



MATERIALS HANDLING EVALUATION FOR COMPANY OPERATIONS

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Abstract

Purpose: This study extensively analyses the preplanning phase, emphasizing the impact of Lean Principles and the Agile system on safety, cost efficiency, and adaptability within the dynamic mining industry. The report aims to identify an efficient and environmentally friendly technology for transporting coal over a 2-mile distance, eliminating the need for road transport.

Approach: Three distinct materials handling methods—Pneumatic Tube Transportation, Overhead Cable System, and Automated Guided Vehicle (AGV)—are explored, with detailed features outlined. However, the primary focus of this report is on conveyor technology.

Results: Through design implementation calculations, the conveyor system exhibits noise reduction and improved energy consumption. This paves the way for the integration of alternative and green energy sources to enhance overall efficiency.

Conclusions: The procurement decision is pivotal, underscoring the importance of securing a reliable supplier to ensure the prompt and efficient delivery of coal. This study provides insights for optimizing coal transportation systems, aligning with sustainable and eco-friendly practices in the mining industry.

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Introduction

In this report, the author has taken on the role of Operational Manager at New Coal Futures. The primary goal is to coordinate the planning and operation of a new deep coal mine. Simultaneously, a significant challenge lies in devising an environmentally compliant material handling system for transporting coal to a local steel company situated two miles away from the proposed mine. Addressing this challenge effectively is crucial. Moreover, careful consideration must be given to planning conditions, emphasizing the need for the material handling system to minimize noise levels and visual impact. The report also outlines the necessity to justify the choice among three potential materials handling options.

A key focus of the author is to assess the efficiency, environmental impact, cost-effectiveness, and alignment with planning conditions for each option.

The literature review examines a comprehensive analysis of the preplanning phase, providing insights into Lean Principles and the Agile system. Lean principles are instrumental in enhancing company safety and cost efficiency, while the Agile system strategically responds to regulatory changes, technological advancements, and project structure.

The Material Handling section elucidates the core principles of coal and emphasizes the critical role of the Life Cycle Assessment (LCA) in analysing the environmental impact of coal processing. The primary technology under consideration is the conveyor system, with a focus on noise considerations and design aspects.

Three distinct materials handling methods have been selected, such as Pneumatic Tube Transportation, Overhead Cable System, and Automated Guided Vehicle (AGV)—which are explored in detail. Each method contributes unique features to the overall handling process.

Lastly, in the last sections, the procurement decision that needs to be considered for the technology mentioned above and the overall recommendation that will need to be considered to have an optimal design.

Literature review

Analysis

Before delving into mine planning, a preliminary analysis is typically conducted. This initial phase allows mining engineers to evaluate whether a specific mining property warrants further exploration quickly. A well-executed preplanning phase can yield results within 10% to 20% accuracy of actual outcomes, leading to significant cost savings before committing to a more detailed analysis.

The primary questions addressed in the preplanning phase include (Bise, 2003):

- What will be the operating conditions of the mine?
- How much time is required to complete the project?
- What health, safety, and environmental regulations will impact the project?

In extensive mining projects, the main objective for mine-planning engineers is to minimize project delays. The Critical Path Method (CPM) stands out as the predominant technique for scheduling large-scale. Given the inherent challenge of balancing cost and time in mine planning, the Program Evaluation and Review Technique (PERT) is frequently employed as a more refined iteration of the CPM.

When utilizing PERT for mine project scheduling, it is crucial to identify all significant activities within the project and understand the interrelationships among them. In summary, both CPM and PERT serve as valuable tools for scheduling extensive projects, such as the establishment of a mining operation (Bise, 2003).

Overview of Lean Principles

In the current hypercompetitive business environment, companies are aiming to swiftly adopt strategic solutions. According to Horta and Camacho, the rise in competition in the construction industry can be attributed to technological evolution and industrial regulations. In response to these challenges, the study aims to formulate a plan to enhance the innovation capabilities of construction organizations. This involves integrating lean and agile principles into the innovation process, as outlined by Sertyeşilışık and Tezel in 2019 (Sertyeşilışık & Tezel, 2019).

Value stream mapping, a lean manufacturing tool utilizes a detailed flow diagram to document each step of a process. Its primary tool is the reduction of process cycle time and the implementation of process improvements as illustrated in Figure 1.

Therefore, objectives that can improve the performance of the mining industry are (Kumar, 2014):

- **Improve Safety:** Implement measures and protocols to enhance overall safety standards for personnel and equipment.
- **Reduce Cost:** Identify and implement cost-saving measures to enhance operational efficiency and financial performance.
- **Increase Production:** Optimize processes and workflows to boost production rates and meet demand effectively.
- **Enhance Productivity:** Implement strategies to improve overall workforce productivity and resource utilization.
- **Other Objectives:** Address additional industry-specific goals or challenges to ensure comprehensive performance enhancement.

