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A case of Longwall coal mining productivity & safety optimisation

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A CASE OF LONGWALL COAL MINING PRODUCTIVITY & SAFETY OPTIMISATION

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ABSTRACT: This paper presents a study, the design and implementation of the Longwall Remote Operations centre that incorporates all aspects of automation for Longwall and coal clearance systems.

Developing the existing Longwall technology strategy and the design of coal transferring conveyors to smart systems incorporating emerging technologies such as artificial intelligence, automation and business strategy development.

The design phase of the project is structured to bring together the overall findings of the diagnose phase, business strategic direction, value case and options analysis to develop an overall project that covers people, technology, systems and process for the automated control of the Longwall. As part of this process a draft implementation plan that includes risk and change management, capability transfer and a roadmap for optimisation is included.

The site engagement team cooperates closely with the analysis team on collecting real data and analysing data in-depth by considering safety regulation and analysis of the business value case for incorporating any current and proposed automation technologies. The achieved designs introduced the opportunity to incorporate in the future of the mining industry as one of the main pillars of Australia's economy. A key objective is to remove people, as far as practically possible, from potentially hazardous operational areas through applying remote operations and control concepts. There is a strong value case for this change. In a Longwall operation this change reduced exposure to underground operational hazards by some 50,000 hours per year, add 3 hours per day to operations, and increase cutting rate by 150 tonnes per hour.

The strategy and design apply to limited mines and their successful outcomes provides a wide approach and an open discussion platform for the current mining industry and make us propose a new strategy for coal clearance methodology.

This paper proposes a practical strategy to revolutionise the conveyor mining industry via implementing Innovation, Technology and Digitalisation and open LEAN management techniques, automation and artificial intelligence based on the real data outcomes.

BACKGROUND

In each century miners tried to apply different kinds of optimisation techniques on the mines process and have achieved more success in the open-pit mines. Due to the complexity of an underground mine, optimisation in processes like transportation to the ground have been limited and less extensive than for open-pit mines. (Alford, C., Brazil, M. and Lee, D.H., 2007)

Mining operation research for practical projects helps to enhance the application of mining-specific and generic optimisation techniques in the mining industry. This is where LEAN management and strategy technology become highlighted in the journey of extraction and transferring resources.

The main operating processes in underground coal mining are cutting and transporting. Around the1950s modern mechanised Longwall mining became widespread. Initial practical design of automated Longwall cutting machine was in 1984. Since then automation and health-and-safety technology for Longwall operations have been developing. Longwall reliability, productivity and cost effectiveness have also been improving. (Peng, S.S., 2019)

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This paper can be a starting guideline to understand and implement the new concepts in a mining workplace and move toward a better future in Australia with proposed new technology strategic innovation. The focus of this new strategy will be on the remote operations of the Longwalls. Fast communication technology was used in stage 1 as a remote control from Remote Operational Centre (ROC). On stage 3 of this practical project fully remote control will be utilised from the site control room and solve any real-time operational problems.

ROAD MAP FOR LONGWALL OPERATIONS

Future smart mining is facing an ever-growing need for resources and this demand is exponentially increasing all around the world. In this path, education development and three key goals will be required to meet future trends:

- Innovation;
- Technology; and
- Digitalisation.

Removing people from potentially hazardous operational areas, as far as practically possible, was a key objective. Instead, remote operations and control concepts or automation from ROC was proposed for Longwall system.

This developed strategy already has been applied successfully on one of the underground hard coking coal mines and accordingly resulted in a strong value case for its remote-control change and its efficient conveying process in 2020. The mining operation has more than 600 employees, and the mine life is estimated at more than 15 years. The size of each development Pillar of this mine is 120m long and 60m wide. Each Panel has 45 pillars (each 4.5km). Coal seam thickness or cut height is 3.5m with roadway width of 5.4m. The Longwall detail is:

- Longwall shearer cuts coal using bi-directional method;
- The Longwall panel width is 300m with 1m advance per shear. Extraction height 4.2m to 4.7m. (Mining Data Solutions, 2001).

