



Lean and Agile Systems ACEA7008

Materials Handling Evaluation For Company Operations

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P1650901

December 2023

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List of Abbreviations

- NCF - New Coal Futures
- MHI - Material Handling Industries
- MHS - Material Handling Systems
- MHP - Material Handling Process
- PVC - Polyvinyl Chloride
- AGV - Automated Guided Vehicle
- KIN - Karnataka Industry News
- UHMWPE - Ultra-High Molecular Weight Polyethylene
- SP - Slurry Pipeline
- TW - Transport Work
- TTW - Total Transport Work

Abstract

This report aims to provide adequate and sound advice into developing a suitable materials handling system that will extract coal from the New Coal Futures mine in Glynedd and then transport it to the Llanwern steel works.

The purpose of this research report was to gain a clear understanding of what types of distinctively different material handlings systems there are currently available in today's market. This report analyses existing systems at both the strategic and operation level to identify opportunities for improvement and design an appropriate solution.

The author was able to collate evidence, information and data through qualitative research methods. From carrying out specific research methods then it has assisted the author in choosing a suitable material handling system. By choosing a well-designed material handling system then it can significantly improve the distribution service and deliver an excellence level of customer service, which in turn will reduce production and handling costs and also improve on Health & Safety standards.

1. Introduction

New Coal Futures have recently been successful in their application for planning permission to open a new deep Coal mine on the disused site of Glynedd. The site will be developed to create a modern operating mine extracting the high quality metallurgical coal product. The planning application states to excavate and transport 2.8 million tonnes of coal per annum to support the manufacture of 4 million tonnes of steel to Llanwern steel works, which is situated two miles away.

The Glynedd site was an operational mine around forty years ago, the mine closed its doors in 2000. The mine has now reopened, modern Coal production methods have become highly efficient and safer environments to work plus the need for clean Coal has become is in high demand.

The mine site is situated two miles east to the nearest village and two miles north of Llanwern steel works. The nearest major town is five miles west of the steel works. The mine is at an altitude of 200 meters above sea level and 160 meters above Llanwern steel works. The A423 public highway connects the steel works with the mine and continues north.

The planning application has come with opposition from local residents and national interest. Representatives of New Coal Futures have collaborated for many months with local planning and residents to develop and provide an environment and landscape that will not be visually intrusive and noise levels kept to a minimum. One of the stipulations of the planning application is that no public highways are to be considered in the transport of coal.

It is the task of the Operations Manager to propose and evaluate three material handling methods to extract coal from the mine and transport it for its use in Llanwern steel works. In this the three proposals will be critically evaluated and a full justification on the chosen method will be given.

2. Materials Handling Consideration

Material handling is the movement, protection, storage and control of materials and products throughout manufacturing / mining, distribution, consumption and disposal. As a process, material handling incorporates a wide range of manual, semi-automated and automated equipment and systems that support logistics and make the supply chain work (MHI.Org, 2023).

A useful method for the selection process of a suitable materials handling system could be to consider in the following 10 principles:

1) Planning

The planning principle involves identifying the materials that need to be moved, in this instance we will be moving coal to the Steel works. We will need to determine the best / efficient and safest way to move the coal from the mine to the Steel works. These points will be addressed over the course of this report.

2) Standardisation

It would be best practice to look at what materials need to be moved and how. As we are moving coal, then we know that coal can be brittle and easy to breakdown if it is not handle carefully. The coal will be broke down to a standardised size, this makes it easier to transport but also keeping the shape intact to a manageable and consistent size. By making the coal particles smaller then it will be easier and more efficient to transport.

3) Work

This involves minimising the amount of physical work required within material handling systems to move the coal by using equipment and automation, rather than pushing the limits of human capabilities. In the selection process for the most suited materials handling system, then It is important in to consider why would this choice reduce the level of physical activity / work, what benefits would it provide such as reduce any injuries or manual handling incidents. This method will result in protecting the workforce, gives them peace of mind and also empowers the workforce to be more efficient.