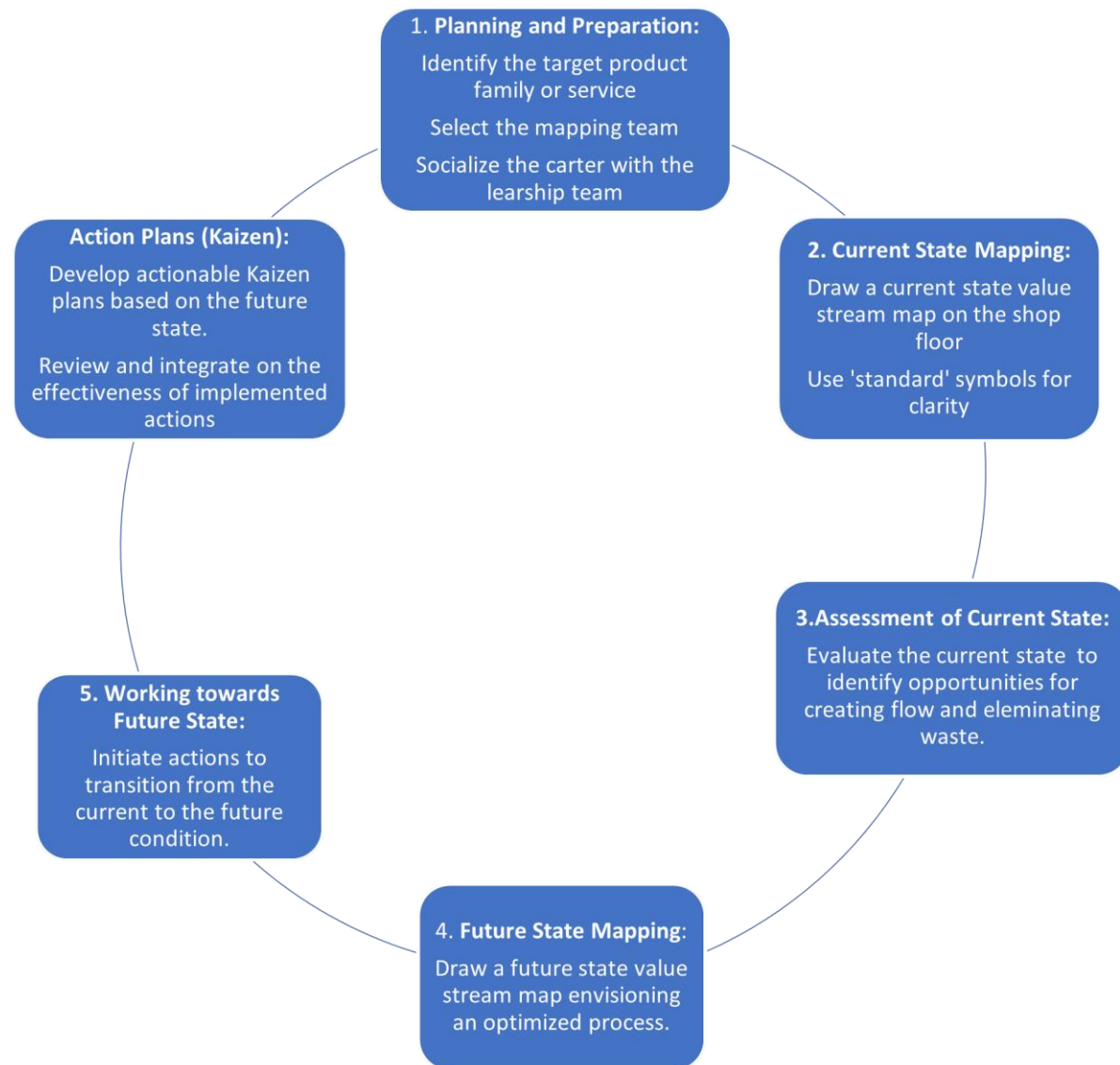


Figure 1. Value stream mapping (Kumar,2014)

Overview of Agile System

Nowadays competitive construction industry companies are actively seeking strategic solutions to boost their innovation capabilities. According to Horta and Camacho, increased competition in construction is driven by technological changes and industrial regulations. To tackle these challenges, a study led by Sertyeşilışık and Tezel (2019) aims to foster innovation by incorporating lean and agile principles into construction processes (Sertyeşilışık & Tezel, 2019).

Agile Project Management (APM) stands out for its adaptability throughout project cycles, allowing for flexible planning and execution. APM aligns well with the dynamic demands of construction projects. On the other hand, the Lean production system, rooted in the "Toyota Production System," focuses on delivering value by optimizing processes and minimizing waste. Tools like Visual Management and fail-safe methods enhance efficiency in processes and products. Santo and Carvalho highlight the applicability of Lean concepts in managing project elements effectively (Santo & Carvalho, 2020).

In summary, combining Agile and Lean principles in construction provides a strategic response to the challenges of a competitive environment, technological changes, and industrial regulations. APM's adaptability suits the dynamic nature of construction projects, while Lean principles underscore value creation and efficiency, collectively enhancing innovation capabilities in construction organizations.

Materials handling considerations

Material processing plays a vital role in crafting the everyday items we use, ranging from simple items like plastic wrap to complex designs like automotive engines and electronic devices. Regardless of the product's complexity, they all undergo a similar manufacturing sequence, and notably, the materials used come from the earth (Martinez, 2021).

Coal, a black or brownish-black organic sedimentary rock with biochemical origins, is widely distributed across inhabited continents. Composed mainly of carbon with varying proportions of hydrogen, nitrogen, oxygen, and sulfur, coal is a combustible rock occurring in rock strata (Speight, 2021).

While coal has historically contributed over 56% to electricity generation fuel and 87% to coal-fired power plants, its utilization has led to adverse environmental consequences. Coal combustion at power plants releases pollutants like sulfur dioxide (SO₂), nitrogen oxides (NO_x), particulate matter, and carbon dioxide (CO₂). Coal is a major contributor to U.S. SO₂ and NO_x emissions, accounting for 93.4% and 80.2%, respectively. Additionally, coal contributes to 35.8% of all U.S. CO₂ emissions and 73.5% of CO₂ emissions from electric power plants.

To assess the environmental impact of generating electricity from coal-fired power systems, Life Cycle Assessment (LCA) is a key material flow analysis. The primary goal of LCA is to measure and analyze

environmental aspects throughout the life cycle of a coal-fired power system. Conducting a comprehensive inventory of resources, emissions, and energy flows from cradle to grave provides a holistic environmental overview of each system. It's crucial to note that while these analyses can be compared, they were not specifically conducted for comparative purposes but aimed to offer an independent environmental overview of each system (Spath, Mann, & Kerr, 1999).

