figure 2. Average cycle time components of dumpers during a shift of 8 hours

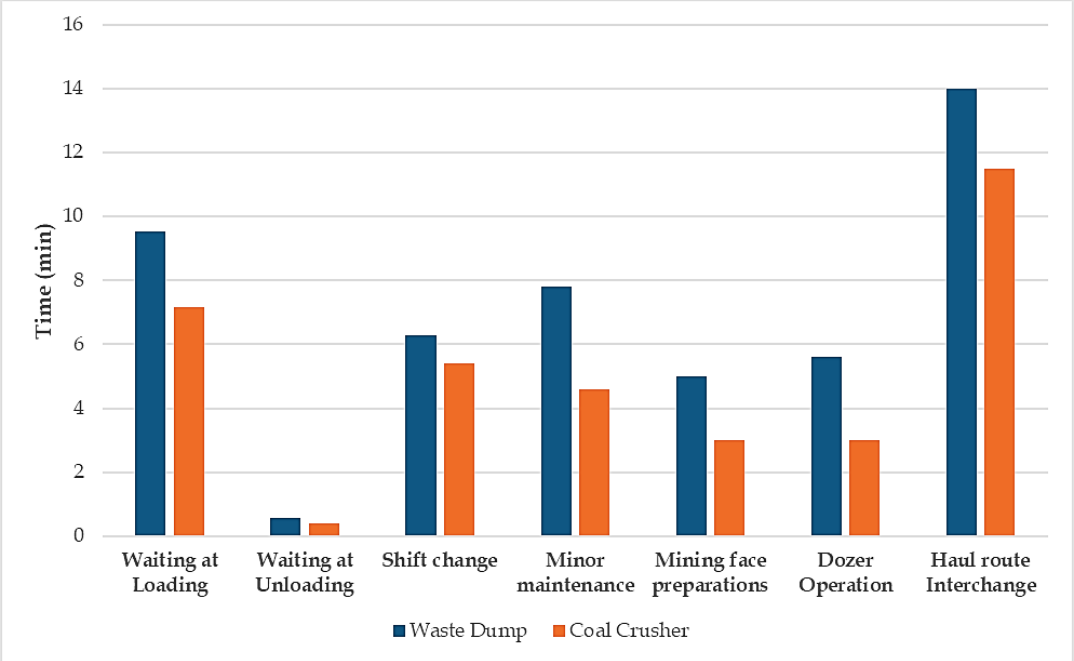

Figure 3. Average operational delays per day for dumper operations

Operational delays affecting the dumper cycle time were determined, as illustrated in Figure 3. These include waiting times at loading and unloading stations, shift change times, time required for minor (unscheduled) maintenance, time required for mining face preparation by the hydraulic excavator, time required for dozer operations on benches or haul roads, and the time during which dumpers stop at intersection points to allow the passage of dumpers coming from adjacent routes. It can be observed that the haul route interchange causes the maximum (average) delays per day for dumper operations. However, haul route interchange delay is directly associated with the pit design and layout of the

haul routes. Therefore, proper traffic control and haul route design strategies must be used to overcome this delay. Additionally, the waiting time of dumpers in queue at the loading point is a major operational delay associated with dumper operations directly. Accurate deployment of dumpers is important to reduce the delays associated with the queuing of dumpers at loading stations.

5. Conclusion

A This study is focused on the operational delays in dumper cycle time in open pit mines in Thar coalfield, Pakistan. Through a comprehensive examination of cycle time components and operational delays, several key findings emerge:

i) The study identifies various operational delays affecting dumper cycle time, including waiting times at loading and unloading stations, shift change times, maintenance activities, and traffic congestion at haul route intersections. Among these, haul route interchange delays emerge as the most significant contributor to overall operational delays.

ii) The results underscore the importance of haul route design and layout in minimizing operational delays. Efficient traffic control measures and optimization of haul road infrastructure are essential for reducing congestion and improving material flow throughout the mining operation.

iii) The study highlights the importance of accurate deployment strategies for dumpers to mitigate delays associated with queuing at loading stations. Effective coordination and scheduling of equipment movements are crucial for optimizing material handling processes and minimizing idle times.

iv) Addressing operational delays in dumper cycle time has significant implications for enhancing operational efficiency, reducing production costs, and maximizing resource utilization in open pit mines. By implementing targeted strategies to mitigate delays and improve cycle time performance, mining companies can enhance their competitive edge and sustainability.

