

Driving Towards Digitalization and Industry 4.0 in the Coal Mining Sector

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Abstract

This research provides an in-depth analysis of the impact of digitalization on the coal mining sector, with a special focus on PT X. The study employs a combination of content analysis, narrative analysis, and business solution mapping to extract insights from interviews conducted with five key stakeholders at PT. X. The objective is to assess how technological advancements can elevate operational efficiency and competitiveness in the era of Industry 4.0, and to identify strategies for effectively reducing reliance on human resources in site monitoring, while ensuring employee satisfaction and smooth transition. Through the methodological triangulation of content and narrative analysis, the study distills crucial themes and perspectives from the interviews. It identifies that the integration of advanced technologies like IoT, data analytics, and automation is vital for enhancing operational efficiency and reducing operational downtime. The research highlights the importance of transitioning from manual to automated site monitoring, emphasizing the adoption of drones and automated systems to bolster operational accuracy and efficiency. A key finding of the study is the identification of potential obstacles in digital technology investment, such as cost, system integration challenges, and employee resistance to new technologies. The study suggests that overcoming these barriers requires effective communication strategies and comprehensive training programs for employees. Drawing on the successful digital transformation strategies of companies like Adaro, the research recommends that PT. X should adapt similar strategies, customized to its unique challenges and context. The study contributes valuable insights into the digital transformation process in the coal mining sector, offering practical recommendations for companies like PT. X navigating the complex landscape of Industry 4.0.

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INTRODUCTION

Information and Communication Technology (ICT) is a pervasive technology with the potential to significantly transform the foundation of our society (Mansell & Silverstone, 1998). In these decades (2020-2023), there has been focus on the rapid advancement of ICT within specific domains. According to the ITU (2017), the Internet of Things (IoT), Cloud Computing, Big Data Analytics, and Artificial Intelligence (AI) are identified as the four game-changing technologies that will help driving the digital transformation. Figure 1.1 illustrates their market sizes in 2015 and the projection for 2025.