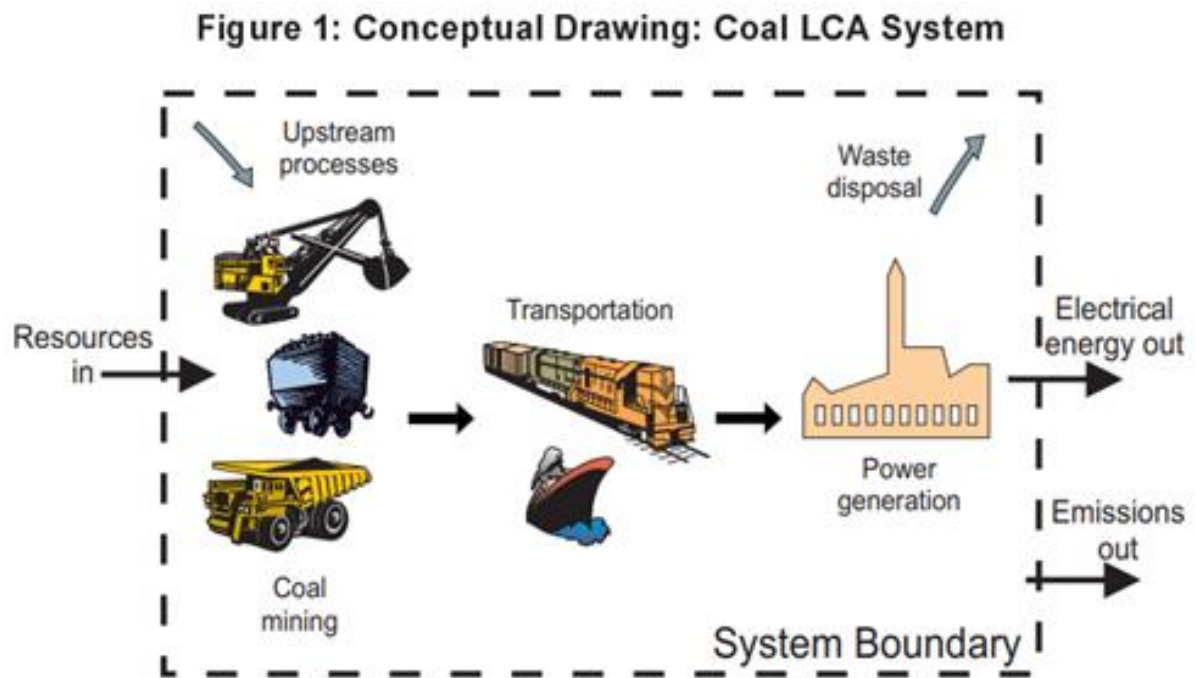


Figure 2. LCA coal flow analysis system (Spath, Mann, & Kerr, 1999, (p.4))

Figure 2, illustrates the LCA systems that can guide the identification of opportunities for minimizing the environmental impact of the system by implementing design enhancements (Spath, Mann, & Kerr, 1999). Importantly, a significant source of uncertainty in any production-distribution system is product demand, which comprises firm orders and demand forecasts. For that, the material requirements planning (RMP) process and the practical aspect are vital in the operating activities of mining enterprises as illustrated in Table 1 (Bak & Michalak, 2018).

Table 1. Theoretical and Practical Considerations in Material Requirements Planning within a Mining Enterprise (Bqk & Michalak, 2018)

Objectives	A mining enterprise relies on a significant amount of material, constituting approximately 15% of the total cost and ranking second in financial impact after personal cost. • It is vital principle of minimizing inventory, as excessive stockpiling serves as both a reassurance for those overseeing supply assurance and an additional, unnecessary cost escalation
Rebuilding plan structure	A crucial component of the supply plan is the material consumption, outlining the quality of the materials that need to be utilized from the mining enterprise's stockpiles during the planning period to meet the requirements. • During the planning process, it is important to categorize material based on their consumption area. For instance, production can be specified for maintenance, works, preparation works, other underground works, mechanical processing.
Materials Planning	Implementing effective methods for planning requirements in materials management within the mining enterprise. • Enhancing information processing techniques suitable for practical use in the material requirement planning process • Developing suitable IT systems that facilitate timely and high-quality information flow for accurate planning and control of supply processes.

Conveyor technology

This report predominantly employs conveyor technology, with the primary loading method utilizing belt conveyors, as depicted in Figure 3. Belt conveyors consist of powered pulleys connected by a continuous loop of belting material, facilitating efficient product movement. Recognized for their cost-effectiveness, these conveyors are widely used for transporting items over long distances, at high speeds, and in scenarios with inclines or declines. This is achieved through a continuous loop of hooks, gears, buckets, and a robust rubber belt supported by a series of rollers.

The advantages of belt conveyors lie in their economic and straightforward nature, offering a seamless solution for transporting products. Their design simplicity, featuring a flat, moving belt, allows for versatility in handling various product sizes, shapes, and weights effectively over long distances with a

single drive. Additionally, belt conveyors are well-suited for facilitating the movement of products through elevation changes, encompassing both incline belt conveyors from low to high and decline belt conveyors from high to low (Primo, 2009).

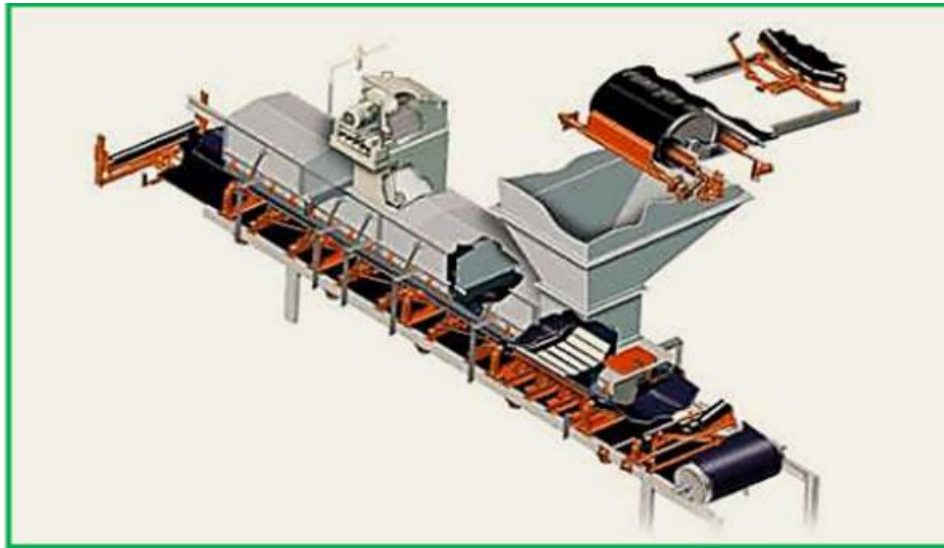


Figure 3. Belt conveyors for bulk materials (Primo,2019,p.3)

Belt conveyors have long been the go-to method for efficiently transporting large tonnages, especially when compared to alternative methods. Their pivotal role is evident in the continuous transportation of significant dry bulk materials, notably in mining and coal power stations. However, a key challenge arises in effectively managing the dynamic behaviours and speed control of these conveyors. This aspect is crucial, as insufficient dynamics and imprecise control can lead to increased energy consumption and suboptimal performance.

Noise productions strategies

Noise emissions from coal handling and preparation plants pose a significant issue in Australia, despite strict legislation and environmental constraints governing plant construction and operation. Plant designers, in recent years, have actively sought practical data to design plants with lower noise levels.

Appendix 1 illustrates the actual noise of a conveyor system, revealing that a substantial number of idlers were imbalanced and deviated from specified standards, leading to unacceptable noise levels. Proactive measures to replace these non-conforming idlers resulted in noise reductions of up to 14 dB(A).

