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INDUSTRIAL INTERNET OF THINGS IN INDONESIAN COAL MINING (CASE STUDY: PT BERAU COAL)

Reo Andreas[a], Manahan Siallagan[b]
[ab] Institut Teknologi Bandung, Indonesia.
Corresponding Email: reo.andreas@sbm-itb.ac.id

Abstract

The future of Indonesian coal mining industry will be redefined in the context where the production costs are determined by global competition and more efficient. Declining coal prices, government safety regulation, increased labor cost, ineffective and inefficient business processes are all pressuring company's profitability. Dealing with the situations, Berau Coal as the top 5 coal mining company in Indonesia must explore the new solutions by implementation of technology in the current business processes. The forefront and most important condition in the future of coal mining industry, company should have effective and reliable technical coal production processes. Business digitalization is a keyword that is often stated to be able to solve the problem in coal mining industry. The research provides SIMBIOSYS (Sinarmas Mining Business Integration Systems) as the IIOT (Industrial Internet of Things) platform to improve and integrate business processes in Berau Coal. It consists of recent architecture, platform development, pilot project and evaluation of IIOT adoption. CPP Binungan, CPP Suaran and coal hauling will be the focus are for implementation of SIMBIOSYS in Berau Coal. IIOT has brought improvement and automated solutions in the business world. The methodology and technologies of IIOT can be used to address business issues in Berau Coal. It can provide opportunities for decision making, optimization operating cost and mining equipment and fuel and electricity savings.

Keywords*:* Business Processes, Coal Mining, IIOT, Platform, SIMBIOSYS.

1. Background and Business Issue

The mining operation of Berau Coal was started on 26 April 1983, following Perjanjian Karya Pengusahaan Pertambangan Batubara (PKP2B, Coal Contract of Works). Currently, Berau Coal has three active mining operations, namely Lati, Binungan, Sambarata and one new development mining operation at Gurimbang. Berau Coal is the main operating subsidiary of Sinarmas Mining Group. The research is focused on Binungan due to the complexity of business processes compared with other area within the company.

Currently, CPP (Coal Processing Plant) Binungan, CPP Suaran and coal hauling are interdependent business processes, but they are independently operated. Each business processes are led by Superintendent, communication and coordination between business processes are conducted conventionally by radio, email or phone. The current processes require a lot of time and have response delay, particularly updating coal production plan, quality change and critical decision making. If these conditions are not immediately managed, in the short run can impact on low productivity of coal haulers and fixed plant equipment, increase energy demand and at the final impact can increase the coal production costs. In the long run, the condition will affect the company financial performance caused by reducing profitability.

Berau Coal requires the business solution to achieve several goals. The first, optimizing coal hauling and CPP operation by increasing productivity and reducing total equipment downtime. The second is cost optimization by reducing operational maintenance costs. The third is energy saving by optimizing electricity and fuel consumption by optimizing coal hauling and fixed plant operations. The last one is reducing time and response delay for making a critical decision related business processes in Berau Coal.

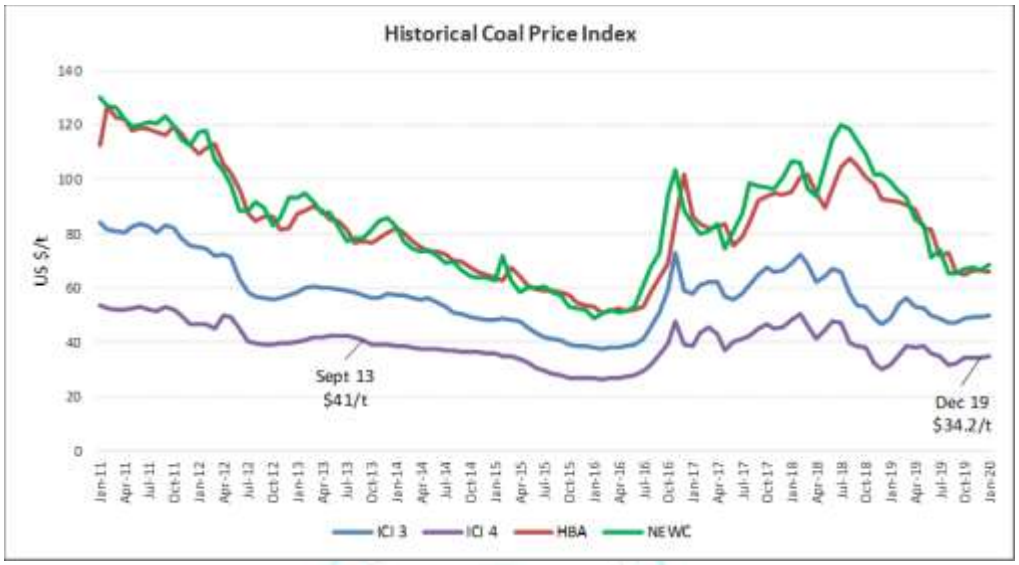

Figure 1. Historical Prices since 2011

2. The Conceptual Framework

The conceptual framework is an analysis to determine the business solution to overcome the business issues in the research. Porter 5 forces and root cause analysis will be conducted to identify internal and external challenges and potential causes of company's problems. Business solution alternative, concept and solution architecture, and implementation plan are developed and used for achieving the goals.