4) Ergonomics

The equipment has to provide the workforce with peace of mind that it will help them to minimise physical strain and fatigue. The workforce will work long hard hours in this industry so they need all of the assistance possible, and a materials handling system provides this then is definitely a positive outcome.

5) Unit Load

The materials handling system should have a weight capacity per load, if a bucket system was to be used then it could only be filled to a certain level whereas if a conveyor belt was to be used, then it can take the load more evenly as the belt moves in a continuous movement. The coal belt moves continuously and never stops until necessary or planned shutdowns.

6) Space Utilisation

When the coal is mined and transported then it will be stored or stockpiled, this would be the case following it being mined. There is a high possibility that not all of the coal will be transported straight away. This could be due to planned shutdowns, or stoppages from 3rd parties, broken down machinery or personnel issues. Then, the company will need provisions for storage or space utilisation.

7) System

The system principle involves using a coordinated system of processes, equipment, and people to improve material flow, improve operational efficiency and reduce waste. The complex system will allow the operators to assess the quantity and quality of the coal produced and transported, it will be able to flag any errors and use an algorithm to generate calculations based on production. This will help to reduce any waste and improve efficiency.

8) Automation

The automation principle involves using technology to automate materials movement for improved efficient and safety. Advanced technology can be used to automate the handling of materials, artificial intelligence will play a huge role in automation, there are pros and cons to this and they affect the business and employees differently.

9) Environment

This involves considering the impact of material handling processes and material handling systems on the environment and taking steps to reduce waste and improve sustainability. There is a possibility that the materials handling system will have a detrimental effect on the environment. The potential landscape movements by laying the stilts for a conveyor belt system or if the pipe jacking system is going underground then local wildlife and habitats will be disturbed. Dust and noise pollution needs to be considered and a plan of action to avoid these measures will require action. Sustainability of the handling system is required, there is a need to use battery powered material handling equipment instead of diesel equipment, and benefits would be to provide easier charging units with zero emissions and reduced noise levels.

10) Life Cycle Cost

The total cost of the material handling systems needs serious consideration and debate. Is there a possibility to purchase used equipment. The term “buy cheap then buy twice” comes to mind, there is a possibility that sacrificing productivity by not investing in the right equipment will have a negative impact but to counteract this, then used equipment can also bring benefits. Maybe parts are easier to purchase and they can be mechanically fixed easier than newer or modern technology (Master Mover, 2023).

The table below illustrates the specific requirements for material handling process design, a process design specification is given to ensure all of the necessary information required is considered and can produce a successful solution to the problem:

Performance	• Function – To transport high quality metallurgical coal. • Quantity of Coal – Approx. 2.8m Tonnes a year. • From Glynedd mine to Llanwern steel works (2 miles away). • Grain / Particle size – 40 – 80mm • Mine & Equipment Lifecycle – 20+ years. • Power throughout – Electrical, minimise diesel machinery.
Environment	• Noise Levels – All areas above 80db will require ear protection for workers. UK Law states that any works outside hours 07:30 – 18:00 require a permit. • Aesthetics – Landscape site to give maximum visual protection. • Dust control – Minimal dust to be disposed of on route to steel works.

	• Dust underground – Very dusty conditions during excavation process. To be risk assessed. • Methane Control – Excavation process method to keep methane emissions to a minimum.
Employment	• Creating up to 450 new positions – This depends on equipment and shift patterns.
Maintenance	• Adhere to maintenance schedules based on handling systems manufacturer's guidance. • Machines and equipment to give maximum output before major overhaul routine maintenance. • Spares inventory to be calculated using risk analysis.
Mine Height Restrictions	• Underground – excavation equipment to operate in average 2.4m seam height.
Operation Control	• Controls for equipment to be accessible for the operator.
Safety	• Full training provided for operation of equipment. • Full restricted access to the public. Secured area. • No manual lifting allowed above recommended safe weight.
Installation	• Main services – electricity, water and telecommunications installation to be established.
Legal & Legislation	• Regulations to be adhered to The Mines Regulations 2014

Table 1: Material Handling Process, (2023)

3. Materials Handling Options

3.1 Option 1 – Underground Belt Conveyor



Figure 1.1: Anti-Tearing Steel Cord Belt (Monster Belting, 2023)

Firstly, the necessary process steps have been considered to transport the coal from the coal face to the steel works is shown.