In some instances, conveyors exhibited ripples in the belt covers, challenging effective belt scraping and generating drumming noise. Discussions with the belting vendor led to the replacement of affected belts, with improvements detailed in Appendix 2. Initially, the primary noise reduction

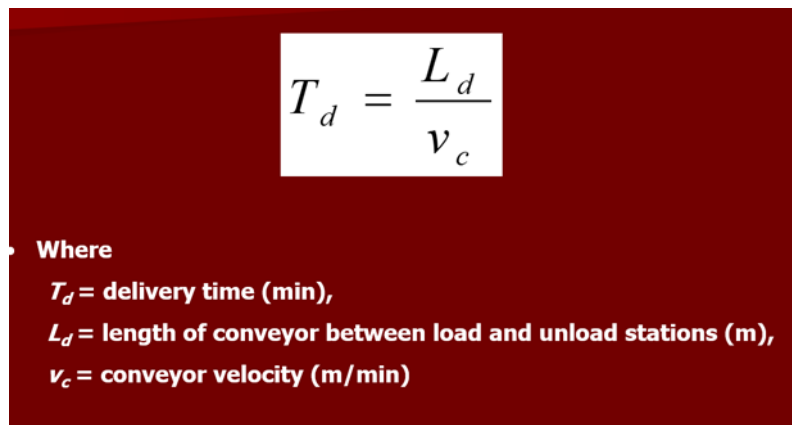
strategy involves maintaining a certain material amount within each bin to mitigate noise from falling material (Mills, Bridges, & Juillerat, 2000)

For the main design, the rubber will be utilized to ensure low-noise operations during conveying (Bortnowski, Król, Nowak-Szpak, & Ozdoba, 2022).

Design Considerations

As the conveyor will need to travel 2 miles or 3218.69 m various calculations have been illustrated.

If the conveyor maintains a consistent speed, the duration needed to transport materials from the load station to the unload station is given by the formula used in Figure 4 to find the single directions of a conveyor that operates at a constant speed and the time that is required to move materials from a load station to unload station (Andrew, 2023).


$$T_d = \frac{L_d}{v_c}$$

Where

- T_d = delivery time (min),
- L_d = length of conveyor between load and unload stations (m),
- v_c = conveyor velocity (m/min)

Figure 4. The formula used to move the conveyor (Andrew,2023)

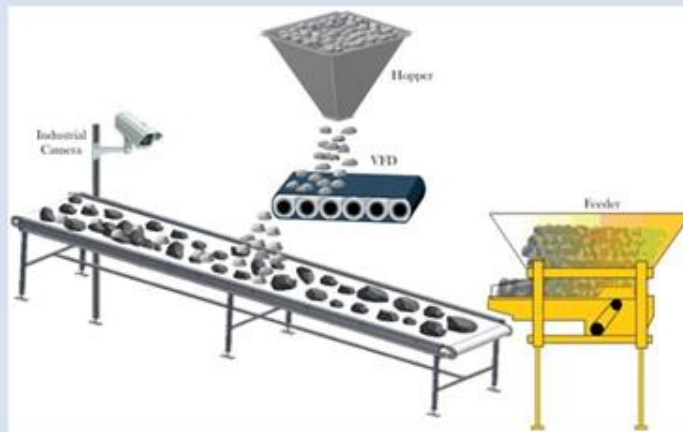
Figure 5, illustrates the space between the tote pans along the conveyor, where (a) represents the space between the tote pans along the conveyor, (b) the maximum achievable flow rate in parts per minute, and (c) the minimum time needed to unload the tote pan in the assembly department. For section (a) the spacing between tote pans on the conveyor is influenced by the loading time. While it takes just 10 seconds to place a tote pan onto the conveyor, the loading of parts into the tote pan necessitates 25 seconds. Moreover, the loading cycle is constrained by this 25-second interval. Given a conveyor speed of 40 meters per minute, the resulting spacing will be 16.67 m.

Section (b), the flow rate was given with a value of 48 parts/min. Consequently, the flow rate corresponds to one tote pan every 25 seconds (Andrew, 2023).

Equation 1

$$Tu \leq 25 \text{ sec}$$

However, other calculations have been made, to check the maximum number of parts that can be transported each time, and as shown in Appendix 4, it is 700 parts. Therefore, as shown in Equation 1, an additional criterion for the loading and unloading process is that the time needed to unload the conveyor must be equivalent to or shorter than the reciprocal of the material flow rates (Andrew, 2023)



Roller conveyor to transport coal to make coke
 A roller conveyor will need to follow the 3218.69
 Following equations will need to be considered

$$R_f = R_L = \frac{v_c}{s_c} \leq \frac{1}{T}$$

$$T_d = \frac{L_d}{v_c}$$

- R_f = material flow rate (parts/min).
- R_L = loading rate (parts/min).
- s_c = center-to-center spacing of materials on the (m/part).
- T_L = loading time (min/part).

- Where
- T_d = delivery time (min),
- L_d = length of conveyor between load and unload stations (m),
- v_c = conveyor velocity (m/min)

Let's consider this element
 Rate that is balanced
 Minutes in an hour
 Velocity of conveyor
 Total pan hold those parts

25 sec/cycle
 60 min
 40 m/min
 20 parts

a	Sc	16.67	Units
b	Rf	48	m
c	or	0.8	parts/min
			parts/sec
	0.8	≤	25sec

Figure 5. Calculations of coal transportation of 20 parts

Other calculations In Excel have been made to find the maximum power that a conveyor can produce as illustrated in Figure 6. Conducting a comprehensive study and following the model of Mhlongo, Nnachi, Nnachi, & Adesola (2020), evidenced that conveyor belts have the potential to decrease power consumption on conveyor belts and therefore, reduce operational costs for companies (Mhlongo, Nnachi, A Nnachi, & Adesola, 2020).