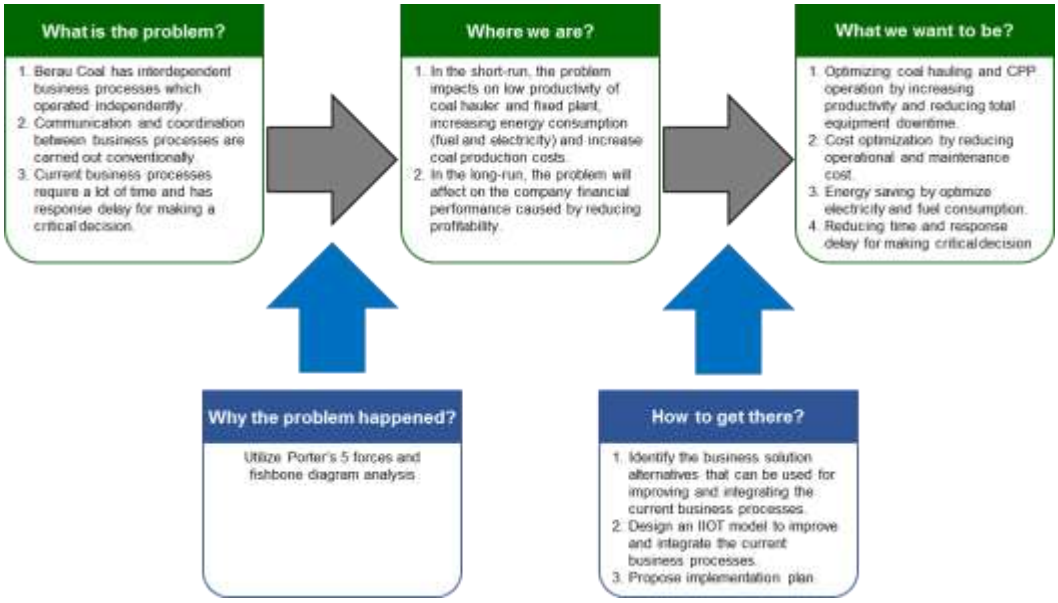

Figure 2. Conceptual Framework of the Research

3. Analysis of Indonesian Coal Mining Industry

Figure 3. Porter's 5 Forces Analysis of Indonesian Coal Mining

From the Porter's 5 forces analysis, Indonesian coal mining must find solution for being competitive within coal mining industry in Indonesia and globally by reducing their coal production costs, increase operational effectiveness and comply with government regulation.

The research also tries to determine the challenges of current business processes in coal mining. The result of analysis and data obtained several root causes are shown in Figure 4. The possible challenges can be grouped into 5 which consisting of people aspect, equipment aspect, money aspect, process aspect, and government regulation aspect.

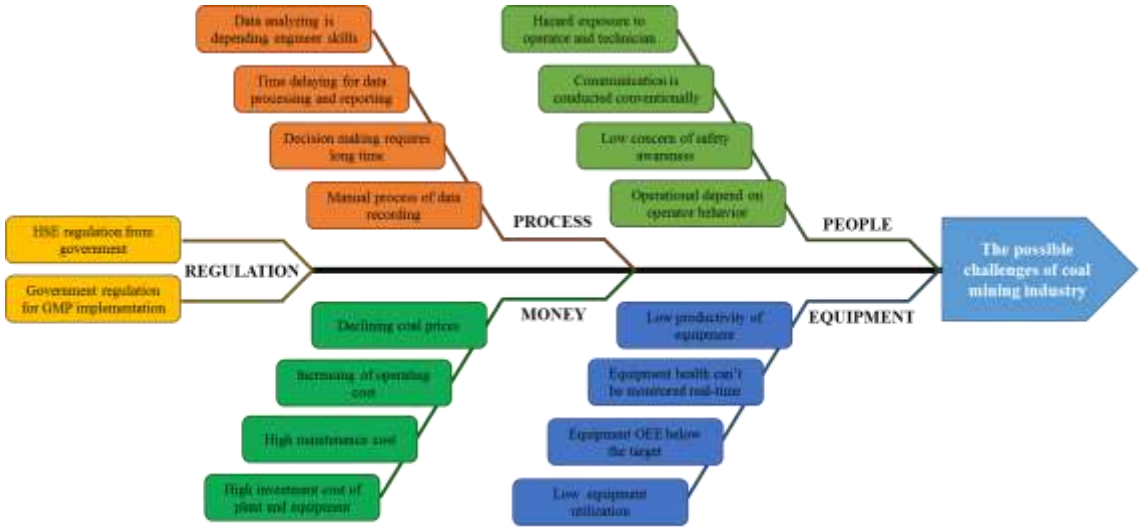

Figure 4. The Possible Challenges of Indonesian Coal Mining

Table 1. Indonesian Coal Mining Challenges and Potential Solutions

The Aspects	The Possible Challenges	Potential Solutions
Equipment	Require improving equipment productivity to increase coal production output	Managing coal inventory; equipment and asset monitoring for optimal utilization; develop preventive maintenance plans for improve equipment availability; reduce unscheduled equipment downtime and accidents within company operational area.
Equipment, Process	Lack of automation process for critical decision making	Providing real time dashboard to expedite total time for equipment troubleshooting, faster and more accurate decision-making process by using of data analytics and business intelligent for coal production.
People, Process	Manual process for data recording and reporting will create inconsistent result and potential human error through current business processes	Providing automated solution for data recording, data processing and reporting. It possible reduces total time for processing data and minimizing error to enable better results.
Process, Equipment, People	Interdependent business processes which are operated independently Lack of indicator and dashboard for operational and equipment performance	Providing automated process for achieving operational efficiency, reduce energy consumption (fuel and electricity), and increase equipment utilization which impact to productivity
Regulation, Process	Strict government regulation for safety, environment, and workforce protection Unavailable tools for business processes integration	Providing internal policy and effective change management for organization to handle sudden changes in the company such as coal production capacity, accident which could potentially stop all operation. Providing real time monitoring for operational critical area.
Money	High operational and equipment maintenance cost will reduce company profitability	Effective coal mining business process management for better cost control by integrating with current ERP, minimizing manual process and interference. The system should be connected with available current technology implementation in the company
	Declining global coal prices	Disruption current company business processes by technology adoption to be more effective and efficient, reduce total operational cost and able to compete in global competition

4. Literature Review

Industrial internet, Industry 4.0 and Cyber Physical Systems (CPS) are described as the industrial systems which integrate computational processes and machines physical capabilities which provide and advance, analytics, and interaction with operators or technicians (Evans & Annunziata, 2012; Hermann et al., 2015; Iansiti& Lakhani, 2014; Lee & Lee, 2015). The Industrial Internet of Things (IIOT) will be beyond the current conventional industrial control and automation, interconnected applications will transform the whole industrial structures and also the foundation and structure of industrial competition (Porter et al., 2015). IIOT can potentially reduce the operating costs for most industrial operation. It has also been discovered that the IIOT and derivates rather the latest advanced technologies (e.g. machine sensors, equipment safety devices, data analytics and various kinds of IIOT platforms) which can create remarkable benefits and opportunities for the business process management information, as an

example combining multiple data types, information and knowledge from across business processes in more effective and efficient way.