- Excavate coal from the coal seam
- Transport coal to main conveyor
- Transport coal on main conveyor to surface
- Transport coal from mine site to steel works
- Unload to storage

An underground conveyor system can be considered to transport the coal from the mine to the local steel company. The conveyor belt system has proven to be a very successful material handling system in the coal industry. The conveyor belt system transports coal which can be too heavy or bulky to carry long distances. The importance of the belt conveyor system can be underestimated on times, as it is just seen as a simple belt however if this breaks down then it does lead to major consequences and losing production can be extremely costly. The belt conveyor can move large amounts of coal at a steady consistent rate, as we will know the speed and distance of the belt then NCF can predict how much coal the steel works will receive per hour, per day which gives the steel works accurate statistics.

In effort to satisfy the planning requirements, the conveyor system will be totally enclosed in a tunnel. This eliminating any noise and dust that would occur during the transfer process. This would be aesthetically pleasing too as the land above the tunnel can be developed with the expansion of woodland. Public footpaths can be created where people can enjoy a walk without the risk of injury.



Figure 1.2: Coke Belt Conveyor with Weather Covers (Feeco, 2023)

The distance between the mine and steel company is 2 miles so the coal does have to travel a long distance. We have been advised that the land between the mine and steel works is private land, this does unfortunately mean that we cannot build roads to transport the coal by mechanical vehicles. New Coal Futures will look into renting the land from the landowner to build the platform for the conveyor belt. The land will have to be surveyed and assessed to see if there are any problematic conditions or levels.

The conveyor belt can be made of many materials such as PVC conveyors belts, rubber conveyor belts and wire reinforced conveyor belts. It would be recommended for the coal to be transferred using the PVC conveyor belt as it is suitable for underground and aboveground applications and is known for its anti-corrosion properties. *“PVC is also flexible, putting less strain on the conveyor support. It is resistant to damage, resistant to impact damage and cannot be damaged by oil and bacteria. PVC conveyors are also very easy to install, and there are numerous different kinds of PVC belt weaves and different levels of strength and resistant properties”* (Joner Mining, 2016)

Underground conveyors provide slow noise pollution as they are underground, this would be beneficial to the local communities and its residents. By the conveyor belt being underground it also reduces dirty pollution too as the coal particles remain underground and exposed to the weather elements. AGV shuttle cars can transfer coal from cutting machines onto the conveyors remotely or / you can get manned shuttle cars which are operated.

The photo below illustrates one of the many ways to transport coal from seam to main conveyor.



Figure 1.3: Mine Shuttle Car (Sandvik, 2023)

The conveyor belt system allows the coal to be loaded and unloaded carefully without disturbing or breaking it down, the coal can be loaded straight onto the belt by machinery and then unloaded onto transport vehicles in the steel work place.



Figure 1.4 Belt Tripper with Diverter Chutes (Feeco, 2023)

A belt tripper with diverter chutes travels on a rail system to continuously discharge material on both sides of the conveyor belt for the length of the conveyor. This setup would be ideal for coal, coke, or pet coke storage facility to create piles on both sides of the conveyor for the length of the facility.

FEECO International advises that *“Selecting the appropriate conveyor belt for a specific application is also important in coal and coke handling systems. In handling coke and pet coke, belt conveyors are often employed after a rotary dryer or kiln. It is important to select a heat-resistant belt that will not degrade as result of constant exposure to high temperature materials exiting the dryer or kiln”*. (Feeco, 2023)

3.2 [Option 2 – Slurry Pipeline](#)



Figure 2.1: JSW Steel Slurry Pipeline (Karnataka Industry News, 2023)

A slurry pipeline is a specially engineered pipeline to move ores such as coal, iron or mining waste over long distances. The coal slurry is pumped from the mine to the steel works and then the water is filtered out. Following the mining process, the coal will be crushed and washed to remove the surrounding soil and rock. *“The washing process generates huge amounts of liquid waste, and the mining process itself produces excessive tons of solid waste.*

This is something that will need to be taken into consideration. A method to dispose of the slurry waste is by constructing dams from the solid mining refuse to store the liquid waste” (Essar, 2023).