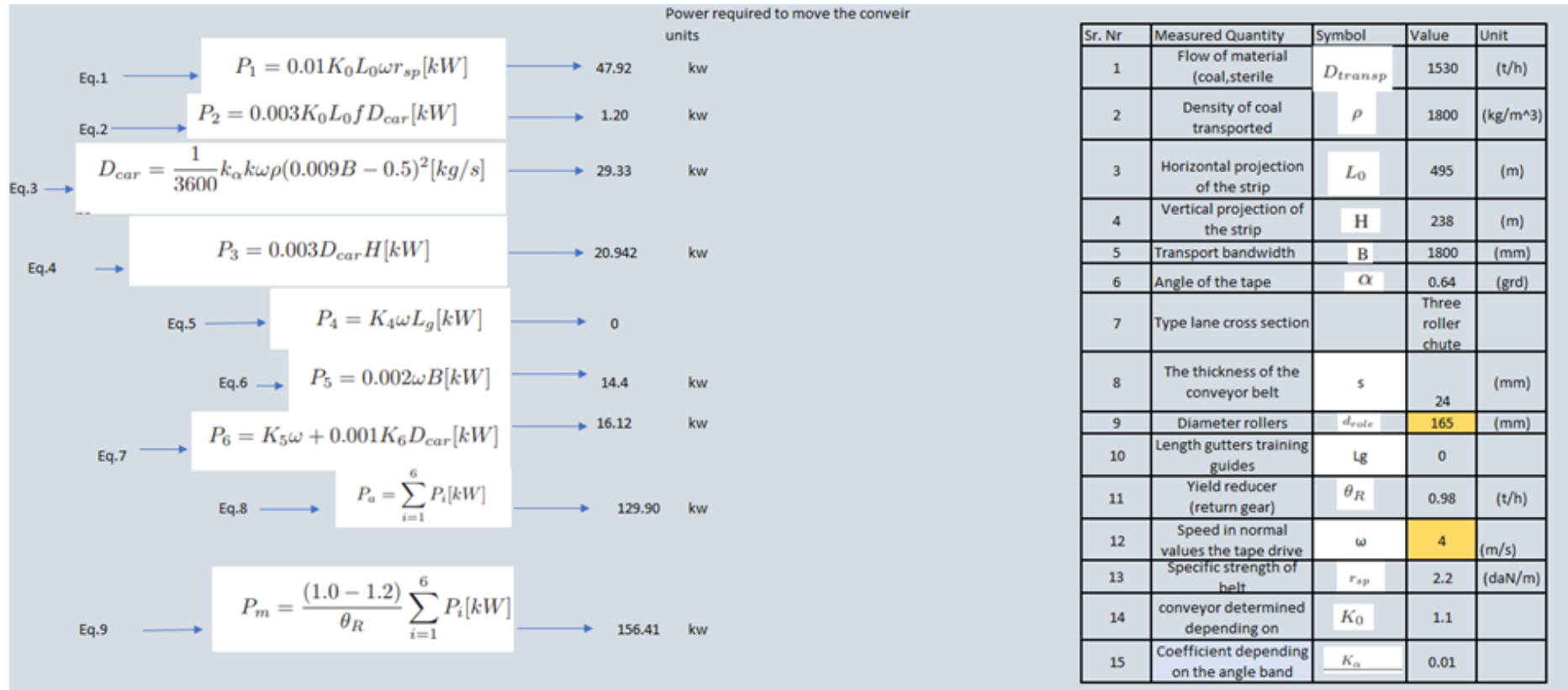


Figure 6. Power required along with a few adjustments (Mhlongo, Nnachi, A Nnachi, & Adesola, 2020).

The author has used the same equation of Mhlongo, Nnachi, A Nnachi, & Adesola, (2020) and transferred it into Excel, however, the speed value tape drive was shown to be 4 (m/s) and the diameter roller at 165 (mm) highlighted in yellow from the Figure 6.

When applying the most appropriate belt for a specific application, various factors need to be taken into consideration such as (Mhlongo, Nnachi, A Nnachi, & Adesola, 2020):

- The carcass's tensile strength should be sufficient to transmit the required power for conveying the material over the given distance.

The selected belt carcass must possess the necessary characteristics to:

- Provide adequate load support for the duty
- Conform to the contour of the troughing idlers when empty
- Flex satisfactorily around the pulleys used in the conveyor installation.

Table 2. The Power calculated (Kw) from the belt conveyor at a maximum load (Mhlongo, Nnachi, A Nnachi, & Adesola, 2020,p.3)

D_{car} kg/s	P_1	P_2	P_3	P_4	P_5	P_6	P_a	P_m
29.33	71.28	2.40	21.38	0	21.42	23.92	140.4	171.92

A slight reduction in velocity to 4 m/s and a smaller roller diameter of 165 cm can potentially enhance the conveyor's energy efficiency, as seen in the comparative analysis with Table 2 from Mhlong, Nnachi, A Nnachi & Adesola's 2020 experiment (Mhlongo, Nnachi, A Nnachi, & Adesola, 2020). Following Lund's (2007) energy development strategies, which focus on energy conservation, improved production efficiency, and transitioning to renewable energy sources, the author proposes that the energy consumption reduction resulting from these adjustments allows for the use of renewable sources to power the conveyor.

Lund's research and data from the Danish Energy Agency suggest wind energy as a viable option. The utilization of electricity from Renewable Energy Sources (RES) not only conserves energy but also enhances efficiency and integrates more flexible energy technology into the transport sector. Notably, the Danish Energy Agency estimates that 20–25% of the current total primary energy supply in Denmark could realistically come from biomass, showcasing the country's significant potential to reduce reliance on fossil fuels through new renewable energy sources (Lund, 2007).

Three options for materials handling

Pneumatic tube transportation

Fundamental Principles

Pneumatic system transportation employs a network of tubes to convey materials through air pressure. Categorized into discrete and continuous methods based on solid phase settings, pneumatic transportation simulations have been widely explored.

Another main advantage of the pneumatic system is the ability to provide fast transportation, making them suitable for time-sensitive materials (Rieber & Soo, 1977).

Advantages

This method of material transportation boasts several advantages, including reliable safety, cost-effectiveness, flexible installation layouts, enhanced intelligence and efficiency, and relatively lower labour costs. Moreover, it can navigate challenging terrains without the need for complex infrastructure (Tian, Cheng, & Kang, 2023).

Overhead cable system

An overhead cable system suspended containers that move along cables from the mine to the steel plant. This method is suitable for transporting bulk materials over relatively short or medium distances. The main advantages it can provide an aerial solution and can traverse difficult terrains, including hills and valleys (Birch, 1948).

Advantages

One of the main advantages of overhead line equipment (OLE) is that a system involves suspended containers or buckets moving along cables from one location to another. Also, it is suitable for traversing difficult terrains, including hills and valleys (Haiderali, 2020).

Justification

The (OLE) can be less obtrusive visually, making them suitable for scenarios where aesthetics are a consideration. Moreover, if the route involves challenging topography an overhead system can navigate such terrains efficiently (Haiderali, 2020).

