COAL INTERNATIONAL

Volume 269 · Number 4

July-August 2021

# Justifying conveyor system equipment upgrades

Safe, efficient conveying systems are the lifeblood of many large coal mining operations.

From mining to biomass, industries that handle bulk materials depend on intelligent, hardworking individuals who can be trained and promoted to positions from which they go on to make experience-based decisions. Using their expertise, they are often tasked with identifying conveyor system issues and proposing critical changes to improve production, safety and efficiency. These projects typically require capital investments, and convincing management to earmark budgets for improvements requires supporting data, solid ROI projections, thoughtful persuasion and good timing.

"Collecting the proper data and presenting convincing arguments is almost an art form," said Dan Marshall, Process Engineer at Martin Engineering. "The first few times you do it can be frustrating and tedious. But reviewing some of the company's past proposals – including those that were rejected – is always educational and working with the manufacturer of the proposed equipment can be helpful."

## CHOOSING THE RIGHT KPIS

Measuring performance requires data, so determining the most relevant Key Performance Indicators (KPIs) is important. These measurements help create evidence for stakeholders so they can make informed budget decisions. From a single piece of equipment to an entire project involving multiple components, KPIs should be part of any strategic process to assess performance and help set objectives. Often displayed in graphs or charts for visual effect, performance measurements relay trends and progress related to a goal that can be easily recognised and absorbed[1].

There are two types of KPIs, *leading* and *lagging*. Leading KPIs are those that indicate future problems which can cause expensive unscheduled downtime, such as Mean Time Between Failure (MTBF). Lagging KPIs are those that happen during or after downtime, such as "reactive maintenance." Keep in mind that KPIs require a reasonable period to collect the data, sometimes stretching across an entire year or more. Benchmarks by which to measure failure or success of the performance metrics are essential.

Common Types of Bulk Handling KPIs:

1. *Unscheduled Downtime* – Labor and servicing during an emergency shutdown are estimated to be three to seven times more expensive than scheduled downtime when workers are not pulled from other essential duties and contractors have time to offer competitive estimates. For example, just a one-percent difference in system

availability for a coal-fired power plant could be worth one to two million US dollars in annual revenue. The cost of even the shortest unscheduled outage is prohibitive.

When calculating the cost of downtime, common expenses to include are:

A. Lost opportunity cost (missed sales, supply line impact, etc.)
B. Purchase of replacement components
C. Maintenance labor
D. Subcontractor labor
E. Consulting and engineering fees
F. Testing and analysis

2. *Labor Costs and Fees* – Although these are included in determining the cost of unscheduled downtime, they are both leading and lagging KPIs, essential budget line items to determine the viability of any pending project. All maintenance related to the targeted project component(s) should be logged, including servicing of the system leading to and from the component(s).

3. *Direct and Indirect Costs* – Direct costs can include labor, but generally also cover replacement equipment, contractor costs, production losses and injuries. Indirect costs are investigations and settlements as a result of injuries or accidents, increased energy usage, increases in insurance premiums, MSHA or OSHA fines and qualitative costs like poor morale, etc.

4. *MTBF* – Mean time between failures is the average uptime between unscheduled outages. It is a vital performance metric to measure safety and equipment design and aids in determining new equipment's return on prevention (ROP) as compared to existing equipment[2]. ROP is an abstract representation of the potential economic success of occupational safety and health. Equipment with a better ROP is generally higher quality, with less maintenance required. It can be expected to carry a somewhat higher purchase price, so MTBF is key to justifying the cost and safety benefits.

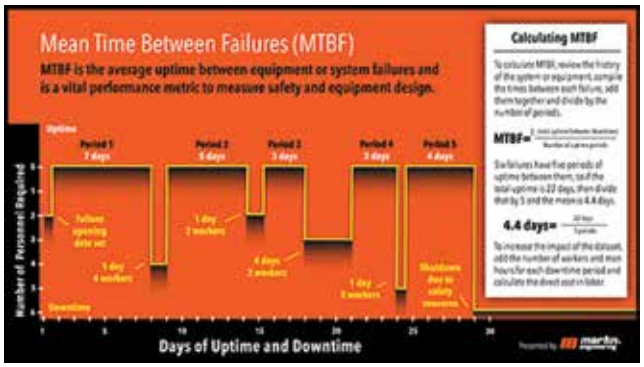


**Figure 1:** MTBF calculated over a sample period.

To calculate MTBF, review the history of the system or equipment, compile the times between each failure, add them together and divide by the number of periods. For example, six failures have five periods of uptime between, so if the total uptime is 22 days, dividing that by five makes the mean 4.4 days. To increase the impact of the dataset, add the number of workers and man-hours for each downtime period and calculate the direct cost in labor. [**Figure 1**]