In order to enable implementation IIOT in Berau Coal, the company should provide a platform that can support development of multiple applications, managing connected physical devices and services. Instead of requiring the company to focus on the low levels of technology development, which is essential but don't give positive value, the IIOT platform can allow the developer to concentrate more on added value applications for various industries. The specific application can be installed into the company's systems faster, giving better services and supports. The various types of IIOT platform in the market are available for supporting specific IIOT applications for company operation. The many IIOT platforms can be found in the market and it can be categorized into three main types: centralized, semi distributed, and fully distributed systems (Castro et al., 2012).

5. The Concept of Coal Mining Business Processes Integration

This section will explain the concepts of development for coal mining business processes integration by implementing SIMBIOSYS in Berau Coal which adopt five logical layers architecture. The integration involves all functions in company from the highest to lowest level. It will give benefits for concurrent process on coal production and controlling cost. The integration concept proposes the ability to cope with business dynamics and frequently situational changing. For example, in coal mining industry, target performance for this initiative could increase productivity 5-10% and reduce operational cost by 15-20% (Lakshmanan et al., 2019). The target performances are achievable and based on benchmarking with improvements in other coal mining companies to get better and simpler coal production processes.

The business processes integration must consider the KPI measurement and value drivers. For instance, if the mine manager has KPIs that only measure coal production achievement and production cost but neglect supervision of safety operation, it will potentially cause accident that can result in direct and indirect cost. On the other word, integration company business processes should be determined comprehensively by hierarchical metrics on whole levels of the organization to better achievement.

In order to give the deep understanding of IIOT environment and the techniques used and its technologies, it is important to have a holistic view of the architecture and how various elements within it interact. this research is trying to create model of integration. At the core of each IIOT ecosystem are three main components the sensing object, data transportation/network, and data processing and consumption platform (Borgia, 2014; Coetzee & Eksteen, 2011; Miorandi et al., 2012). Previously noted by multiple researchers on of the main challenges the vision of IIOT faces is lack of unifying standard architecture to facilitate the implementation of IIOT ecosystem (Miorandi et al., 2012).

The proposed model for business processes integration using an IIOT applies combination of elements from three point of views. The model consists of:

- The four layered architecture (Xu et al., 2014; Yu & Tie-Ning, 2012).
- The three-phase data flow process (Borgia, 2014).
- Definition and description of IIOT based functions, techniques and patterns based on Green's IOT seven level reference model (Green, 2014).

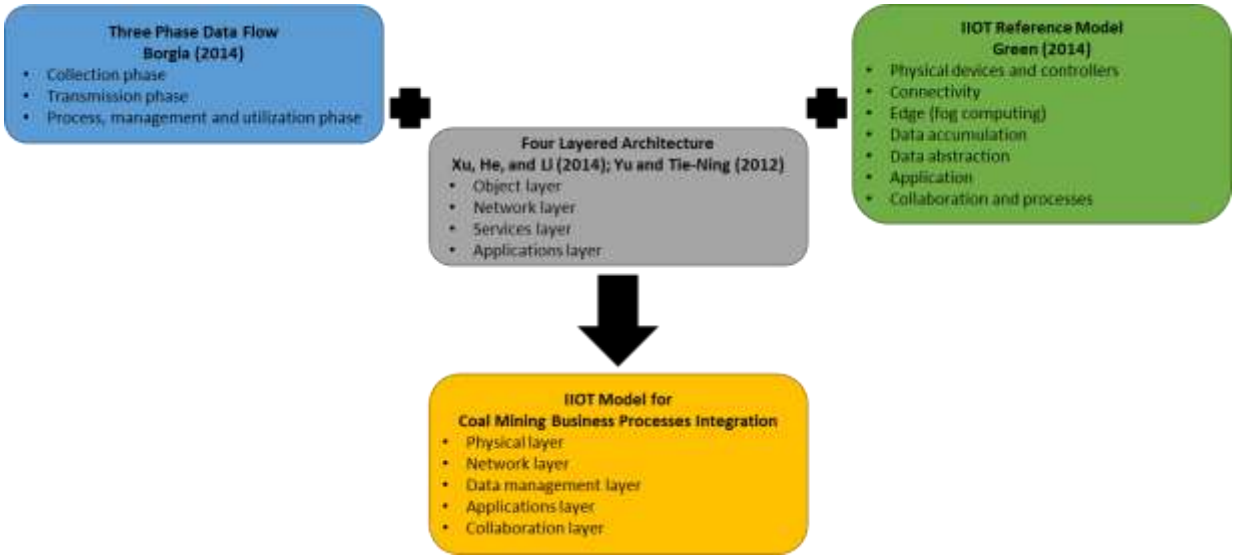

Figure 5. The Combination of Elements from Three Point of Views

The proposed IIOT model for coal mining business processes integration consists of five layers based on the four layers of the layered view architecture proposed by several researchers, namely:

- The Physical Layer
- The Network Layer
- The Data Management Layer
- The Applications Layer
- The Collaboration Layer.