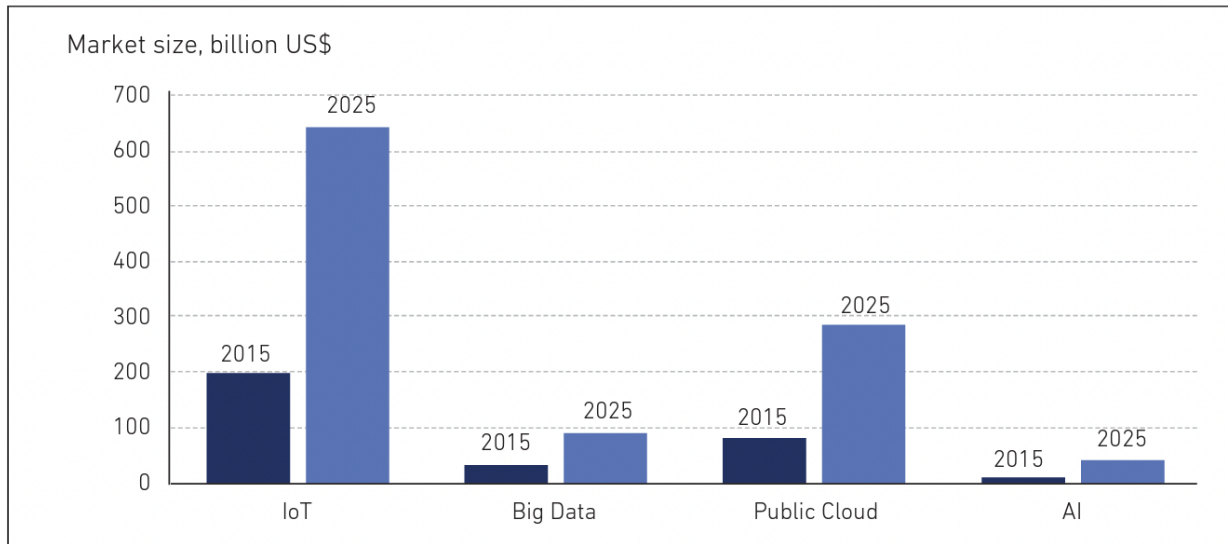


Figure 1. Global Market for Emerging Technologies, 2015 vs 2025

Furthermore, when digitalization has emerged as a transformative force in various industries, and the Indonesian coal mining sector is no exception. The integration of digital technologies is reshaping the way coal mining operations are conducted, making them more efficient, safer, and environmentally sustainable. In Indonesia, the Government has recognized the application of digital technologies would remain their business competitive in the market, enhance customer experiences, and improve operational efficiency. Digitalization is no longer an option but a necessity especially for the coal mining sector. Digitalization and Industry 4.0 cannot be separated as when Industries drive its business towards Industry 4.0, meaning that it forces them to get closer to the digital technology (Communications, 2021). In addition to that, Indonesia can increase its level of economic growth by going digital (Das, Gryseels, Sudhir, & Tan, 2016).

As technology continually improving, the world has encouraged industries to enter new market revolution– Industry 4.0. This new industrial revolution 4.0 was believed to have massive impacts on firms and become customer-centric in how the industry itself operates (Communications, 2021). If the firms fail to adapt with the quick changes of this revolution, they might be left behind and less-competitive compared with other industries especially within the same sector. Digitalization is a major trend within Mining sector (Pavlikhina, Shishkin, & Shishkina, 2021). It became essential factor for survival as it can encourage company in improving its efficiency, productivity, and safety. Implement digital technology within mining industry can also help mine operators improve their workers well-being (Lath & Peacocke, 2020).

PT. X has an ambition to become one of the leading companies in the coal mining sector to fulfil domestic energy needs. In that way the company needs to quickly adapt with the current situation in the market, which is mostly driven by the development of technology. PT. X is fully aware that they have

to evolve with technology yet putting it into action is a different story. In the current situation, PT. X is still lacking on some parts such as they do not have a website which some researchers believed if you have a business but do not have a proper website, you are not trustworthy nor your sales will suffer too (Lesonsky, 2022). In addition to that, PT. X is heavily relied on its human resources (HR) to monitor the situation on the site. Not to mention that HR remains essential for companies, yet when the company does not have enough resources, they are struggling to do monitoring and becoming less-secure. In addition to that, their managements are mostly coming from older generations where they resisted to rapidly adapt with technology improvement and learn new technologies.

This scope of this research will primarily focus in examining PT. X which is in the coal mining sector and its specific challenges and opportunities related to Industry 4.0 and digitalization. Specifically, this study will address the issue occurred within PT. X including their needs to adapt with new industrial revolution. Along with that, the author utilizes all the data ranging from PT. X employees, management, and potentially other stakeholders within PT. X. The findings of this study may not be directly applicable to all industries in the coal mining sector or other businesses in different industries. The results and recommendations provided at the end will be according to the availability and accuracy of data offered by PT. X. In addition to that, there is a potential challenge due to available timeframe. It is conceivable that not all intended interviews may be conducted within specified timeframe. However, the author remains committed to mitigating this limitation by prioritizing key informant interviews and ensuring a comprehensive analysis of available data.

METHOD

Research methodology often refers to the process used to collect data and information for the purpose of making decisions. For this topic, the author will conduct a descriptive qualitative research methodology as a way to carry out this research. The objectives of qualitative research is to comprehend the ways in which individuals interpret their personal experiences, whether independently or within societal settings. It assumes that an objective reality does not exist, and instead, the social world is interpreted (Yilmaz, 2013). In addition to that, Sugiyono (2010) stated that qualitative research is descriptive, meaning that collection of data was in the form of words than numbers.

Research design is a platform that provides a structure for conducting a scientific investigation. It is a framework to guide the author in the process of collecting, analyzing, and interpreting observations. As forementioned, the author will use descriptive qualitative research methodology to carry out the topic of "Driving towards digitalization and Industry 4.0: Case Study at PT. Bara Sumatera Energy". Furthermore, this research will be conducted at PT. X, hence will be limited to the selected employees within the company.

The current design study was made to provide an understanding on how the research will be carried out by using descriptive qualitative research. Thus, the collection of data will be

subjective as the conducted techniques to gather the data will be from interviews. As Sugiyono (2010) explained, qualitative research is presented in the natural settings as the data collected and the analysis are more qualitative in nature. Sugiyono (2010) also stated that qualitative research is managed by natural objects, meaning that the objects will develop as they are without getting influenced by the presence of the author. The design of this descriptive qualitative research is as shown in Figure 2.