5. *Opportunity Cost* – Opportunity cost is the value of production lost due to unscheduled events such as machine breakdowns, shutting down to clean up fugitive material or safety incidents. The concept is that if the product is not available for processing, and therefore sale, a profit opportunity is lost. [**Figure 2**]

## MAKING THE CASE

"As technical people who work with the equipment day in and day out, perhaps the most difficult part of this process is having to justify or 'sell' it to management," said Marshall. "To do this, operators need a good narrative, solid data, reasonable cost projections and a convincing ROI (return on investment)."

Stakeholders will typically visit the area when the system is working well, so photos and video bolster the narrative and help with visualization. More is better, and quality matters. Graphs are also invaluable for visualization, so plan KPIs with a clear X & Y axis that will reveal evident "differences over time" or "costs per unit," etc.

ROI is extremely important in any equipment purchase but calculating it can be tricky. That is why all direct and indirect costs need to be applied. The goal for many smaller projects such as belt cleaner upgrades is to get the payback period to 1 year or less. [**Figure 3**] Categorise all possible causes of increased costs and then figure out the costs associated with each category.

For example, calculating ROI to upgrade belt cleaners starts first with isolating a cleaner, then identifying the challenges associated with it. Likely one category will be spillage from carryback. Some of the common costs associated with spillage are cleanup time/labor, low air quality, safety (lockout/tagout, PPE, etc.), replacement parts (fouled rollers and machinery) and unscheduled downtime. [**Figure 4**]

Although ROI is a focus for management, Return on Prevention is arguably just as important. Staying with the example above, lower quality equipment may offer a quicker ROI but might only clean 80% of material from the belt and deliver a shorter service life before unscheduled downtime starts all over again due to dust and spillage. Higher quality equipment with proven performance may be a higher cost with a slightly extended ROI, but the cost is generally justified over the long term. Reviewing equipment

$$\text{Opportunity Cost} = \frac{\text{tons}}{\text{hour}} \times \text{Unplanned Downtime (hours)} \times \left[\frac{\text{Sales(\$)}}{\text{ton}} - \frac{\text{Cost of Sales(\$)}}{\text{ton}}\right]$$

**Figure 2:** Opportunity cost calculation[2].

**RDI conversions**

| ROI | Payback years | Payback months |
|---|---|---|
| 10% | 10.0 | 120.0 |
| 20% | 5.0 | 60.0 |
| 30% | 3.3 | 40.0 |
| 40% | 2.5 | 30.0 |
| 50% | 2.0 | 24.0 |
| 60% | 1.7 | 20.0 |
| 70% | 1.4 | 17.1 |
| 80% | 1.3 | 15.0 |
| 90% | 1.1 | 13.3 |
| 100% | 1.0 | 12.0 |

**Figure 3:** ROI payback over the specified time[1].

**Data used in ROI calculations**

| Data | Units |
|---|---|
| **Administrative/operating** | |
| Cost of compliance: record keeping and reporting | currency |
| Health and liability insurance premiums increase | currency |
| Reduced life of equipment | currency |
| Safety/environmental fines | currency |
| Legal costs | currency |
| Energy costs | currency |
| Waste disposal costs | currency |
| **Production** | |
| Throughput: per hour, day, week, or month | tons (st) |
| Production time | hours |
| Cost per ton of bulk material | currency/ton (st) |
| Cost of down time | currency/hour |
| Cleanup manual (1 ton per hour is avarage) | labor cost/hour |
| Cleanup machine (5 tons per hour is average) | labor and machine cost/ hour |
| Lost product due to dust and spillage | 0.5% to 3% of production rate is typical |
| **Safety** *(Reference 31.2)* | |
| Cost of recordable incident | currency |
| Cost of lost-time incident | currency |
| **Maintenance** | |
| New installation: *estimated cost of labor and materials* | currency |
| Adjustment: *estimated labor cost per adjustment* | currency |
| Replacement Parts: *cost of parts and labor* | currency |
| Equipment wear: *cost of belt and wear-resistant mateials* | currency |

**Figure 4:** ROI categories for a belt cleaner replacement[1].

Factory-trained personnel help ensure that projects will meet government-mandated safety standards.

specs, examining the construction and evaluating case studies from similar applications can help determine ROP.