Figure 6 shows the model and its various layers and components. The Physical Layer contains the smart objects and other elements that bridge the gap between the cyber and the physical environments (safety devices, sensors, PLC systems, etc.). The Network Layer contains networking protocols and technologies that enable the transfer of data between the Physical Layer and the Data Management Layer. Data Storage and abstraction data processes along with data analysis process are found withing The Data Management Layer. This layer contains cloud computing and AI technologies. Services offered by the model are defined and consumed within The Application Layer. The final layer in this model is Collaboration Layer which has the function to collaborate and synergize multiple stakeholders to achieve optimum target. It also involves human and machine interaction loop for business processes supervision. Within each layer are technologies that have been identified as enabling technologies for IIOT and necessary for business processes integration. The examples of these technologies include cloud-computing, mobile technologies and machine learning.

In an IIOT ecosystem, just like an integration business processes, there are multiple devices that generate and process data and transmit it to different locations. The data will be consumed and acted upon by multiple applications to meet the requirements of relevant stakeholders. The proposed prescriptive model purposes present components and their functions within the integration ecosystem. The five layers of the layered architecture of the model is presented. The Physical Layer is the first layer of architecture. It is then followed by the Network Layer. The Network Layer precedes the Data Management Layer which is the third layer of the model. The Application Layer is the fourth layer and the topmost layer is The Collaboration Layer. The layered architecture shall be used to highlight the different elements of the model and how they

interact. The data flow across the various elements within the model shall be discussed by means of a data flow architecture.

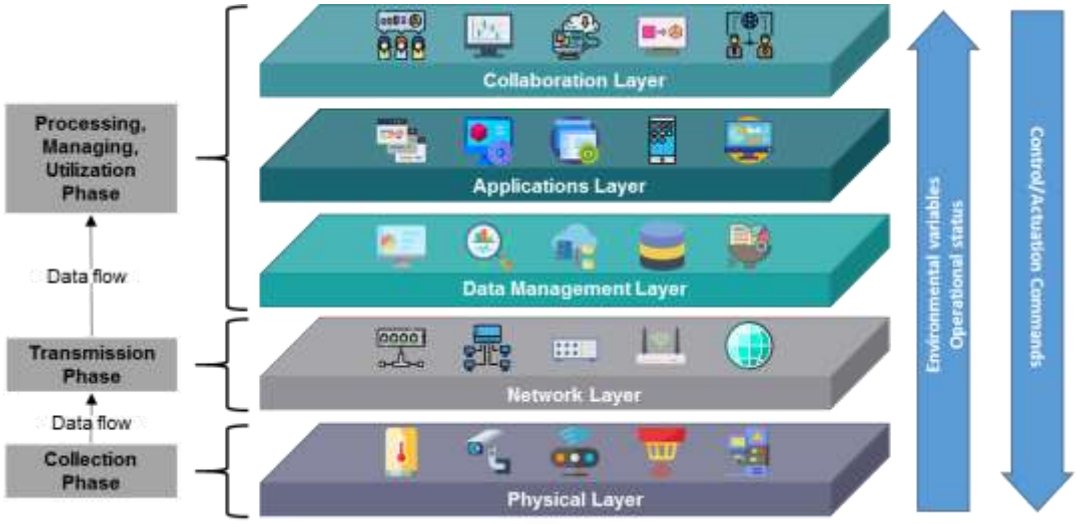

Figure 6. The IIOT Model for Coal Mining Business Processes Integration

5. The IIOT Adoption in Berau Coal

The adoption of IIOT in Berau Coal is evolving in which fixed plant and coal hauler equipment have the capability to communicate with each other and tailoring them with SIMBIOSYS. SIMBIOSYS will be develop and implemented as the pilot project. It has target to combine and process data from multiple devices which are installed in the mining equipment (crushers, conveyors, coal haulers) and data analytics to obtain insight for coal mining business processes. Figure 7 shows SIMBIOSYS as the integration of coal production in CPP, coal hauling, operation and maintenance systems to improve equipment productivity by implementation of prescriptive maintenance.

Conventionally, predictive maintenance in coal mining is condition-based maintenance which monitors the equipment condition using sensors and smart devices. These installed sensors and smart devices provide real-time data, which is used to predict when the mining equipment require maintenance and prevent equipment failure. With the emergence of the IIOT platform, implementation of business processes integration of equipment utilization into prescriptive maintenance schedules became possible. The figure 7 also shows SIMBIOSYS collecting equipment data (working hour, tonnage, performance, etc.) from CPP Binungan and Suaran, coal hauling Binungan to Suaran and the information will be updated automatically in real time.

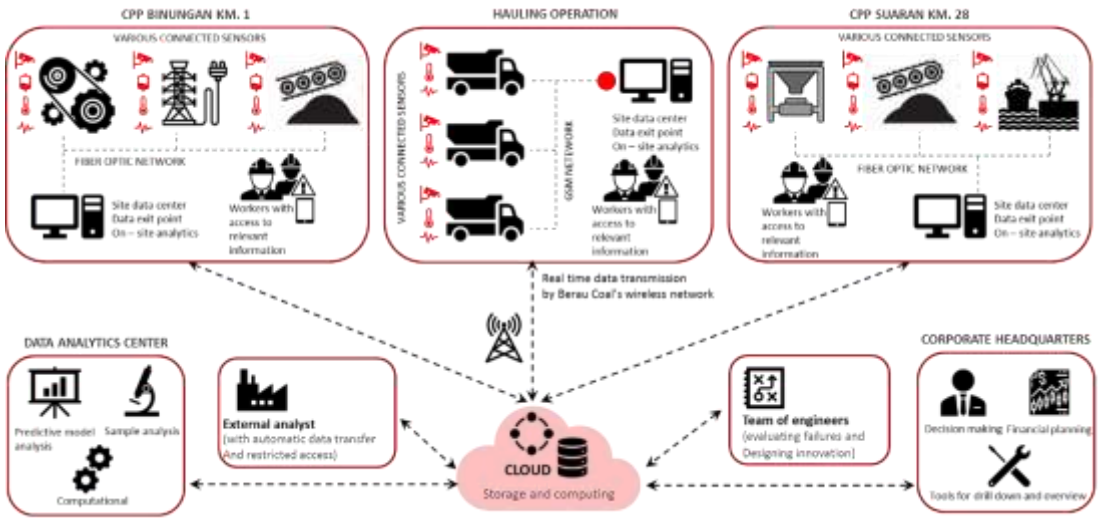

Figure 7. SIMBIOSYS in Berau Coal Business Processes

a. CPP Binungan and Suaran

CPP Binungan has 2 units coal weighing to accommodate 30 ton and 120-ton coal hauler and Suaran only has 1 coal weighing for 120-ton coal hauler. Current operation and weighing process is conducted manually by CPP operator located in weighing post. Figure 8 shows the current weighing process in CPP. This process requires weighing verification and witnessed from representatives of coal hauling contractors. Automate weighing process and integrate it with fixed plant equipment will bring benefits for CPP operation and improvement on the current process.