Figure 2. Descriptive Qualitative Research Design

According to the Figure 2 the author needs to define the goals of the project and do theory review related to the topics based on the existing studies. After determining the objectives and doing external research, conceptual framework is made as a guidance to design the methodology that will be used during the research. Furthermore, the author is planning to use purposive sampling as to delimit and narrow the study population then conduct interviews with the selected employees to gain more insights in a subjective manner. Additionally, the author also needs to consider regarding the sample size, as they need to ensure that they have enough collected data to meet the study aims (Ritchie & Lewis, 2003). Moreover, after gathering all the data, the data will then be analysed. According to (Lambert & Lambert, 2012), analysing data in descriptive qualitative research is data driven and not getting influenced by a pre-existing philosophical or epistemological perspective. Last but not least, all the findings will be reported and the author can draw conclusions based on that.

The data collection will be taken from both primary and secondary data. Primary data sources, namely data that is directly gathered by the author will be done by having one-on-one interviews with the selected participants (n=5). The types of interviews are usually done by conducting semi-structured individual face-to-face interview (Kim, Sefcik, & Bradway, 2016), telephone interviews and online approaches are also used. The author is planning to conduct semi-structured interview with a case study that need to be solved by the interviewee. The case study will be provided to see how each person handles different situations while making decisions and negotiations. Furthermore, secondary data sources are supporting data to the

primary data sources, such as existing study related to the topics. In this research, secondary data will be extracted from internal company reports, books, journals, and articles from the internet.

The interviewee of this project will be chosen by using purposive sampling. This technique is believed to select respondents that are most likely to provide appropriate and useful information (Kelly S., 2010). The interviewee will be limited from people within PT. TRH that have the authority in making decisions and negotiations with both internal and external partners. The author is planning to have five samples for the interview, including Board of Directors, Managers, and Corporate Secretary. These participants were selected as they meet the pre-determined criteria related to the goals of this research. To collect primary data, a list of key topics along with example questions have also been prepared by the author as a guidance while doing the interview. The lists are portrayed in the Table 1 below.

Table 1. List of Key Topics and Questions Guidance

No.	Key Topics	Questions Guidance
1.	Aware of the concept of Digitalization and Industry 4.0	<ul style="list-style-type: none"> - How familiar are you with the concept of Industry 4.0? - Are you aware that Industry 4.0 has transformed the mining sector and is potentially to be critical development for PT. X to remain competitive in its industry?
2.	PT. X's Current Situation	<ul style="list-style-type: none"> - Could you describe PT. X's current technology and digital presence? - How many stakeholders involved in the company? - How heavily reliant is PT. X on its human resources?
3.	Understanding the technological infrastructure and challenges	<ul style="list-style-type: none"> - What digital technologies or tools is PT. X currently using in its mining operations? - What are the major technological challenges or gaps that PT. X is facing in its operations? - How do these technological limitations affect the company's operational efficiency and productivity?
4.	Competitiveness and Strategies	<ul style="list-style-type: none"> - How do you perceive PT. X's competitiveness compared to other companies in the coal mining sector? - Are there specific strategies that PT. X has in mind to enhance its operational efficiency in the future? - Do you think by transforming into digitalization and industry 4.0 can help PT. X to have better improvement?

RESULTS AND DISCUSSION

Narrative Analysis

This analysis section explains narratively the results of interviews conducted based on reduction and verification between sources and confirms several important things in common. In the results of further analysis, it was discovered that each source had a significant correlation with each other in their answers, especially in explaining several important topics which are summarized in Table 2 below:

Table 2. Correlations from the responses of the five interviewees

Topic	Subject 1	Subject 2	Subject 3	Subject 4	Subject 5
Awareness of Digitalization and Industry 4.0	Basic understanding of Industry 4.0, sees its general importance.	Highly knowledgeable about Industry 4.0, sees it as crucial for the future.	Moderately familiar, interested in the environmental aspects of Industry 4.0.	Adequately familiar, focused on operational efficiencies.	Conceptually familiar, especially with legal and compliance aspects.
PT. X's Current Situation	Aware of current tech, sees room for advanced systems; acknowledges reliance on human resources.	Advocates for more digital integration; views stakeholders as important for decision-making.	Recognizes current tech; emphasizes need for environmental tech solutions.	Acknowledges current tech; sees potential for improvement.	Notes basic compliance software usage; highlights lack of advanced tools.
Technological Infrastructure and Challenges	Uses basic digital tools; feels the lack of advanced technology hinders efficiency.	Advocates for smart mining technologies; sees significant gaps in automation and analytics.	Utilizes environmental monitoring tech; needs more sophisticated technology.	Familiar with current operational tech; points out need for IoT integration.	Highlights lack of advanced legal compliance tools and AI.
Competitiveness and Strategies	Suggests investment in modern equipment and training for improvement.	Confident in PT. X's competitive edge; emphasizes innovation and digital transformation.	Recommends focusing on sustainable practices and green technology.	Believes in operational efficiency as key for competitiveness.	Focuses on legal compliance and risk management for competitiveness.

Recognition of the Need for Technological Advancement

This research explains strong findings regarding the need for technological progress, as explained by Subject 2, Subject 3, Subject 4, and Subject 5. This common perception underscores the shared understanding across the company's various departments, highlighting

the importance of leveraging advanced technology for BSE's future success and sustainability. Subject 2, with a clear and forward-looking perspective, emphatically articulates the essential nature of this technological shift.

“Industry 4.0 is not just a choice; but it is a necessity for our growth and survival,”

Subject 2

His statement, not only fighting for the inevitability of welcoming Industry 4.0 but also making it an important factor for the continued relevance and prosperity of companies in a rapidly developing era. industrial landscape. Subject 3 explains the sustainability dimension of this technology conversation.

“Digital technology can revolutionize our approach to sustainability,”

Subject 3

according to him reflecting increasing awareness within companies about how technological advances can be leveraged to achieve environmental goals. Subject 3's perspective positions technology as a key factor in reducing environmental impacts and encouraging sustainable practices, indicating a change in the way mining operations become efficient and ecologically responsible. Subject 4 gave more or less the same answer regarding operational efficiency, emphasizing the practical benefits of digitalization in BSE's daily operations.

“Efficient operations through digitalization is the way forward for us,”

Subject 4

His comment acknowledged the direct impact of technology on increasing productivity and streamlining processes. This operational perspective shows that the integration of digital technology is not only a strategic step but also a necessity to achieve operational excellence.

Subject 5 focuses on legal compliance and risk management, emphasizing the importance of technology in navigating the complex legal landscape of today's world.

“Staying compliant and managing risk in today's world means embracing digital advances,”

Subject 5

His statement highlights the important role technology plays in ensuring regulatory compliance and managing risk effectively. This perspective is particularly relevant in the mining sector, where legal and regulatory challenges are ever-present and continually evolving. Subject 2, Subject 3, Subject 4, and Subject 5's answers weave a narrative that positions technological progress as a multifaceted necessity for PT. X. It's not just about remaining competitive or operationally efficient; but also, about sustainability, legal compliance and readiness for the future. The consensus among interviewees reflects the company is at an inflection point, where the use of digital technology is seen as key to meeting the challenges and opportunities in the modern mining landscape.

Concern for Operational Efficiency and Productivity

The results of this research concern concerns regarding operational efficiency and productivity, which were expressed by Subject 1 and Subject 4. Both interviewees expressed their concerns about current operational efficiency and productivity at the company, pointing out areas that require attention and improvement. Subject 1, with a practical approach, emphasized the importance of maintaining industry standards but in a way that can be realistically implemented at BSE.

"We need to keep up with industry standards but in a way that's practical for us,"

Subject 1

His words show a desire to improve without disturbing the stability of existing operations. This reflects a pragmatic view towards change and adaptation, showing that while he recognizes the need for improvement, he also considers operational limitations and realities on the ground. Subject 4 gave an answer that emphasized the role of digitalization in increasing efficiency.