The findings of this study contribute to the body of knowledge on material handling efficiency in open pit mining operations. By addressing operational delays and implementing targeted strategies for optimizing dumper cycle time, mining companies can improve their overall operational performance and sustainability in the dynamic and challenging environment of open pit mining.

Future research endeavours should focus on further exploring the root causes of operational delays and evaluating the effectiveness of specific mitigation strategies in different mining contexts. Additionally, advancements in technology, such as the integration of automation and real-time monitoring systems, offer promising avenues for enhancing material handling efficiency and productivity in open pit mines in Thar, Pakistan.

References

Afrapoli, A. M., Tabesh, M., and Askari-Nasab, H. A multiple objective transportation problem approach to dynamic truck dispatching in surface mines. *European Journal of Operational Research*, *276*(1), 331-342. 2019.

Anani, A., and Awuah-Offei, K. Incorporating changing duty cycles in CM-shuttle car matching using discrete event simulation: a case study. *International Journal of Mining and Mineral Engineering*, *8*(2), 96-112. 2017.

Arputharaj, M. M. Studies on availability and utilisation of mining equipment-an overview. *International Journal of Advanced Research in Engineering and Technology*, *6*(3), 14-21. 2015.

Bao, H., and Zhang, R. Study on Optimization of Coal Truck Flow in Open-Pit Mine. *Advances in Civil Engineering*, *2020*, 8848140. https://doi.org/10.1155/2020/8848140 2020.

Bechtsis, D., Tsolakis, N., Vlachos, D., and Srai, J. S. Intelligent Autonomous Vehicles in digital supply chains: A framework for integrating innovations towards sustainable value networks. *Journal of Cleaner Production*, *181*, 60-71. https://doi.org/10.1016/j.jclepro.2018.01.173 2018.

Bnouachir, H., Chergui, M., Machkour, N., Zegrari, M., Chakir, A., Deshayes, L., Semmar, A., and Medromi, H. Intelligent Fleet Management System for Open Pit Mine. *International Journal of Advanced Computer Science and Applications*, *11*(5). https://doi.org/10.14569/ijacsa.2020.0110543 2020.

Bölükbaşsi, N., Koncagül, O., and Paşsamehmetoğlu, A. G. Material diggability studies for the assessment of bucket wheel excavator performance. *Mining science and technology*, *13*(3), 271-277. 1991.

Chang, Y., Ren, H., and Wang, S. Modelling and optimizing an open-pit truck scheduling problem. *Discrete Dynamics in Nature and Society*, *2015*.

Chernos, M., MacDonald, R. J., Straker, J., Green, K., and Craig, J. R. Simulating the cumulative effects of potential open-pit mining and climate change on streamflow and water quality in a mountainous watershed. *Sci Total Environ*, *806*(Pt 1), 150394. https://doi.org/10.1016/j.scitotenv.2021.150394, 2022.

D. Tannant, B. R. (2001). *Haul Road Design Guidelines*.

Dayo-Olupona, O., Genc, B., Celik, T., and Bada, S. Adoptable approaches to predictive maintenance in mining industry: An overview. *Resources Policy*, *86*. https://doi.org/10.1016/j.resourpol.2023.104291, 2023.

Erkayaoglu, M., and Demirel, N. A comparative life cycle assessment of material handling systems for sustainable mining. *J Environ Manage*, *174*, 1-6. https://doi.org/10.1016/j.jenvman.2016.03.011, 2016.

Kumar, N. S. H., Manjunath, C., John, R. P., Chand, R. P., Madhusudhana, S., and Venkatesha, B. K. Reliability, availability and maintainability study of 6.5 cubic meters shovel and 60 tone dumper in a surface limestone mine. *Materials Today: Proceedings*, *54*, 199-204. https://doi.org/10.1016/j.matpr.2021.08.292 ,2022.

Liu, G., and Chai, S. Optimizing Open-Pit Truck Route Based on Minimization of Time-Varying Transport Energy Consumption. *Mathematical Problems in Engineering*, *2019*, 1-12. https://doi.org/10.1155/2019/6987108 ,2019.

Ozdemir, B., and Kumral, M. Simulation-based optimization of truck-shovel material handling systems in multi-pit surface mines. *Simulation Modelling Practice and Theory*, *95*, 36-48. 2019.

Pathan, S. M., Pathan, A. G., Siddiqui, F. I., Memon, M. B., and Soomro, M. H. A. A. Open pit slope stability analysis in soft rock formations at Thar Coalfield Pakistan. *Archives of Mining Sciences*, *67*(3). 2022.