In the late 1800s and early 1900s, mines were changing from carrying the ore to the surface by different type of conveyors instead of any manual skip or self-dumping bucket. After World War 2 the coal mining industry became one of the hot industrial topics and this industry started to develop since then. In the 1970s this industry had achieved various technical developments. In the early 1980s, remote connection and automatic control of mining equipment such as shearer-loaders and frame support started to develop. (Nishimatsu, Y., 1992)

Longwall operations have made coal mining safer but still carry risks for Longwall cutter operator and other operators in the area. Another critical risk that threatens operators' health is black lung disease. Especially in underground coal mines, dust may cause pneumoconiosis in coal workers. This disease is a chronic, irreversible lung disease. (Halldin, C.N., …, 2015) (Barczak, T.M., 1992)

The method of Longwall mining is a highly productive and smooth underground operation. The main part of the Longwall machine is a drum shearer whose direct role is cutting the coal. It is important to keep the mine production at a desired level. The position of the drum cutter, and accordingly the roll angle, plays a very important role in cutting and remaining in the coal seam.

The main role of a Longwall operator is measuring and adjusting the degrees of the roll of the body of a Longwall shearing machine. In order to achieve remote supervision of the roll angle to control drum cutting positions via roll angle needs signal detecting and camera monitoring systems. (Ramsden Jr, J.W., American Mining Electronics Inc, 1993).

SCOPE

Controlling Longwall operation remotely from ROC resulted in the following benefits as detailed in Table 2:

- Exposure to underground operational hazards (exposure hours per week) reduced by 17%;
- Operating hours per week increased by 7%; and

- Cutting production rate (tonnes per hour) increased by 7%.

Remote Longwall operation control has required substantial advancements in automation. However, the first step which has been implemented was developing operation to semi-automated process. Future improvement in the remote supervision, including further automation incorporating best practice and lessons learnt from Phase 01, will further reduce risk and moving the operation to a completely automated process as outlined in Figure 1.

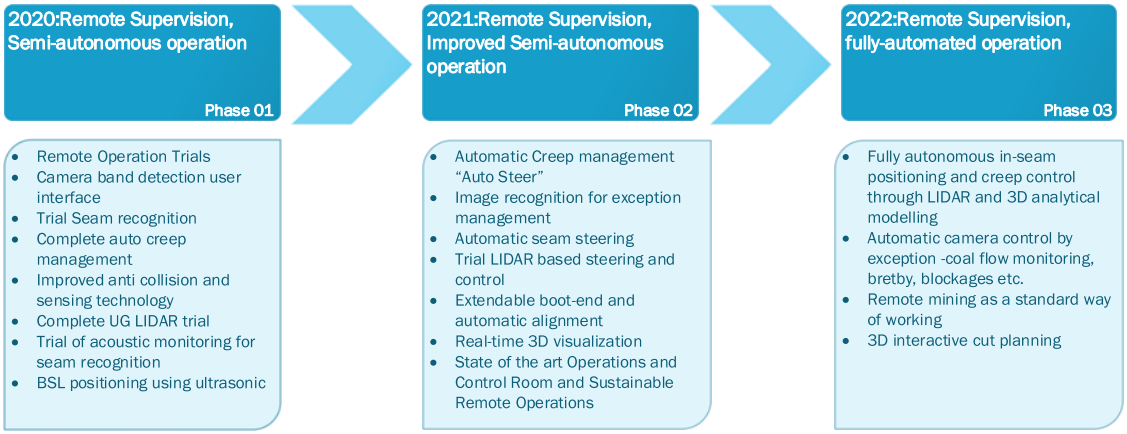

Figure 1: Longwall automation roadmap includes scope of work.

The implementation timeline for individual activities has been scheduled in Figure 2. As the project schedule confirms, the fully automated operation will be implemented in 2022. The Longwall automated design is cost effective and has minimal interruption on day-to-day operations. The project schedule milestones were set to compare work to date performance with the past.