Successful proposals generally offer a direct line to a solution and the next steps for implementation. Make sure the intent of the project is clear, the bottom line is as close to the real outcome as possible and that all project variables are considered (downtime, labor, installation obstacles, special equipment such as cranes and any associated safety regulations or certifications).

To ensure that projects will meet government-mandated safety standards, insist on factory-trained technicians with certifications from OSHA, MSHA and other industry-recognised organizations. Many equipment suppliers contract their installation and service functions to outside firms, which often represent dozens of different product lines. Personnel trained by the equipment manufacturer and dedicated solely to its proper care will have greater knowledge and experience, ultimately delivering superior results over the long term.

## DETERMINING THE INVESTMENT STRENGTH

One of the most anxiety-inducing aspects of this process is determining how to make the best financial decision on equipment. Luckily, there are the general calculations of net present value (NPV) and internal rate of return (IRR) to help with this endeavor. These are financial tools that can be used to compare investment options, including safety investments.

NPV is a financial measurement of life cycle costing where two or more options are evaluated based on initial price, annual costs and expected life as expressed in terms of today's currency. Generally, the option with the highest NPV would be the wisest choice. IRR shows the annual compounded rate of return on an investment and is defined as the interest (or discount) rate that makes the NPV equal to zero.

NPV and IRR are calculated in **Figure 5**. The calculations are linked to:

- Cash Flow = the expected savings for a specific year minus the costs of operating and maintaining the project

$$\text{Net Present Value} = -\text{Initial Investment} + \sum_{i=1}^{I} \frac{\text{Annual Cash Flows}}{(1+R)^i}$$

$$\text{NPV} = -\text{Initial Investment} + \frac{\text{Cash Flow Year 1}}{(1+R)^1} + \frac{\text{Cash Flow Year 2}}{(1+R)^2} + \frac{\text{Cash Flow Year 3}}{(1+R)^3} \ldots$$

$$\text{Internal Rate of Return} = \text{What Rate R will Make NPV} = 0?$$

$$0 = -\text{Initial Investment} + \frac{\text{Cash Flow Year 1}}{(1+\text{IRR})^1} + \frac{\text{Cash Flow Year 2}}{(1+\text{IRR})^2} + \frac{\text{Cash Flow Year 3}}{(1+\text{IRR})^3} \ldots$$

**Figure 5:** NPV and IRR are common industry-wide tools used to approximate investment strength[2].

in that year.

- I = The total number of periods (usually years) used in the analysis.
- Initial Investment = the initial purchase, delivery and installation costs of the project.
- R = the weighted cost of money for the company from all sources: borrowing, selling stock, etc. Expressed as a decimal and often called the discount rate, this can also be thought of as the inflation rate.
- IRR = the discount rate that makes the NPV equal to zero.

## HALF MEASURES OFTEN ACHIEVE LESS THAN HALF RESULTS

Purchasing decisions are often based more on price and what's in the budget than on achieving performance (ROP) and reducing costs. A common question is: "This is what I have in the budget, what can you do for that?" The correct answer is often, "Nothing." That's because taking half measures often only temporarily treats the symptoms of conveying problems and doesn't address the root causes. To illustrate the point, a belt cleaning case study[3] is analyzed using actual customer data and making some assumptions based on industry averages[2]. The installation and maintenance costs consider that the conveyor is a reversing design and dual belt cleaners were installed at both ends. It's critical to specify equipment that is designed for safety and ease of service, rather than just seeking the lowest-cost options. These components may carry a slightly higher initial price, but they will pay off over the life of the equipment and ultimately result in lower life cycle costs.

Belt Cleaning effectiveness is the % of material the cleaner removes from the belt and is measured by the grams per square meter ($g/m^2$) that the cleaner removes from the dirty portion of the belt. Many manufacturers claim 98% or more cleaning efficiency without specifying 98% of what: 98% of 500 $g/m^2$ or 98% of 100 $g/m^2$ of carryback? The desired result is not cleaning efficiency, but the effectiveness in reducing carryback – expressed in the tons of fugitive material that have to be cleaned up. In this study the carryback levels were measured by a technician using a standardised test method. Equipment design and effective maintenance are keys long term safety and cost control. Components that are engineered with these priorities will deliver longer service life and reduce maintenance costs, while minimising the risks inherent to bulk conveying. In this analysis, the effectiveness is assumed to be 50% for the precleaner and 55% for the secondary. It was assumed the cleanup was done manually by shoveling at a rate of ½ a ton per hour and labor cost is $25/hour.