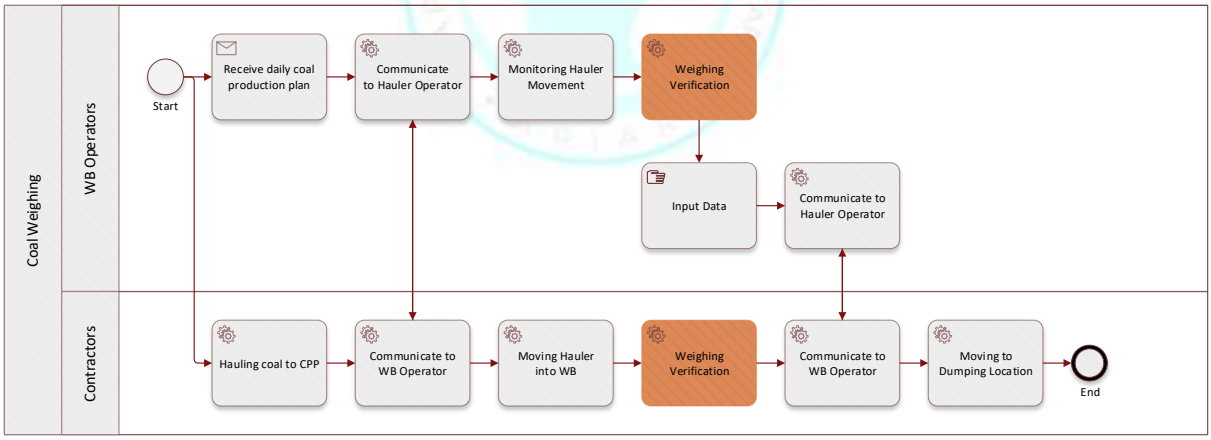

Figure 8. Current Coal Weighing in CPP Binungan

Weighing process will be centralized on each CPP Binungan and CPP Suaran control centers and installation of RFID tag on coal haulers and scanner in existing weighing post will provide automate weighing process. CCTV will be installed in coal weighing area to conduct remote monitoring from control center and ensure weighing process meets procedure and safety requirements. Table 2 shows the benefits after implementation pilot project in coal weighing process.

A journey of business process improvement and integration in CPP Binungan and Suaran has been started the previous year and give great impact for performance, cost saving and increase productivity. The following achievements are explained below:

- Reducing 68% troubleshooting time during unscheduled downtime.
- Increasing fixed plant operator's effectiveness and cost saving USD 85,200 per month.
- Potential added revenue 4.3 million per year by improving total 123.4 hours for fixed plant operating hours.

Table 1. Indonesian Coal Mining Challenges and Potential Solutions

Current Activity	**Implementation Plan**	**Benefits**
Manual data recording	Installation RFID tags and scanner	Eliminate human error Reduce weighing time from 2 minutes to 1 minute
Manual weighing verification	Automate weighing process	Potentially reduce total 25 workforces for operators and coal hauling contractors.
Manual weighing report	Connected with CPP equipment	Substitute end shift reporting to real-time reporting
On location supervision	Installation CCTV for remote operation	Reducing hazards for operators Provide better workplace

Implementation of SIMBIOSYS will accommodate real-time reporting and show it to web portal. It provides real time data and information, so the CPP supervisor and coal production engineer can optimize equipment performance in real time. SIMBIOSYS also gives advantages to CPP operation and maintenance, the following are the most impact ones:

- Increase overall equipment effectiveness (OEE).
- Eliminate manual processes and reduce paper-based documents.
- Increase workforce productivity and reducing total workforce for fixed plant operation.
- Improving fixed plant operator safety and health due to operate fixed plant remotely from control room.