Automated Guided Vehicle (AGV)

Automated Guided Vehicles (AGVs), also known as driverless vehicles, follow predefined paths or markers to efficiently transport materials within a factory. Strategically positioned at specific locations and routes, AGVs play a crucial role in seamlessly moving materials and goods from inventory and pre-assembly lines to the central manufacturing line for truck assembly.

In the Volvo experiment, numerical designations from 1 to 4 were assigned to missions, each representing a distinct operational objective. The Pugh method was chosen for its practical and effective approach to determining the optimal solution for AGV implementation. Despite missions 3 and 4 receiving similar scores, mission 3 was preferred to enhance AGV resilience against failures.

Mission 3's utilization of a PLC register, instead of an I/O module, for signalling the completion of unloading by operators proved more advantageous. The limitation of the I/O module, allowing the AGV to read input only when actively awaiting signals, was identified. Addressing this limitation involved adjustments to the internal software, as highlighted in the experiment conducted by Rex and Klemets in 2019 (Rex & Klemets, 2019).

Table 1, illustrates the advantages of AGV vehicles (Schulze & Wullner, 2006). On the other hand, Table 2 illustrates the disadvantage of AGV vehicles (Radtka, Paramashchuk, & Shevock, 2021).

Table 3. *Advantages of Automated Guided Vehicle (AGV) (Schulze & Wullner, 2006)*

Flexibility	Precision	Autonomus vehicle
• Adaptable to change layout • Navigate across obstacles around their routes	• Can operate with high efficiency • Perfect for application of materials handling	• Reduce human jobs • Therefore, reduce manual work from employees.

Table 4. Disadvantages of AGV System (Radtka, Paramashchuk, & Shevock, 2021)

Investment	Limited capacity	Complex technology
• High initial capital to invest • AGV systems units very high	• The capacity of the bulding is limited • Therefore, hard to work with heavy-duty materials	• Special knowledge and people • Staff must be trained to have a successful integration

Issues that need to be considered as part of the procurement decision

Designing and managing the procurement process is complex due to the intricate interplay of contractual challenges, competitive screening and risk management issues. Furthermore, procurement is a dynamic, recurrent process where short-term goals often compete with long-term objectives. Effective strategic procurement decisions require a forward-looking perspective that takes into account the evolving dynamics of the demand-supply relationship.

Table 5 illustrates the main characteristics of procurement decisions for the Pneumatic Tube that will need to be considered. Table 6, for the Overhead cable system and Table 7 for the Automated Guided vehicle system (Dimitri, Piga, & Spagnolo, 2006).

Moreover, in the conveyor system procurement, a few details will need to be considered such as (Budelli, 2015):

- **Supplier selection:** Carefully consider the conveyor system supplier based on their reputation, experience, and ability to meet specific requirements.
- **Contractor:** Important to take into consideration to the contract details, ensuring clarity on the deliverables timeline and any penalties or incentives.
- **Quality:** Ensuring that the conveyor system functions perfectly to meet requirements and regulatory standards.
- **Payment:** Clearly define and negotiate payment terms with the suppliers and the contracts, including milestones, methods, and related penalties or incentives.

Following these 4 strategic plans, the procurement process for the conveyor system can be strategically managed, ensuring that successful collaborations with suppliers and contractors will meet project goals and requirements.