“The Ultra-High Molecular Weight Polyethylene (UHMWPE) pipes offer high wear and abrasion resistance, making them ideal for slurry pipe. The low friction of UHMWPE pipe enables coal particles to slide easily over the surface and avoids scaling and fouling” (The Economic Times, 2023)

Long distance slurry pipelines are widely used in the mining industry and, compared to bulk-transport systems, have a good performance record for high-availability, excellent safety, and profitability in transporting mineral concentrates such as coal, copper, iron, phosphates, and oil sands. Mining operations also use shorter pipelines to pump tailings or water. The abrasive products transported can erode the pipeline wall, causing a leak or even a rupture. Pipelines in areas prone to mudslides or earthquakes are at even greater risk of a spill. (Research Gate, 2023)

Leak detection in slurry pipelines must minimise false leak alarms because stopping the flow could block a pipeline as the particles fall out of suspension, causing expensive downtime. Sometimes it is even necessary to cut the pipeline to clear the blockage.

Each shutdown can cost hundreds of thousands in lost revenue. The nature of slurry products makes accurate and repeatable flow measurement more challenging than other products. Leading companies can use patented algorithms and self-trained filters to automatically compensate for those measurement error to maximise sensitivity and reliability of leak detection performance (Science Direct).

Transportation of coal fines by slurry transportation is especially attractive when cost in terms of kilocalorie of fuel transported is considered. For slurry transportation, development of necessary surface active chemicals which prevent fine coal particles from settling down at the bottom of suspension medium during transportation or storage becomes important. This part of chemical development we discuss in more detail in later section (Science Direct, 2023).

It is worth noting that a number of coal slurry impoundment failures have been noted over the last two decades, either from failure of the dams holding back surface impoundments or seams which contain coal with an average thickness of 2.4m, 770 kilograms of coal to make one ton of steel.

Long wall mining is an efficient and high production mining method, a single long wall face can produce more than 25,000 tons of coal per day. The dams are often composed of loose rubble from mining activity, reinforced with soil (Quaranta et al., 2004, Science Direct, 2023).

Below is a calculation to determine the daily requirement and quantity per shift.

The annual requirement is 2.8 million tonnes; it is planned for the mine to operate 5 days a week for 46 weeks of the year. Therefore, the daily requirement is 12,174 tonnes.

The table below (Table 2 & 3) illustrates the tonne per shift required to achieve the daily demand. Daily requirement based on an 8 hour shifts for 46 weeks per year.

Shifts/ day	Shifts/ year	T/ Shift	T/ Day
1	230	12,174	12,174
2	460	6,087	12,174
3	690	4,058	12,174

Table 2: Tonne per shift requirement – Example 1

Demand	T/Year	Weeks/ Year	Days/ week	Shifts/ day	Shifts/ year		T/ shift	T/ day
	915,000	46	6	3	828		1,105	3,315
	2,800,000	46	5	1	230		12,174	12,174
	2,800,000	46	5	2	460		6,087	12,174
	2,800,000	46	5	3	690		4,058	12,174

Table 3: Tonne per shift requirement – Example 2

It is essential to know this information so that accurate calculations can be made to determine the processes, equipment and quantities to use.