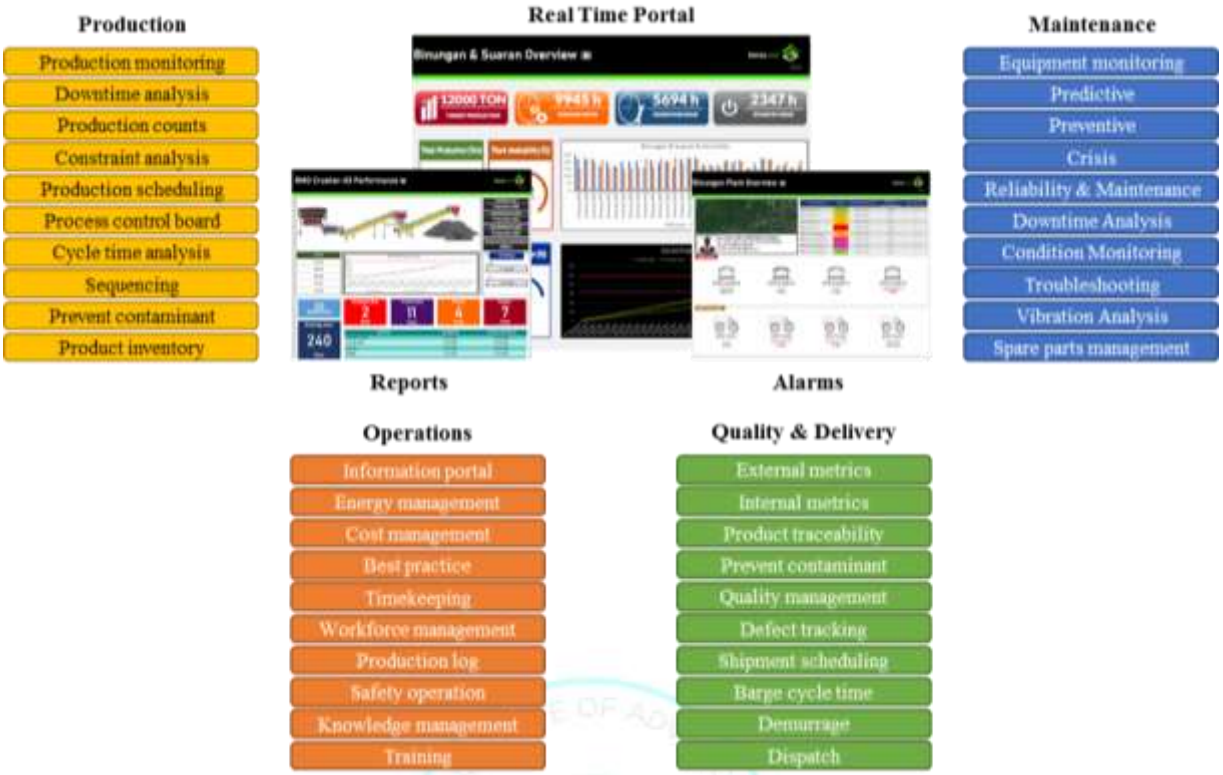

Figure 9. SIMBIOSYS Built in Features

Figure 9 shows SIMBIOSYS built in features which help integrate multiple company's functions in a single database. The database can be shared for coal production and maintenance functions to optimize production schedule by considering coal supply from pit, fixed plant and coal hauler availability. Furthermore, SIMBIOSYS has possibility for instance tracking the optimality of process, it will track equipment and process efficiency such as crusher and conveyor electrical drives, hydraulic motors, pumps and give a feedback with alarms if the values over the threshold. Other SIMBIOSYS built in features include tracing the equipment complete history, this unique feature is important in coal mining industry for fulfilling government regulation. In summary, implementation of SIMBIOSYS in Berau Coal will allow the company to eliminate inefficient processes, monitoring, giving alert for suboptimal performance, automate and integrate internal business processes, tracking and monitoring process execution, improving quality and standardization, and the most important, reducing operational costs.

Implementation SIMBIOSYS in CPP area also covers the automation in Binungan TLC operation. It helps in automatic coal feeding from crushed coal stockpile to coal hauler. For this objective, video analytics software will be installed on the existing CCTV systems. The software can identify and analyze motion and position of coal hauler. If coal haulers are on their specific position, the system will detect it, communicate to PLC systems, giving command to run TLC and feed the coal into coal haulers. The implementation of video analytics will increase consistency in TLC operation, more stable coal throughput, increase TCL productivity, and potentially reduce 10 CPP operators. After the development and implementation of SIMBIOSYS in CPP area, it's projected to increase fixed plant utilization up to 70% along with reducing cost of coal processing by 10% per ton.

b. Coal Haulers Fleet Management Systems

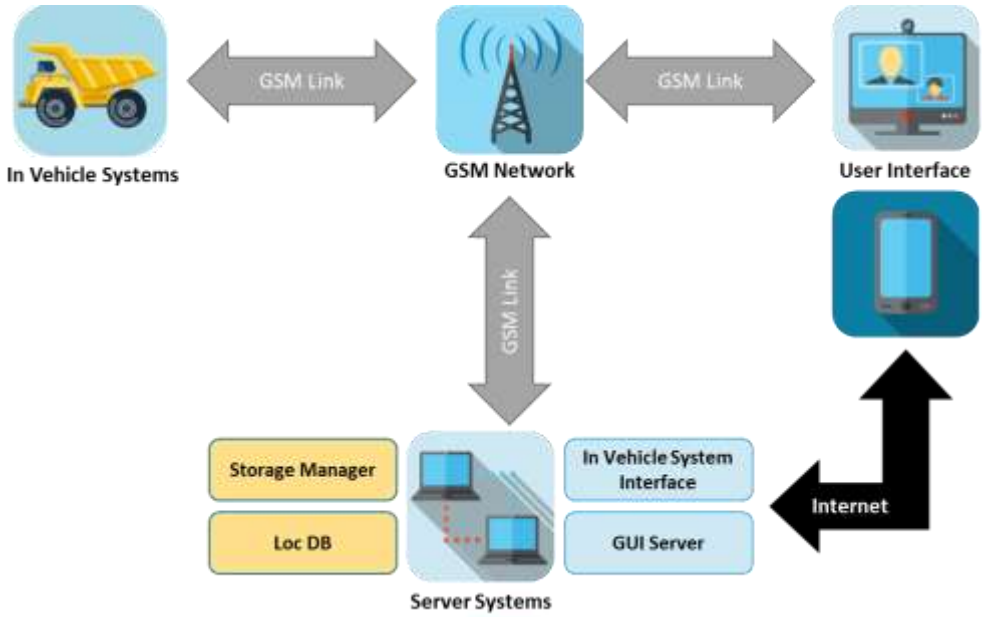

Figure 10. The Overview of Coal Haulers Fleet Management Systems

Coal hauling contractors in Berau Coal currently operates Scania and Volvo as the prime mover of coal haulers. They have distinct FMS (Fleet Management Systems) and try to develop own FMS to accommodate all coal haulers. This FMS provides basic services such as coal haulers planning and scheduling, as well as more complex tasks in most effective and efficient possible method. Global Positioning Systems (GPS) and Mobile Network (GSM) are used for coal haulers tracking and real time monitoring. The technologies and other hauler telematics have provided many advantages by allowing coal hauling supervisors to keep a closer eye on their coal haulers. Moreover, the technologies can help improve coal haulers productivity and reduce hauler costs, which are the two main objective of coal hauling contractor. Another benefit of FMS is that it provides data to avoid overtime on work and improve operator accountability by reducing hauler idling and unnecessary stops.