Quigley, M., and Dimitrakopoulos, R. Incorporating geological and equipment performance uncertainty while optimising short-term mine production schedules. *International Journal of Mining, Reclamation and Environment*, *34*(5), 362-383. 2020.

Scott, A., and McKee, D. The inter-dependence of mining and mineral beneficiation processes on the performance of mining projects. Proceeding of the Australian Institute of Mining and Metallurgy Annual Conference, Melbourne, Australia, 1994.

Shaikh, Z. A., Pathan, A. G., and Pathan, S. M. *Influence of Rockmass Properties on Excavation Performance of Mining Shovel* 6th International Conference on Energy, Environment and Sustainable Development 2022 (EESD 2022), Mehran University of Engineering and Technology, Jamshoro, 76062, Pakistan. 2022.

Smith, A., Linderoth, J., and Luedtke, J. Optimization-Based Dispatching Policies for Open-Pit Mining. 2020.

Wang, Q., Gu, Q., Li, X., and Xiong, N. Comprehensive overview: Fleet management drives green and climate-smart open pit mine. *Renewable and Sustainable Energy Reviews*, *189*. https://doi.org/10.1016/j.rser.2023.113942 2024.

Biographies

Shafi Muhammad Pathan is pursuing a Doctor of Philosophy (Ph.D.) in Mining from Mehran University of Engineering and Technology. He is currently serving as an Assistant Professor in the Department of Mining Engineering at Mehran University of Engineering & Technology (MUET), Jamshoro, Sindh, Pakistan, since December 13, 2022. Prior to this, he worked as a Lecturer in the same department from July 16, 2011, until December 12, 2022. He earned a Bachelor of Engineering in Mining from MUET, Jamshoro. He furthered his education with a Master of Engineering in Mining from the same institution. Throughout his academic and professional journey, he has been actively involved in research projects. He has undertaken various research projects, both as a researcher and as a supervisor. His research interests span a wide range of topics related to mining engineering, including Open-pit Mine Optimization, Production Planning, Slope Stability, and Rock Mechanics Design. His research articles have been published in reputable journals and presented at international conferences.

Abdul Ghani Pathan is a Professor at the Department of Mining Engineering at Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan. He completed his Bachelor's degree in Mining and Metallurgical Engineering with distinction from Mehran University of Engineering and Technology, Jamshoro, in 1979. Upon graduation, he was honored with two gold medals. Immediately after his graduation, he joined the faculty of Mining and Metallurgical Engineering at Mehran University. In 1983, he was awarded the C.O.T scholarship by the Government of Pakistan and went to Nottingham University, UK, for his Ph.D. During his Ph.D. research, he developed a new and innovative technique for designing underground mining galleries. Upon completion of his Ph.D. in 1987, he returned to Mehran University and served as Chairman of the Department of Mining Engineering. In 1992, he was promoted as Professor by the University. He has served as Director of Research, and Dean of the Engineering

Faculty at Mehran University. He has also served as Chief Mining Engineer at Lakhra Coal Development Company (LCDC) and as General Manager and Director-General of Services at Sindh Coal Authority, Government of Sindh. He has also served as a member of the Mining Services in Thar Coal and Energy Board (TCEB), Government of Sindh, Pakistan. In 2010, Dr. Pathan was awarded the "Best University Teacher" award by Higher Education Commission. He has also won two research awards from HEC and British Council under the Higher Education Links and Inspire Program. In research and development, Dr. Pathan remains very active and focuses primarily on Thar Coal. Dr. Pathan and his team have designed the latest coal gasifier. This design is very suitable for Thar Coal gasification. Dr. Pathan has completed several research projects in collaboration with Nottingham University, UK, Hacettepe University, Turkey, and Shaanxi Aero Space University, China. He has published 40 research articles and one book. Almost all of his research articles have been published in renowned international journals and conferences.

Muhammad Saad Memon is an Associate Professor in the Department of Industrial Engineering and Management at Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan. With extensive experience in academia and a strong commitment to the field of industrial engineering, Dr. Memon has made significant contributions to both the academic and professional spheres. His expertise includes supply chain management, operations management, and production management. He has published over 50 research articles in esteemed international conferences and journals, contributing to the advancement of industrial engineering knowledge. Dr. Memon has also been distinguished as a keynote speaker, sharing insights and expertise at conferences and academic events. He is committed to continuous research and innovation, driving progress in supply chain management, operations, and production.