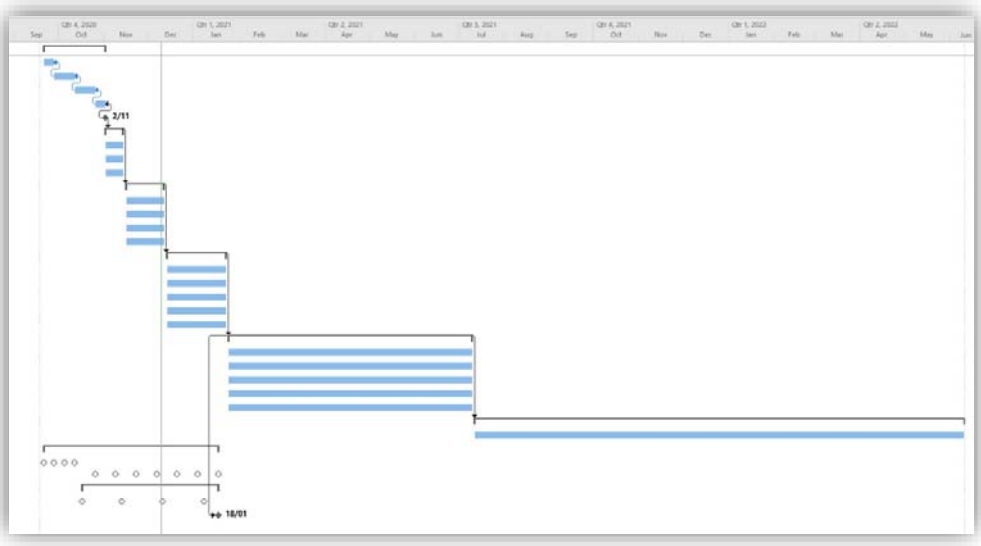

Figure 2: Longwall automation implementation schedule

A new role as remote operational control operator was required in the ROC. The role was filled with a suitable candidate, who passed the 2 weeks training successfully.

The scope of work is optimising the coal cutting and transport from the coalface without human presence with minimal human interaction (Figure 3) and develop the implementation plan towards remote operations. The aim is to automate the operations and control of the Longwall from the site control room.

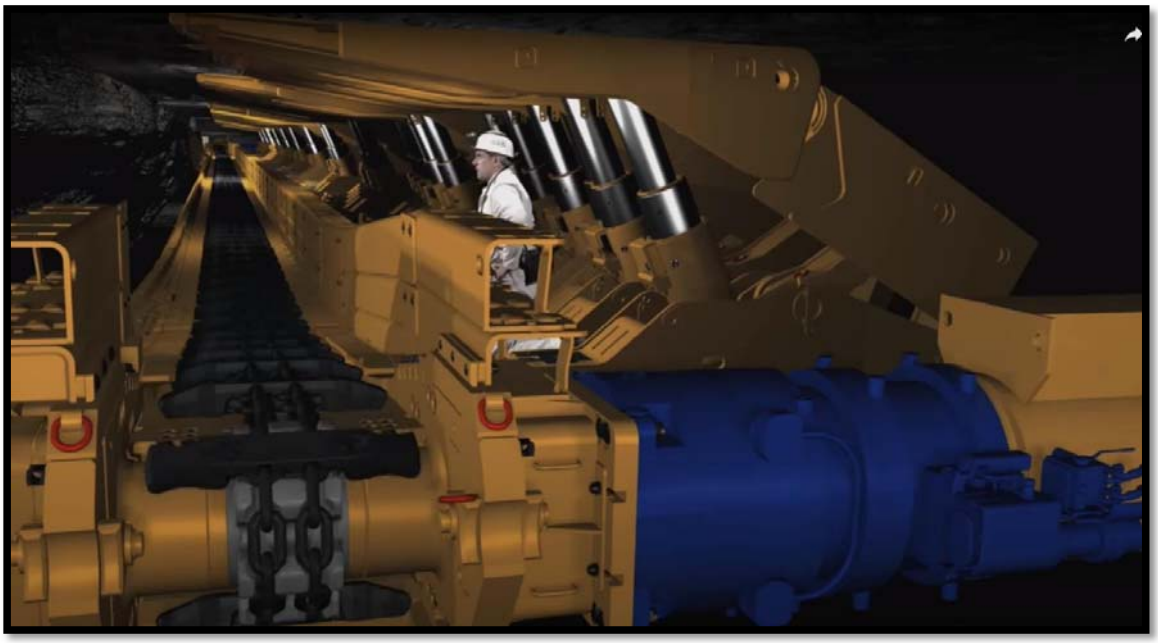

Figure 3: Longwall machine with an operator

OPERATING MODEL

There were some technical challenges in moving from in-situ control (face control) of the Longwall operations, to the site based remote control, and there will be more challenges from the level of equipment automation between now and 2022 with Longwall becoming a fully automated operation.

For assuring that all challenges have been considered, an operating model was proposed, Figure 4.

Figure 4: Operating Model

To stay on the line of efficiency, the proposed operating model monitors and focuses on how the organisation operates and delivers value. This operating module helps for better understanding and management of the operations. A Target Operating Model for remote operations control was proposed and presented in the Scope of the work.

Operating model has been proposed based on the business expectation and LEAN management requirement for the Longwall cutting process. Project leading practice, industry learnings, and operating experiences informed development of the operation plan. Accordingly work management was developed to achieve the purpose process of planning, scheduling and execution.

Operating model was planned, managed and executed on a real site with site useful data. Mine operation was managed via received updated site data. The data was analysed by designers and technology strategy consultants. Where the data revealed any process point gap, experience learned and apply the efficiency on the process where the gap initiated.