Table 5. Pneumatic Tube procurement decisions

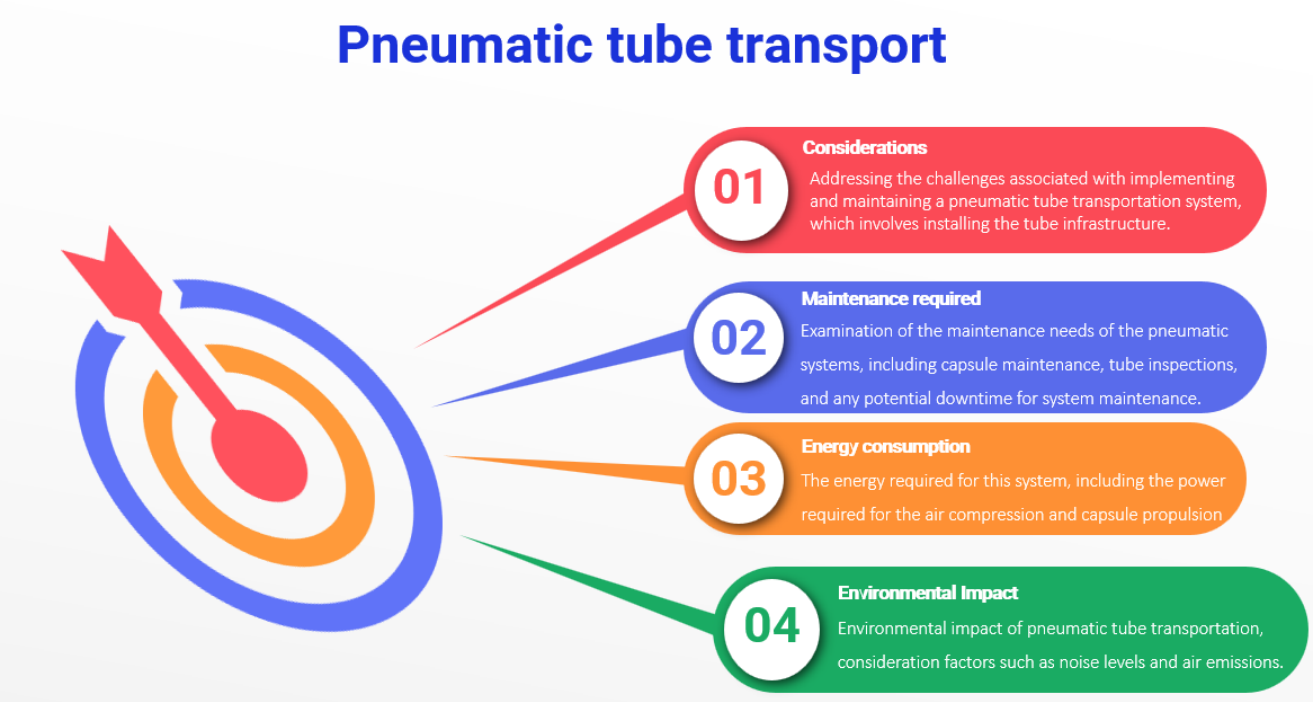


Table 6. Overhead cable system procurement

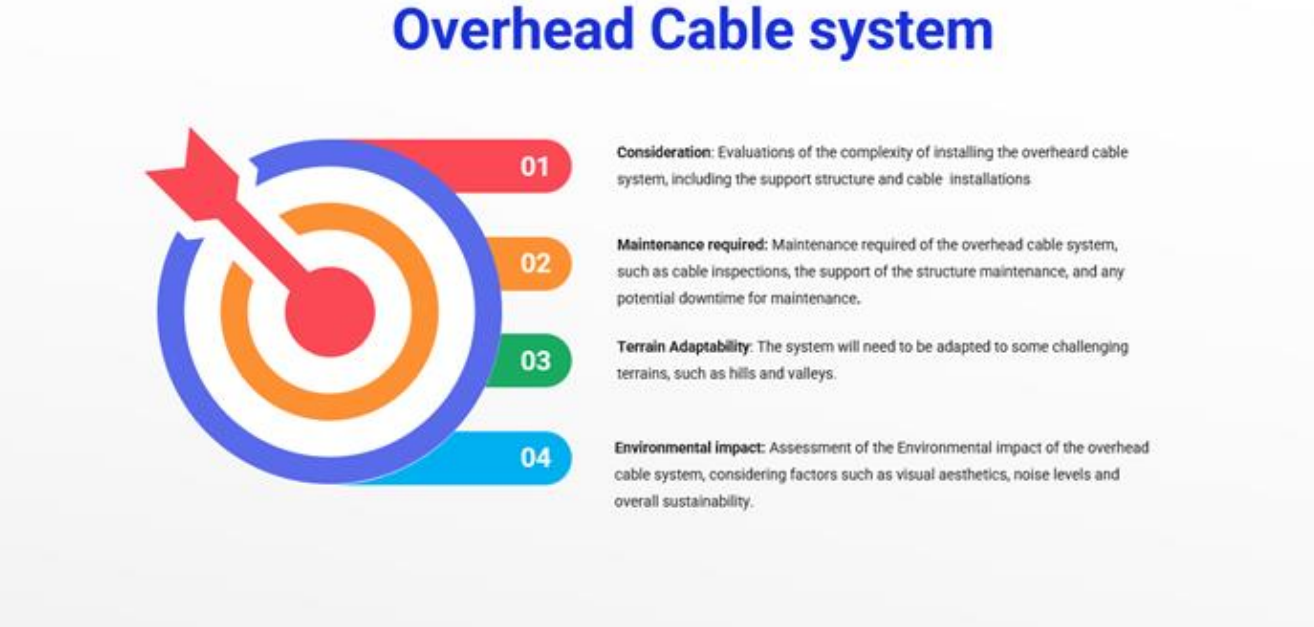
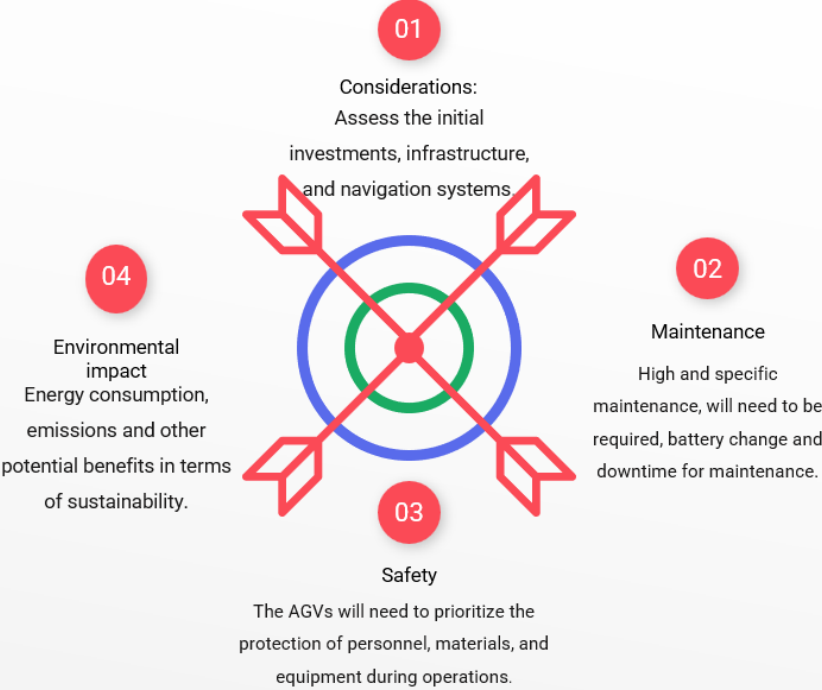


Table 7. Automated Guided vehicle procurement

Automated Guided Vehicle (AGV) system



Overall recommendations

In any project, to have an optimum project an accurate analysis will need to be considered. In fact, for this design Value Stream mapping will need to be evaluated as shown in Figure 1.

The main design that has been used is the rotatory conveyor which will be able to transport the coal for 2 miles. However, the main advantage of a rotatory conveyor system is that it is able to transport a large amount of material effectively in comparison to other technologies.

On the other hand, the main disadvantage is the noise that the conveyors generate, indeed, following the main design for this report a rubber will be utilised to ensure that the conveyor has a lower noise.

Drawing insights from Andrew's documentation (2023), calculations were conducted to determine the capacity for transporting parts. The first test of 20 parts shows to be accurate, however, as soon as the parts have been increased from 500 to 700 as illustrated in Appendix 4, from Equation 1, the time needed to unload the conveyor must be equal to or shorter than the material flow rates as illustrates in Equation 1. In addition, a few adjustments have been made to the diameter roller and decrease the speed of a conveyor to be 4 m/s. Furthermore, with those small adjustments, the total energy consumption is going to be 156.41 kW in comparison to the first test which was 171.92 kW. Therefore, in any design, it is crucial to have energy that can handle a better efficiency along with the use of alternative energies such as wind turbines or solar panels.

Materials handling options have been explored, with the Automated Guided Vehicle (AGV) emerging as a potential alternative to replace the conveyor technology.

To conclude, the main equipment that will need to be considered for the procurement find a strong and right supplier to ensure that the coal will be delivered on time.