The 5-year time frame was chosen as a reasonable life for this type of equipment. Doing nothing is costing $800,800 in discounted cash flow over 5 years. For spending an additional $10,000 up front on equipment and $5,000 a year in maintenance, the additional cash flow for the full solution (installing two cleaners on each end of the reversing conveyor) compared to the half solution is $201,700 on labor alone for the dual cleaning system vs. a single belt cleaner on each end of the conveyor and $578,000 compared to doing nothing.

| Customer data | | Assumptions | |
|---|---|---|---|
| Material | Frac Sand | Initial Installation Cost | $20,000 |
| Carryback Before | 4,225 tons/y | Annual Maintenance Cost | $7,000 |
| Carryback After | 930 tons/y | Cost of Money | 10% |
| Additional Sales | $400,000 | Evaluation Time Frame | 5 years |
| Downtime Reduced | $? | Cleanup Rate per Hour | 0.5 t/h Shoveling |
| Cleanup Reduced | $? | Belt Cleaner Effectiveness | 50% & 55% |
| Safety Savings | $? | | |

**Figure 6:** Belt Cleaning Case Study Data.

| | Cleaner Effect. | Carryback Clean Up | Labor Cost/y @ 0.5 t/h Shoveling | Initial Installation | Annual Maint. | NPV: 5 years @ 10% |
|---|---|---|---|---|---|---|
| Before Upgrade | 0% | 4225 t/y | $211,250 | $0 | $0 | $800,800 |
| NPV of Cash Flows from Labor Savings | | | | | | |
| Half Solution 2 Precleaners | 50% | 2113 t/y | $105,650 | $10,000 | $3,500 | $377,300 |
| Full Solution 2 Precleaners & 2 Secondaries | 77.5%[a] | 950 t/y | $46,500 | $20,000 | $7,000 | $578,000 |

[a] Assume the dirty belt has 100 g/m$^2$ of carryback. Effectiveness = 100 g/m$^2$ x [(1-50%) x (1-55%)] = 22.5 g/m$^2$ remaining on belt after cleaning or (100g/m$^2$ - 22.5 g/m$^2$)/100 g/m$^2$ x 100% = 77.5% effective.

**Figure 7:** NPV of Cleanup Labor Savings for Half and Full Solutions

If the one-year ROI on the initial investment for the full solution compared to the half solution is considered as savings divided by costs, it would be ($211,250 – 46,500)/$20,000 = 1.76 or 176%, which is very good. But ROI doesn't tell the whole story, and that's why the NPV method should be used. One could also consider adding tertiary cleaners, but at some point there is a diminishing return, as it's not possible to clean a conveyor belt 100% consistently over time.

A company's cost of money may be different, or it may have a different labor rate. Once the NPV spreadsheet is set up, it's very easy to change assumptions, costs and savings to compare the results. If the cash flow from added sales and reduced accident exposure and other identifiable costs are included, it becomes even more clear that best financial, safety and production is the full solution. As is the case of most upgrades for the control of fugitive materials, the ROP is so great that the Internal Rate of Return is off the charts.

## PROJECT MANAGEMENT

The success or failure of a project can come down to good project managers. They manage the schedule and budget to ensure that work is completed on time, and on budget. Establishing reasonable and clear expectations for co-workers, vendors and subcontractors helps ensure the quality of the finished product. Some manufacturers offer conveyor inspections and cleaner maintenance as part of a managed service relationship. Their monitoring systems can track component wear and update the service technician and/or operations personnel via wi-fi or cell phone on upcoming service needs. Some new systems can even adjust belt cleaner tension automatically, and the technology will also send an alert through a mobile app in the event of upset conditions.

Clear scope, budget and timeline management are critical to a successful project.

Factory-trained service technicians provide an added set of eyes on the conveyors, travelling to and from the equipment to be serviced and logging details in their service reports. Because they see so many different applications, they can often alert on problems that maintenance personnel don't see or have become accustomed to ignoring. With factory-direct managed service, the responsibility for maintenance falls on the manufacturer, allowing the staff to focus on other priorities.