The figure 10 shows the overview of FMS for coal hauler in Binungan to Suaran. This FMS is developed as the part of IIOT adoption and integrated with SIMBIOSYS. Coal haulers operation and maintenance will be synchronized and aligned with fixed plant operation and maintenance in CPP Binungan and CPP Suaran. The FMS will be integrated with in cabin camera, it will enable coal hauling supervisor observe coal hauler operator and give real time feedback, measure the safety outcomes of hauling operations, increasing coal haulers safety, and allowing to observe coal hauling road conditions and environmental around the operator. Coal hauler repair and maintenance (R&M) is also important in order to make certain maximum efficiency and hauler productivity. R&M will avoid interruptions during coal hauling operation due to hauler failures, it will give great impact to company stakeholder and increase cost incurred by company. FMS and in cabin camera will utilize the smart devices which are installed on coal haulers such as RFID tag for coal weighing, GPS and GIS for hauler positioning and tracking systems, and GSM for data transmission. There is no doubt that the integration between coal processing and coal hauling can help coal hauling contractors operate more efficiently, increasing benefits for both the coal hauling contractor and coal mining company.

c. Data Analytics and Remote Operation Centers

Executing SIMBIOSYS, Berau Coal will use data analytics as a feature to provide faster and better decision-making process, particularly for the executive. Adopting data analytics, the different data from all mining equipment can be analyzed to develop knowledge and recognize the interdependence. It is possible utilized for evaluating gigantic coal mining operational data for trends and recognize the opportunities. Data analytics will be one of built in features in SIMBIOSYS and it will collect and analyze centrally all operational dan maintenance data from CPP and coal hauling. The data generated from sensors, safety devices, and smart devices which are installed in mining equipment (Figure 11) will be processed at Berau Coal HQ as the Analytics and Integrated Operations Center.

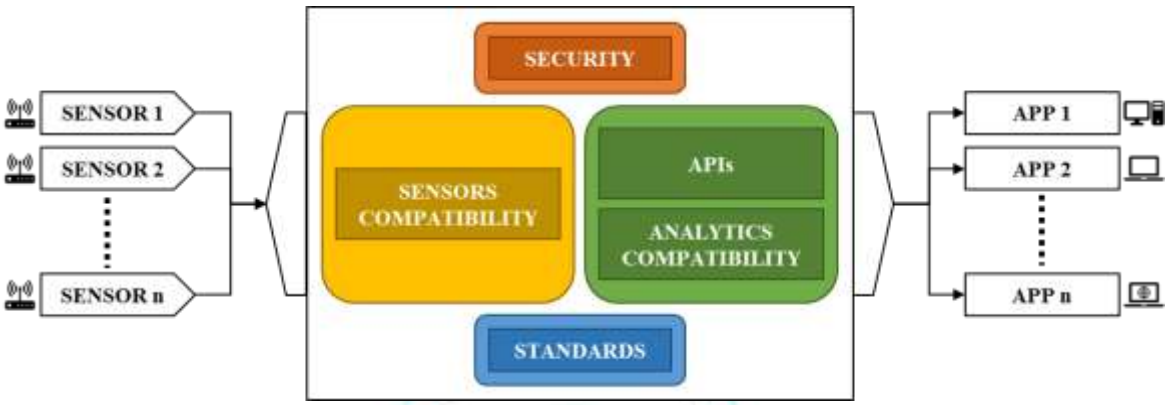

Figure 11. The Overview of Data Collecting and Processing

The data will be extracted timely and provide valuable information to support the decision making process based on data driven in real time. The operation center will engage in-house engineering to portray data and develop knowledge for the executive and on-site supervisor to create better, faster, and safer decisions. It will convert data to visual dashboard and provide help for engineer to grasp in real time how on-site supervisors are performing against KPIs. It will benefit the company by identifying potential risks and opportunities before making critical decisions.

SIMBIOSYS has also developed a fixed plant equipment health monitoring application for maintenance on multiple equipment critical parts. It will provide easier maintenance job due to the information can be automatically shown into maintenance department from multiple equipment data sources and work order information. The fixed plant equipment health monitoring application will process equipment data and come up with specialized recommendation for equipment maintenance. It will reduce the amount for fault finding, troubleshooting and confirming the equipment spare parts are reserved before the equipment failure. It also helps the maintenance department to deliver specific reports and provide them early warning when the equipment is not performing optimally.

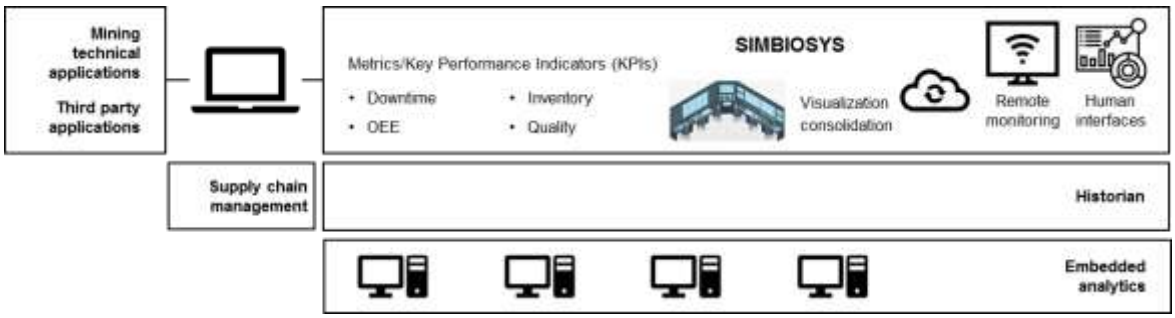

Figure 12. The Concept of Data Analytics and Remote Operation

5. Evaluating IIOT Adoption

The business process transformation is usually anticipated and celebrated in particular ways across the company. The company which develops and adopts it has high expectancy, although employees at the high operational level have personal factors that might think it as unnecessary actions. They must face new jobs, or they might feel insecure and intimidated due to the new technology will endanger their current jobs. Training programs can help the employees understand the need for IIOT implementation in the company and how to operate it.