"Efficient operations through digitalization are the way forward for us,"

Subject 4

Its more technology-oriented approach is seen in its statement, which shows the belief that the application of digital technology is the key to increasing operational efficiency. Subject 4's

view paints a picture where digitalization is not only about technological innovation, but also as an important tool for increasing productivity and work efficiency. Both though coming from different viewpoints, collectively underscore the importance of focusing on efficiency and productivity at BSE. Both Subject 1 with his practical approach and Subject 4 with his technology focus both recognize that there is significant room for improvement in the way the company runs its day-to-day operations. This shows a shared awareness among BSE leaders that to remain relevant and competitive, companies must continue to look for ways to increase efficiency and productivity, both through practical adaptation and the adoption of innovative technology solutions.

Balanced Approach to Digitalization and Human Resources

In the findings of this research, it can be seen that there is a prominent correlation related to a balanced approach between digitalization and human resource development, as expressed by Subject 1 and Subject 2. Both recognize the importance of finding a balance between technological advancements and employee development, highlighting that both aspects are equally important for a company's progress. Subject 1 explained a realistic view of the role of technology, saying,

"We're using some tech solutions, but there's room for more advanced systems. Our people are important, but we can enhance efficiency with better technology,"

Subject 1

This statement reflects the realization that although BSE has adopted several technological solutions, there is still a need for further improvements. Meanwhile, he also emphasized the important value of human resources, showing that technological improvements do not have to exclude the role of employees. Subject 2 emphasized the importance of increasing the use of technology to remain relevant and competitive.

"Our tech use is not where it should be. We need to digitize more to keep up. Our stakeholders play a big role, and we value our employees' contributions,"

Subject 2

His statement sees digitalization as the key to progress, but also recognizes the importance of employee involvement and contribution. There is agreement that the development of

technology and human resources must go hand in hand. They both recognize that investment in advanced technology is essential, but this must be done taking into account its impact on employees and the need to ensure that they are engaged and skilled in dealing with these changes. This shows a mature understanding that success in the digital era does not only depend on tools and systems, but also on the ability and readiness of the people who operate them. This balanced approach is important to ensure that BSE not only advances technologically but also remains a workplace that empowers and supports its employees.

Emphasis on Legal Compliance and Risk Management

The findings explain the significant correlation seen in the emphasis on legal compliance and risk management, especially with regard to environmental sustainability, as expressed by Subject 5 and Subject 3. Both voiced the importance of ensuring legal compliance and effective risk management as a key part of corporate strategy, with a particular focus on environmental sustainability. Subject 5, with her views focused on legal compliance, stated,

"Staying compliant and managing risks in today's world means embracing digital advancements,"
Subject 5

His statement highlighted that in this fast-paced and changing era, the application of digital technology is the key to maintaining compliance and managing risk effectively, especially in the mining sector which is highly regulated by legal regulations. Subject 3 explained the dimensions of environmental sustainability in this discussion.

"Digital technologies can revolutionize our approach to sustainability,"
Subject 3

His words show that he views digital technology as an important tool in promoting sustainable mining practices and reducing environmental impacts. Subject 3's approach combines legal compliance with environmental responsibility, demonstrating that these two aspects are inseparable in achieving a company's sustainability goals. These findings demonstrate a deep awareness that legal compliance and risk management, especially in the context of environmental sustainability, are key elements in maintaining BSE's reputation and long-term success. They both recognize that digital technology is not only a tool to increase

efficiency, but also an important means to meet increasingly stringent environmental legal and ethical standards. Through their views, it became clear that BSE must integrate technology in a way that ensures that companies are not only efficient and productive, but also responsible and compliant with existing regulations. This holistic approach is important for companies that want to not only survive but also thrive in a future that increasingly emphasizes the importance of compliance and sustainability.

Sustainability and Environmental Responsibility

The findings of this research reveal the importance of sustainable practices and environmental responsibility, as stated by Subject 3 and Subject 4. Both emphasized that a focus on sustainability and environmental responsibility are important aspects for the company's future. Subject 3 explains the orientation towards sustainability, emphasizing the role of technology in changing the way companies address environmental challenges.

"Digital technologies can revolutionize our approach to sustainability,"

Subject 3

His words show his belief that technological innovation can help companies implement more sustainable and environmentally friendly methods. Subject 3's approach describes a vision where the use of technology is not only aimed at increasing operational efficiency but also to ensure that company operations are more environmentally friendly. Subject 4 focuses on operational efficiency, also seeing the importance of digitalization in supporting sustainable practices.