OUTCOME

The outcome of this design was a practical strategy implemented by local engineers for Phase 01. This practical strategy revolutionised the Australian conveyor mining industry via implementing Innovation, Technology and Digitalisation and open LEAN management techniques, automation and artificial intelligence based on the real data outcomes.

The Longwall operation is being optimised gradually, in 3 phases. At Phase 01 Longwall operation remote control was implemented in ROC. This process will be enhanced more in Phase 02 towards reliable automated operation.

In Phase 03 the Longwall operation will be fully automated incorporating the following enhancements:

- Fully automation in-seam positioning and creep control through 3D analytical modelling;
- Automatic Camera control for coal flow monitoring and blockage;
- 3D interactive cut planning;
- Remote control of the Longwall from site control room by a trained operator.

Phase 01 of this project implemented successfully. A key success was removing people, as far as practically possible, from potentially hazardous operational areas.

Phase 03 of the project (fully automated remote control) will be implemented in 2022.

The purpose of the three individual phases are as below, refer to Figure 5:

Phase 1: Trial incremental introduction of remote operation functions;

Phase 2: Committed, steady state remote operation and increasing automation;

Phase 3: Business as usual remote operation & automation with ongoing further optimisation. Change management will be reassessed.

Figure 5: Longwall automation 3 Phases

By terminating Phase 01 currently Longwall primary control moved from Underground face control-UG to ROC remote operations control brings down the operator's life risk tremendously.

The following Target Operating Model for Remote Operations Control design had been planned and constructed successfully.

The execution of the change plan in Phase 03 has been planned to move, the operational centre from main gate to a control room. This fully automated remote control will be implemented in 2022.

A clear and consistent approach to project management is a key success factor. A weekly project status update was arranged, and the project sponsor and any other nominated points of contact attended. This covers progress against plan, work achieved the previous week, issues encountered and actions to resolve, and work forecast for the next week.

Transitioning to remote longwall operations reduces exposure to hazards, increases operational hours and increases cutting rate and rate consistency.

The entire project is supported by an implementation plan and change management plan.

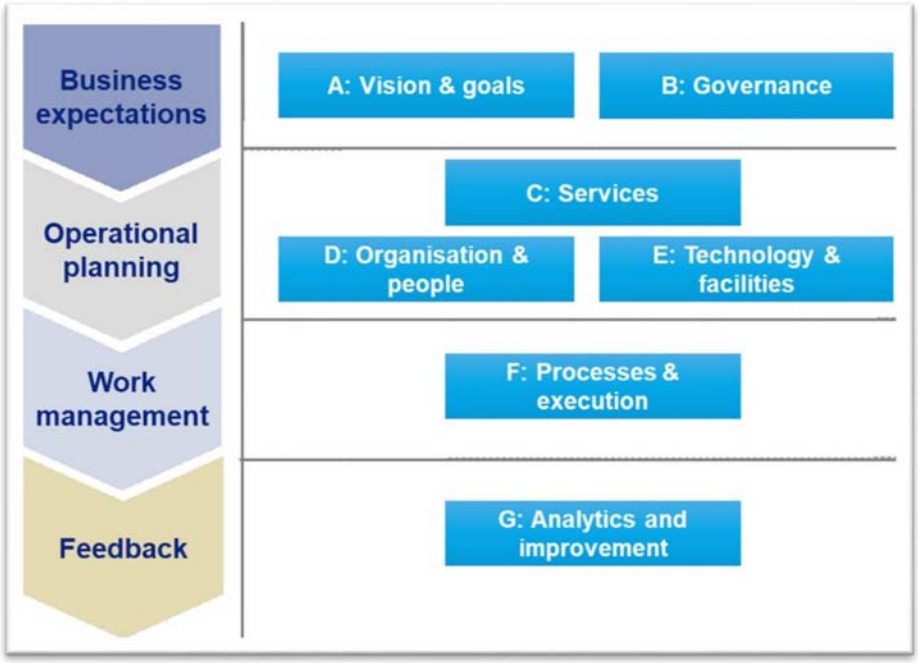

Figure 6: Target Operating Model (TOM) for Remote Operations, aligned with proposed Operation Module

Target Operating Model achievements are:

Business Expectation: (TOM: Vision and goals; Governance)
Specify the ROC operational goals as a new vision and goals to support the Business expectation. Determine governance and assurance processes, providing clear accountabilities and pathways for decision making.