At first glance it may seem that a plant has the in-house capacity to maintain belt cleaners, and hiring a managed service provider doesn't make sense. The reality is a conveyor will run with a belt, a head and tail pulley and a drive – maintaining everything else can be put off (and often is) for production at any cost. A "run until broken" philosophy means more than non-functioning equipment – it can increase unplanned downtime, exacerbate financial issues and affect worker morale, too. Then, in the rush to patch things together, maintenance workers are tempted to take shortcuts and work around established procedures, exposing them to greater potential for injury. In contrast, a service contract that employs factory-trained technicians will often result in problems being identified before they become catastrophic failures, reducing downtime and further equipment damage.

Factory-trained direct service personnel and replacement parts are key to obtaining expert maintenance for optimum performance and component life, leading to on-time deliveries and high customer satisfaction. Some manufacturers will even supply free remote monitoring and reporting equipment that's accessible by wi-fi or cell phone. These managed service technicians, supported by a financially stable, well-established manufacturer and armed with the specific knowledge and equipment to do the job, are often the answer to common belt cleaning

A properly configured conveyor controls emissions for improved safety and easier maintenance.

problems. For these technicians, who spend every day assessing and servicing belt conveyors, maintenance and repairs become more of a precise science than a judgement by rule of thumb.

## PRIORITIZING SAFETY JUSTIFIES THE COST

Often issues like excessive dust, mistracking, spillage, carryback, etc. are considered commonplace and "the cost of doing business." In reality, they are extremely unsafe, costly and easily remedied with modern equipment. A common injury for cleaning or maintenance personnel is a muscle strain. A common injury for cleaning or maintenance personnel is a muscle strain. The OSHA Safety Pays Calculator[4] estimates the cost of a single lost time muscle strain injury at $32,023 in direct and $35,225 in indirect costs for a total of $67,248. If there is a history of safety incidents, improvements can often be justified on safety alone. Identifying that an issue exists is the first hurdle; another is asking for help collecting data and making sure it's recorded correctly. Keeping the project and equipment decisions simple and safety-focused is the best approach.

Regular inspections by factory-direct professionals help minimise downtime and improve efficiency.

"The earlier service technicians are brought into the process, the more they can assist," Marshall added. "We often walk the belt and inspect conveyor systems along with operators to find practical solutions that can help define their KPIs, narrow the scope of data collection and get them to their goal faster and more safely. Regularly-scheduled reviews of conveyor belts, cleaners, tracking, chutes, dust control and other components from experienced specialists with extensive training and expertise will help conveyor operators maximise productivity and reduce downtime.

## REFERENCES


1. Swinderman, R. Todd; Marti, Andrew D.; Goldbeck, Larry J.; Marshall, Daniel; Strebel, Mark G.: Foundations; Fourth Edition; pg. 465, pg. 443; Martin Engineering; Worzalla Publishing Company; Stevens Point, Wisconsin 2009.

   https://foundations.martin-eng.com/foundations-4-book-download
2. Swinderman, R. Todd; Marti, Andrew D.; Goldbeck, Larry J.; Marshall, Daniel; Strebel, Mark G.: Foundations for Conveyor Safety; First Edition; pg. 451; Martin Engineering; Worzalla Publishing Company; Stevens Point, Wisconsin 2009. https://foundations.martin-eng.com/foundations-4-book-download
3. Martin Engineering Problem Solved Paper, https://www.martin-eng.com/content/case_study/16434/belt-cleaners-reduce-carryback-78-percent
4. https://www.osha.gov/safetypays/estimator accessed 6/30/21


**Martin Engineering** is a global innovator in the bulk material handling industry, developing new solutions to common problems and participating in industry organizations to improve safety and productivity. The company's series of Foundations books is an internationally-recognised resource for safety, maintenance and operations training – with more than 20,000 print copies in circulation around the world. The entire 500+ page volumes can also be downloaded as free PDFs from the Martin web site. Martin Engineering products, sales, service and training are available from 19 factory-owned facilities worldwide, with wholly-owned business units in Australia, Brazil, Chile, China, Colombia, France, Germany, India, Indonesia, Italy, Japan, Mexico, Peru, Russia, Spain, South Africa, Turkey, the USA and UK. The firm employs more than 1,000 people, approximately 400 of whom hold advanced degrees. For more information, contact info@martin-eng.com, visit www.martin-eng.com, or call (800) 544-2947.



**R. Todd Swinderman**
*CEO Emeritus / Martin Engineering*