"Efficient operations through digitalization are the way forward for us,"

Subject 4

His statement shows that he believes digitalization can strengthen the company's efforts to run operations that are not only efficient but also environmentally responsible. Subject 4's views highlight that efficiency and sustainability can go hand in hand, with technology as the main catalyst. This research explains the shared recognition at BSE of the importance of integrating sustainability and environmental responsibility into corporate business strategies. Through their views, it is clear that BSE must strive not only to be financially successful but also act as a pioneer in sustainable practices and environmental conservation. This approach is important to ensure that companies can not only survive

in the future but also contribute positively to a greener and more sustainable world.

Discussion

Based on the analysis carried out in the previous section, there are several solutions that can be adopted by PT. X to overcome challenges in the era of digitalization and Industry 4.0. This solution focuses on three main aspects: increasing operational efficiency through digitalization, strategies for reducing dependence on human resources for site monitoring, and key considerations and potential barriers to digital technology investments. First, increasing operational efficiency through digitalization can be achieved by adopting advanced technologies such as IoT, data analytics and automation (Ashima et al., 2021). According to Bhattacharyya and Shah (2022), IoT technology and data analytics have been proven to have a significant impact on industrial development, including the mining sector. This technology allows companies to optimize mining operations through real-time monitoring and faster and more accurate decision making. Subject 3, one of the speakers in this study, emphasized that "Digital technologies can revolutionize our approach to sustainability," which shows the potential of digital technology in changing the way companies operate, not only in terms of efficiency but also sustainability (Bibri, 2018; Salam, 2020; Wu et al., 2022).

Second, strategies for reducing dependence on human resources for site monitoring can be carried out through the implementation of drones and automatic monitoring systems (Lee & Choi, 2016; More et al., 2020). This not only reduces the need for physical labor but also improves monitoring accuracy and efficiency (Tejado-Ramos et al., 2021). It is also important to provide training and development for employees to ensure a smooth transition and employee satisfaction (Asuman et al., 2018; Guan & Frenkel, 2019), as emphasized by Subject 1: "We need to keep up with industry standards but in a way that's practical for us." Third, in the context of digital technology investment, BSE must consider implementation costs, employee training, and integration with existing systems (Löw et al., 2019; Ranjan et al., 2008). Potential barriers that may be encountered include resistance from employees and challenges in adopting new technology (Leong et al., 2022; Zhang et al., 2020). The solution involves effective communication and a comprehensive training program to ensure that all employees are engaged and able to adapt to change.

CONCLUSION

This study has provided several key findings. Firstly, assets, capital, and the number of employees were found to significantly influence innovation within start-ups, but they demonstrated an opposite effect on shares. Specifically, assets were found to inversely affect innovation costs, suggesting that companies may prioritize other interests as their total assets increase. Capital, on the other hand, displayed a positive correlation with innovation costs, indicating that higher company capital leads to

increased expenditures on innovation. Lastly, the more employees a company has, the higher the innovation cost, potentially due to the increase in ideas generated for innovation.

Moreover, neither assets, capital, nor the number of employees had a significant direct impact on start-up shares. This indicates that these variables might not be the primary determinants of share value, which tends to be influenced more by financial factors. Furthermore, the cost of innovation did not significantly affect shares either, possibly due to the perception of investors regarding high R&D costs as a potential drawback. However, when innovation was considered as a mediator, both assets and capital were found to indirectly influence start-up shares, implying the potential significance of innovation in affecting share value. As with all studies, this research has limitations. The primary limitation lies in the focus on start-ups during the period 2019-2022, which might limit the generalizability of the results. Additionally, the study only looked at the effects of assets, capital, employees, and innovation on shares, neglecting other potential influencing factors like management, market trends, or governmental policies.

For future research, it would be beneficial to extend the research timeline to understand the impact of these variables over a longer period. Additionally, it would be interesting to examine these effects in different industry sectors, as start-ups in various industries might have differing dynamics. Lastly, future research could explore other potential influencing factors on shares to provide a more comprehensive understanding of share value determinants. Such research will not only enrich the academic literature but also offer practical implications for start-up management and investors, enabling them to make more informed decisions.

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