Causal loop diagram (CLD) for adoption IIOT in coal mining company (Figure 13) shows important aspects that forms the system behavior. The model at the current phase hasn't been executed, all major definitions are based on premises deduced from stakeholder's interaction within company. It's expected to portray positive and negative aspects, and risks and benefits from adoption of IIOT.

The modelling as presented in this section is developed to specifically evaluate the IIOT adoption in the company which associated with business processes integration, technologies implementation, and the critical infrastructure systems (e.g. communication and data networks and power generation). There are system requirements to propose methods to factor in qualities and quantities which are inherently uncertain to forecast and also hard to quantify. The IIOT and other supporting technologies will become complicated and dynamic to predict, due to it convergence with advanced technologies. Boundaries of the system also become hard to define because the interdependencies of the systems. IIOT adoption will impact not only to the company performances and costs, but other interdependencies (decision making process, the new way of communication and data acquisitions, skill development, knowledge management, training, and employees safety and health).

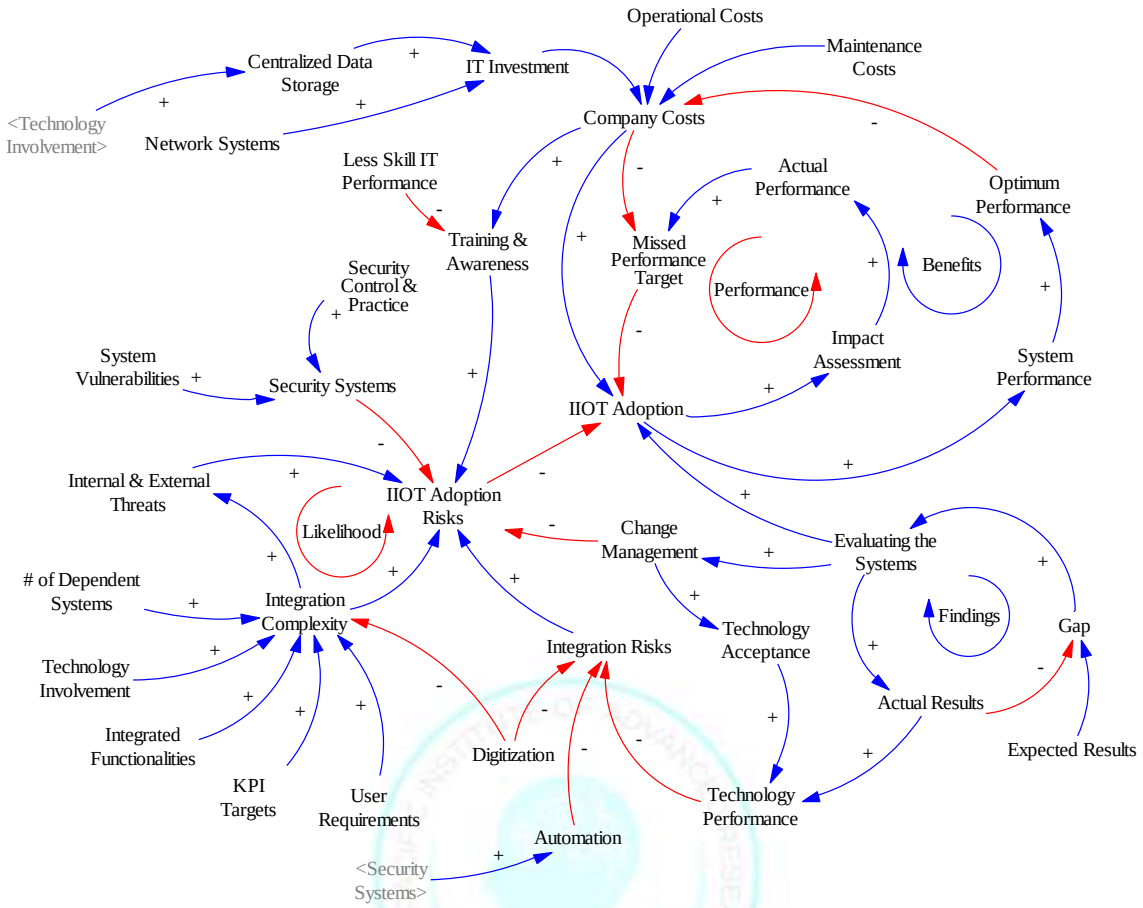

Figure 13. CLD for IIOT Adoption in Berau Coal

Conclusions

This research revealed that methodology and technologies of IIOT can be used to address business issues in Berau Coal. These business issues were addressed through the proposed business solution. The propose business solution consists of IIOT and automation technologies, the architectures and devices as well as techniques and functions used within the project. The main objective of the research was to develop an IIOT platform to improve and integrate the current business processes in Berau Coal.

Responding to current business issues, IIOT adoption, vertical and horizontal integration of company business processes had been established with the most relevant architecture for analyzing the data related to coal processing and coal hauling. The concept of machine-generated data was required for further system development, operational log files and reports from coal hauler will be used for data analytics. The research provided a discussion of current IIOT adoption in Berau Coal, particularly, technology feasibility, and IIOT adoption to coal processing and coal hauling. The research tried to briefly describe the current of global coal mining industries and particularly the company operation, concentrating on the business challenges, and trying to describe unique condition in the company. Particularly, the research discussed operation and maintenance in coal processing and coal hauling and discovered that company could get benefits by improving current business processes and provide contribution to company operational costs.

The IIOT adoption will disrupt current processes, require advanced technologies and mindset shifting. Therefore, to anticipate unintended effect and evaluate the IIOT adoption, this chapter also tried to develop CLD to show related aspect which shaped the new behavior in the company.

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