To quantify measures of calculations, an equation is broken down to the following:

Transport Work (TW)

- $TW = R_f L_d$

R_f = Flow rate

L_d = Length of delivery

Units for TW are components/h multiplied by the distance (m)

Total Transport Work (TTW)

$$TTW = \sum R_f L_d$$

- TTW is the sum of the individual TW values for each delivery
- TTW provides a measure of the total requirements that must be satisfied by the material handling system. (Journal of Transport & Health, Science Direct, 2023)

3.3 [Option 3 – Underground AGV Train System](#)

Track System/Rail-mounted systems can provide fast transport of all materials and equipment over relatively long distances. Poor grading and water drainage, insufficient sleepers, inadequate surveying and levelling and the lack of good ballast will lead to an unreliable track, derailments and slow operation. Mechanical rail laying with purpose-built machinery to reduce manual handling was successfully introduced.

The cost of setting up the roadways and track work is high but the ability to handle high volumes and heavy loads with speed is an advantage in large mines with long distances and particularly where the floor is incompetent.

The system lacks the flexibility of trackless arrangements and is comparatively slow to extend but can handle much larger loads per trip than a trackless system. Distances over which materials and equipment must be transported vary with mining operations. For most mines, supply distances are not so long. However, at some mines, supplies must be transported over 10 km. Mines with very long supply distances most often use a rail transport system. Figure 4 shows the transport of steel arches by using the rail-mounted system. (Underground Tracks, 2023).

An underground AGV train system doesn't need a dedicated operator, the sophisticated software keeps the material haulage system running efficiently and continuously. The operator can control 3-4 trains simultaneously, each train can hold up to 25 cars per trip, the low-profile steel cars link together with a spill-proof connection to create a continuous U-shaped trough. These versatile, heavy-duty cars can hold up to one tonne per load. Each train is fitted with cameras on the front and rear, so that the sole operator can monitor each trip. The electric motors drive horizontal wheels, which contact side plates to move cars forward and back.

Once the trains have reached the steel works and are ready to offload the coal, then in order to discharge the coal the carts are ingeniously inverted into a continuous loop that can be run 180-360 degrees, easily unloading into a stockpile or a crusher.

The train requires minimal clearance, able to travel through existing tunnels and drifts. The trains are adaptable, and the size can be altered if need be, the trains can climb grades of up to 30% and can handle curves with a radius as tight as 30m. A train requires minimal clearance, able to travel through existing tunnels and drifts. (Railveyor, 2023)

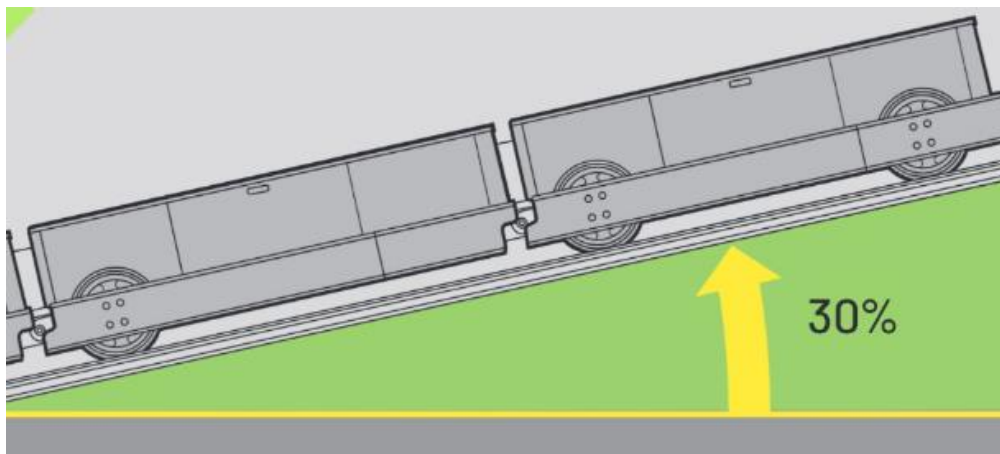


Figure 3.1: Gradient Levels, (Railveyor Trains 2023)

The cars travel on rails that are simply bolted together with joint bars and bolts. An AGV train system like this requires only a minimal base of fine crushed aggregate to provide a smooth path compared to heavy rail that requires a wooden tie, ballast and sub ballast.