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Appendices

Appendix 1

Table 8. Background Noise Levels (Mills, Bridges, & Juillerat, 2000,p.2)

Monitoring Site	Day		Night	
	Range L ₉₀ dB(A)	Average L ₉₀ dB(A)	Range L ₉₀ dB(A)	Average L ₉₀ dB(A)
1	36-41	39	32-42	39
2	35-44	37	34-39	36
3	38-40	39	32-48	36
4	35-51	37	32-39	34
6	34-48	38	33-52	42
7	30-38	34	33-43	38
8	31-39	34	31-39	35
9	31-43	34	31-38	34
10	37-46	40	30-38	33
11	31-37	33	31-39	34
12	30-42	33	31-45	35
13	31-38	35	31-43	35
14	31-40	35	30-42	36
15	30-40	35	30-50	37
16	31-38	33	30-39	35

Appendix 2

Table 9. Conveyor noise (Mills, Bridges, & Juillerat, 2000,p.8)

Conveyor	Noise Level at 1m, dB(A)			
	Initial Operation	After Idler Clean	After Idler Change	After Belt Change
Raw Coal	85	76	73	N/A
Sized Coal	81	73	N/A	N/A
Raw Stockpile	88	73	N/A	N/A
Train Loadout	92	85	83	79
Overland (Raw)	71	N/A	N/A	N/A

Appendix 3

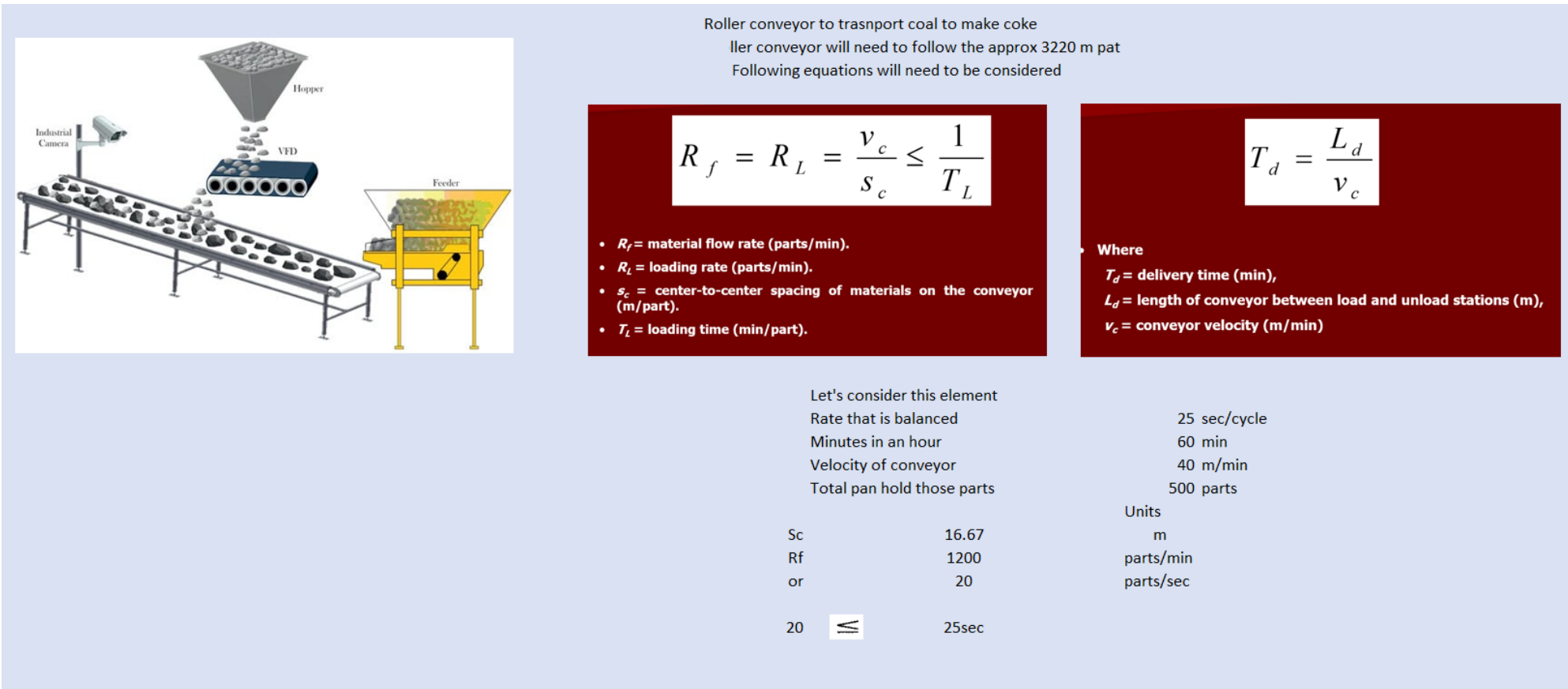
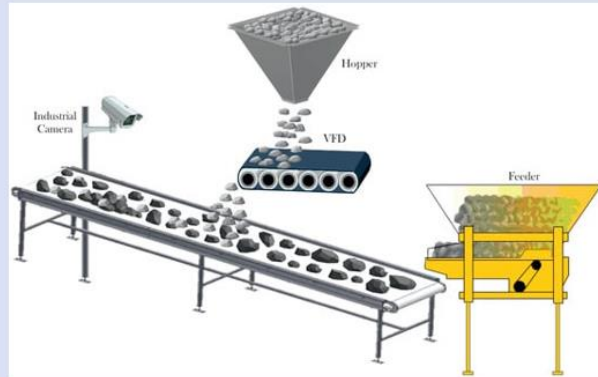


Figure 7. Calculations of coal transportation of 500 parts

Appendix 4



Roller conveyor to transport coal to make coke
 Roller conveyor will need to follow the approx 3220 m path
 Following equations will need to be considered

$$R_f = R_L = \frac{v_c}{s_c} \leq \frac{1}{T_L}$$

- R_f = material flow rate (parts/min).
- R_L = loading rate (parts/min).
- s_c = center-to-center spacing of materials on the conveyor (m/part).
- T_L = loading time (min/part).

$$T_d = \frac{L_d}{v_c}$$

Where

- T_d = delivery time (min),
- L_d = length of conveyor between load and unload stations (m),
- v_c = conveyor velocity (m/min)

Let's consider this element
 Rate that is balanced
 Minutes in an hour
 Velocity of conveyor
 Total pan hold those parts

25 sec/cycle
 60 min
 40 m/min
 700 parts

Units

m
 parts/min
 parts/sec

Sc 16.67
 Rf 1680
 or 28

 28 ≥ 25sec

Figure 8. Calculations of coal transportation of 700 parts