Operational Planning: (TOM: Services; Organisation and people; Technology and facilities)

The target is planning and providing client's expectation services with enhanced technology. In this path, employees need to receive operating culture training with co-commitments for success and deliver the services.

Determine the technology and workplace requirements for delivering the services.

Work Management: (TOM: Processes and execution)

Manage the operating processes to execute the services.

Feedback (TOM: Analytics and improvement)

Create processes to analyse and measure performance and apply a solution on the process where the gap initiated. Feedback of analysed data helps innovate on how services to be delivered.

Reviewing the Target Operating Modules will be used to review of work to date and make the process to fit-for-purpose operating model. Also, the review of Target Operating Modules helps to identify and assess the process's risks.

PRODUCTION AND COMMERCIAL TERMS

At the end of the project Phase 01 in 2020, not only the Longwall Remote Operational Control from main gate design became successful, but also there were significant progress on the Production and Operation hours.

According Table 1 and Table2, the cost analysing divided into the following factors:

Direct ROC improvement only- (remote control from face to the main gate)

- Production improved by 15 tonnes per hour
- Operation hours improved 2 Hours per week with less waste hours
- Exposure hours reduction was -381 hours per week

Automation improvement-

- Production improved by 170 tonnes per hour
- Operation hours improved 5.2 Hours per week
- Exposure hours reduction was -1 hours per week

Table 1: Production and exposure hour benefits

Item	Production Rate (T/hr)	Operating hours (hrs/week)	Exposure hours reduction (hrs/week)
Baseline Actual	2500	100	2208
Improvements attributed to ROC	185	7.2	-382
Direct ROC improvements	15	2.0	-381
Automation improvements	170	5.2	-1
Future baseline	2685	107.2	1826
ROC Improvements (%)	7%	7%	(-382/2208) - 17.3%

Table 2: % Improvement in the ROC Project

Item	Improvement %	Improvement	Units
Exposure Hour Reduction	17%	-382	Hrs / week
Production Rate Improvement	7.4%	185	T / Hr
Operating Hour Improvement	7.15%	7.2	Hrs / week
Improvement due to rate		(185*100*40) = 740,200	T/year
Improvement due to hrs		(2500*7.2*40) = 715,000	T/year
Total Increased Improvement	15.5%	740,200+715,000=1,455,200	T / Year

The actual production rate was reported 2500 tonnes Per Hour with 100 hours per week operation hours. This production rate increased by 185 tonnes per hour.

The operation hours enhanced by 7.2 hours per week. Future actual production rate will be 2685 tonnes per hour and future actual operation hours will be 107 hours per week. 77% utilisation of a year with 52 weeks will be 40 weeks.

CONCLUSION

This project outcomes confirm the success of the remote control of Longwall from the ROC as follows:

1. The improvements in productivity achieved through remote operation / automation;
2. The commercial realisation business value improves;
3. The system and the way that detect the coal is more improved than the overseas Longwall versions;
4. Health and Safety of the system improved compared to the old automated Longwall operation;

5. Automation development undertaken using local engineering expertise with Australian regulation and approving process, as overseas technology can't be implemented and maintained easily in Australia, especially after COVID19 (Australian regulation is firmer than overseas). Regulations and risk appetites vary between countries; and
6. Introducing a new skill to the mine industry. Although, there is no need for Longwall cutter operator at the coal face there are opportunities to reemploy and retrain operators for control room and automation engineering maintenance.
7. Personnel costs within the budget has been managed.

This project faced some challenges as expected of a project of this kind.

The main challenges that were overcome were:

- Remote Operations Centre (ROC) operator competency level selection who already has face experience and control experience;
- Training ROC operator to follow client's standards and make the new role compatible with the Enterprise Agreement;
- Stability of communications between surface and underground via redundant comms system;
- High quality of communications between surface and underground with low background noise via a strong filtered standard coverage;
- Placement, coverage, maintain and redundancy function of cameras;
- Resolving the experienced issues after implementing the design;
- Accurate simulation of scenarios prior to implementation; and
- Training the clients at the end of the project and handover.

At Phase 01 & 02 Longwall primary control moved from face to main gate in Intelligent control unit. This process needs to be enhanced more on Phase 03 to be fully automated and for operator to remotely control the Longwall from site control room.

Designers and strategy development teams closely work with the client and follow their standard policies while developing in different phases to ensure risks are managed appropriately with improved productivity.

This Longwall coal mining case study has been successfully commissioned. This execution can be applied to any underground Ore Longwall mining to achieve optimised cutting with high productivity and reduced risks.

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