4. Evaluation of Chosen Three Options

This section of the report evaluates the three chosen options.

4.1 Underground Belt Conveyor System

Following the review of an underground belt conveyor system then the author has identified many advantages and disadvantages. They are as follows:

Advantages

- Cost effective to move materials long distances.
- Minimal degradation of coal caused by conveying.
- The conveyor can adapt to elevations.
- The coal is visible on the belt unless it is covered, however cameras can be installed to monitor the material.
- The speed of the belt can be adjusted to speed up or slow down.
- Weigh belt selections can be added for continuous product weighing (should it change).
- Belt conveyors can pivot at one end allowing the discharge to be moved over an arc.
- Incline belts can have cleats added to the belt to stop product roll back, and sidewalls to stop product spillage.

Disadvantages

- To add a cover to the belt can be costly.
- Maintenance on the belts can be difficult if it breaks down in between trips.
- Depending on the coal particles, if heavy loads then it could damage the belt.
- In order to install the underground conveyor belt then the tunnel will need to be excavated, to do this then the pipe jacking process will need to be carried out. This is extremely expensive and time consuming.

Following reviewing the advantages and disadvantages of an underground pipeline then it is plain to see that the advantages outweigh the disadvantages.

4.2 Slurry Pipeline

Following the review of the slurry pipeline then they are characterised for long distances, reliable, low maintenance, low air & noise pollution and importantly they are eco-friendly. Slurry pipelines have proven to be cost effective for saving long distance transportation / haulage and provide safe handling of the materials. “Since the inception of long slurry pipelines in 1957 in Ohio to transport coal, gradually over the period, new technologies in slurry transportation has made it possible to transport minerals and materials over long distances safely and effectively” (Researchgate.net, 2023).

However, slurry pipelines do come with disadvantages such as they require high capital investment, the infrastructure of the landscape needs to be adequate and if not then this could be costly to achieve. Grinding down the coal particles to a small grade to make it suitable to travel through the pipeline is a wet process, and then at the other end of the pipeline, there is an added cost to dry the coal out. In order for slurry pipelines to be economic then the distance of transportation requires a long distance and not really suitable for short distances.

4.3 Underground AGV Train System

This report leans towards the notion of choosing an underground AGV train system as it is an innovative concept which uses modern technology to deliver a loading / unloading service. The author has specifically chosen and focused this system on the Railveyor’s underground AGV train system. The narrative below is extracted from Railveyor publications.

Loading

The system can be loaded by several different methods, including a simple overhead hopper or chute, a pan feeder or a discharge conveyor. The system can sense adequate load weight for transport and dispatch a train to collect the payload. The system matches the train speed to the loading rate to optimise material flow.

Tracks

A typical installation features a 962mm gauge track installed on stamped steel rail ties. Tracks and ties can be installed on a lightly ballasted substrate, unlike conveyors which require concrete foundations. This lightweight infrastructure may be relocated by a small crew in a matter of hours – meaning the system is far more flexible than other material handling solutions.

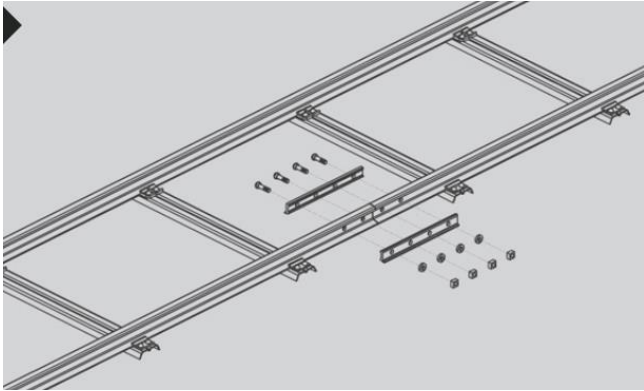


Figure 4.1: Railway Tracks (Railveyor, 2023)

Rail Cars

Trains are made of any number of individual U-shaped steel Rail Cars, which are connected to each other with steel clevis assemblies and flexible flaps that prevent material leakage. The Rail Cars ride on steel wheels with heavy duty automotive bearings. A lead car, with four wheels instead of two, is placed at the head of each train and is equipped with safety signals.

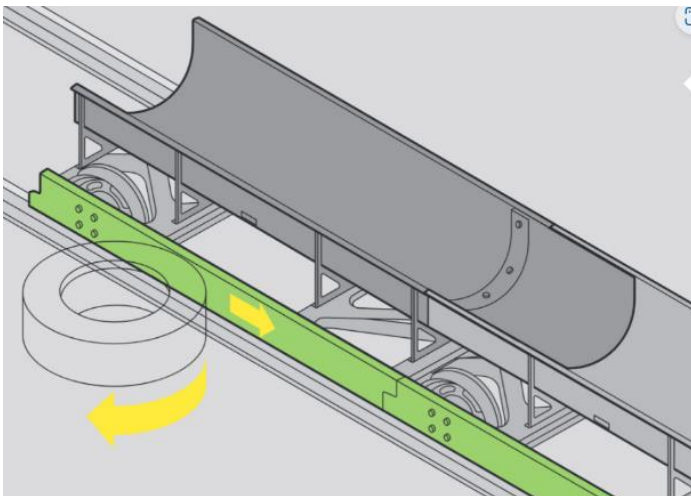


Figure 4.2: Rail Cars (Railveyor, 2023)

Drive Stations

The drive stations are two horizontally oriented wheels driven by electric motors that propel the train by making contact with its side plates. Also able to be installed on lightly ballasted substrate, the Drive Stations are activated by the system at the precise time a train approaches, saving energy. When the train returns on a decline, energy is regenerated by the Drive Stations.

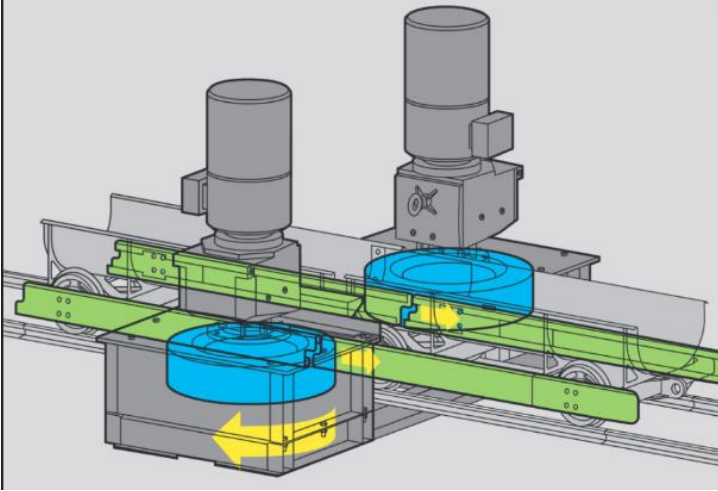


Figure 4.3: Drive Stations (Railveyor, 2023)

McCall Discharge Loop

A special feature of the typical system is the “McCall” Discharge Loop, which inverts the train and dumps the coal. The train may then return to the load point. Discharge loops may be in a fixed position or constructed for easy relocation. Configurations include Loop, Shuttle and Shuttle with Bypass Sidings.

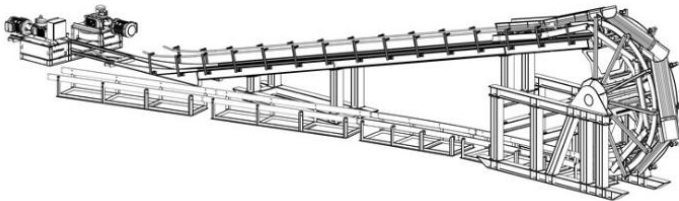


Figure 4.4: McCall Discharge Loop (Railveyor, 2023)

Automation & Software

The autonomous system is fully automated by sophisticated, industry-leading software.

- Dispatches trains to collect materials only when required.
- Activates drive stations with timing down to the precise time.
- Controls tramming speed intelligently at every track segment.
- Ensures safety with multiple alert levels.
- 24/7 operation with no dedicated operator required.
- Cloud-based remote monitoring, control and system updates.
- Tablet and mobile device friendly software interface.

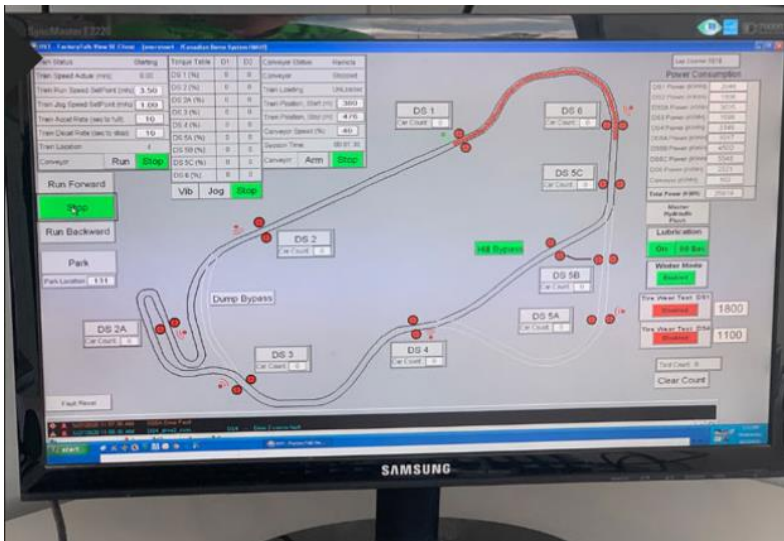


Figure 4.5: Automation & Software (Railveyor 2023)

5. Procurement

There are a several issues to consider as part of the decision process, the issues vary from the design of the equipment to suitability. The design needs to be suitable and specific for the level of work required. The author has researched what the most suitable material handling system needs to be. There is a need to set up an early dialogue with the supplier based on future requirements, and then for a quote and breakdown of the costs involved, lead times will need to be discussed and agreed.

Normally on large engineering equipment then the lead times are lengthy, this will need to be factored into the business case. The service delivery and logistics of the machinery will need to be strategically planned in advance, if the equipment needs to be delivered on extra wide load vehicles then they will need a highway permit and escort.

It will be beneficial to the company to find out what materials are used in the machinery, and whether they are renewable and sustainable. There is a need to find out how the machinery is manufactured and what production methods are used. It is quite possible that the machinery will have a maintenance contract but this does come at a premium cost.

The company could decide to buy re-conditioned equipment to save cost but this does come at a risk of failing and whether parts are accessible due to the equipment's age. If the company is going down the line of purchasing brand new equipment then it is recommended that they factor into the business case the life cycle and possibility re-sell value of the machinery.

There is a possibility that at the end of the life cycle of the machinery then the company will need to dispose of safely, legally in the most environmentally friendly manner, this will definitely come at a heavy cost.

6. Overall Recommendations

The aim of this report is to critically and specifically develop a suitable materials handling system that will extract coal from the mine and transport it to the steel plant two miles away. The author carried out research on three specifically well suited systems, these systems have been successfully tested in previous case studies.

Following reviewing these material handling systems then it is fair to say that the positives outweigh the negatives, and would provide the company with a solution from transporting the coal to the steel works without the use of a road.

To be more specific, the author recommends New Coal Futures to procure a material handling system that concentrates on the underground AGV train system. This type of system is innovative with cutting edge technology, it will give strength to the business case and planning application.

Investors will see that the company is heading in the right direction and is serious about enhancing its reputation as an eco-friendly coal manufacturing company who takes into consideration local communities and environment rather than just profit.

The underground AGV train system technology allows the company to analyse data more accurately and consistently, this will benefit New Coal Futures to predict loads and deliveries to their clients. The underground system benefits local communities as the noise and dirt pollution is controlled and kept to a minimum.

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