Using a Risk-Cost Calculator to make Good Maintenance Decisions

Abstract

Using a Risk-Cost Calculator to make Good Maintenance Decisions. Maintenance is a risk management strategy used to control plant and equipment operating risk. Because risk is situational dependent there is no one universally right maintenance choice that always applies regardless of circumstances. A risk cost calculator is a simple spreadsheet tool to study the risk in a situation and help you understand the impact of the choices that you have available to address the risk.

Keywords: operational risk management, risk control, risk reduction, risk model tool,

Albert Einstein advised us that, "Everything should be made as simple as possible, but not simpler". Unfortunately, the opposite has happened in the case of the risk equation—it has been made so simple that most of its value to business risk management and operational risk management has been lost. It is now too simple for us to use to fully understand our dangers and our options for managing risk. Fortunately, a risk cost calculator lets us use the risk equation in a realistic and useful fashion.

The simplified risk equation is usually written as:

Risk = Consequence ($) x Likelihood of Failure (/yr)

The risk equation is so simplified that it misleads us and hides its full usefulness to us. Unfortunately, it is so widely used in books about risk that people think that is all that there is to it. As a result, they miss the great decision-making value that is hidden in the equation.

The 'Likelihood of Failure' actually divides further so the full risk equation becomes:

Risk = Consequence ($) x [No. of Opportunities (/yr) x Probability of Failure]

- The 'Consequence' is the cost to the business if the risk happens.

- The 'Number of Opportunities' is how many times a year the situation arises, that should it go wrong, will produce the failure event (if an event happens every two years, then the chance is 0.5 ($^1/_2$) per year).

- The 'Chance of Failure' (or Probability) is the odds that a situation will go through to failure. It is one (1) if it will definitely fail every time the situation arises and zero (0) if there will never be a failure if the situation arises. It normally takes values between 1 and 0 because the chance of a thing going wrong is usually possible to some degree.

A vital connection that is missed in the simplified version of the risk equation is how risk and reliability are locked together. Reliability is the opposite of the probability of failure. If you want to reduce your operating risk simply increase the reliability of your operating plant and equipment.

Risk = Consequence of Failure x [Frequency of Event x Probability of Failure]

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We can in fact control risk in three ways:

1. **Consequence reduction:** If an unwanted event happens you act to reduce the consequence (i.e. its impact or severity). For example, if a fire starts in your kitchen you get the fire brigade out fast so only one room is destroyed but not the whole house. After the fire you wonder if there should have been a fire extinguisher or fire blanket available close-at-hand (yes is the right answer because it probably would have saved the kitchen). In the case of a wise business, they will have emergency plans already developed to address unwanted events. Having the emergency plan minimises the impact of the event—the event will already have happened when the emergency plan is activated but the plan comes into operation to limit the losses.

2. **Opportunity removal:** You remove the opportunity for the event to happen. The opportunity for a kitchen fire is not possible if there is no fuel source to burn. For example, instead of cooking a meal that creates hot oil spitting over the stove, which can collect and sustain a fire, you cook a different meal that does not need boiling hot oil.

3. **Chance reduction:** You minimise the chance that a problem can occur in a risk event situation. If you must use boiling hot oil in the kitchen to make a favourite meal, then cook with the lid on the pan so less oil will spit out and thereby lessen the amount of oil to catch alight.

The simplified risk equation limits our thinking by listing only two factors for managing risk — consequence and likelihood. Because of the equation's simplicity we miss the full complexity of risk, and we miss spotting other viable solutions. A fuller appreciation of risk and of our migration choices is possible by using a risk cost calculator that makes us look at the whole situation and all our risk control options.

Risk Cost Calculator

The operating and maintenance decisions available in a situation can be assessed with the use of a risk cost calculator. A risk cost calculator turns the risk equation into an interactive risk model. Typically, the calculations are done in a spreadsheet table and the results can even be displayed graphically on a chart. We will use the example of the risk event in Figure 1 to see how a risk cost calculator is developed and used.

The image in Figure 1 is of a seized return roller on a mined ore conveyor system. It is an event well known in the mining industry that occurs from time to time when a roller cannot be quickly and easily replaced (known as maintainability). Often the repair work is left until a shutdown when it can be safely accessed.

The problem with waiting to do the roller replacement is that the seized roller wall casing can be worn to a knife-edge by the conveyor belt at the spot the belt rubs on the roller over the next few weeks of operation. Once the knife edge forms the opportunity exists that the edge can cut into the rubber belt and rip its full length. A ripped belt is a major production outage and a big maintenance job to install a new belt. In some situations, the knife edge shreds rubber shavings off the belt which can collect around the drive motor and gearbox. If some part of the equipment gets hot enough e.g. from friction heating, or a spark is generated, the rubber shavings catch fire and burn the complete conveyor system and drive. If that happens the site is forced to close down and rebuild the entire conveyor system.

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Figure 1 Failed Conveyor Return Roller

Figure 2 Roller Wall Cut-away

The cut-away of a light-weight roller in Figure 2 shows you the roller wall and how the wall creates a knife edge once the roller wall is worn through. The wall thickness on mining conveyor rollers is 4mm-6mm, much more than that of the roller in Figure 4, but the wall will still be worn through if the belt is allowed to rub over it for long enough.

The risk scenarios are identified one situation at a time. Had the roller been in proper working condition there would be no risk of a catastrophic event. The risk can be indicated on a risk matrix such as that in Figure 3, which shows that for an annual maintenance cost of $1,000 there is an estimated risk of a failure event happening once in 1,000 years.

The risk matrix in the figure is calibrated with a Low boundary set at an equivalent risk of $10,000 per year. Above the Low risk boundary, you would act to reduce risk to Low or less.
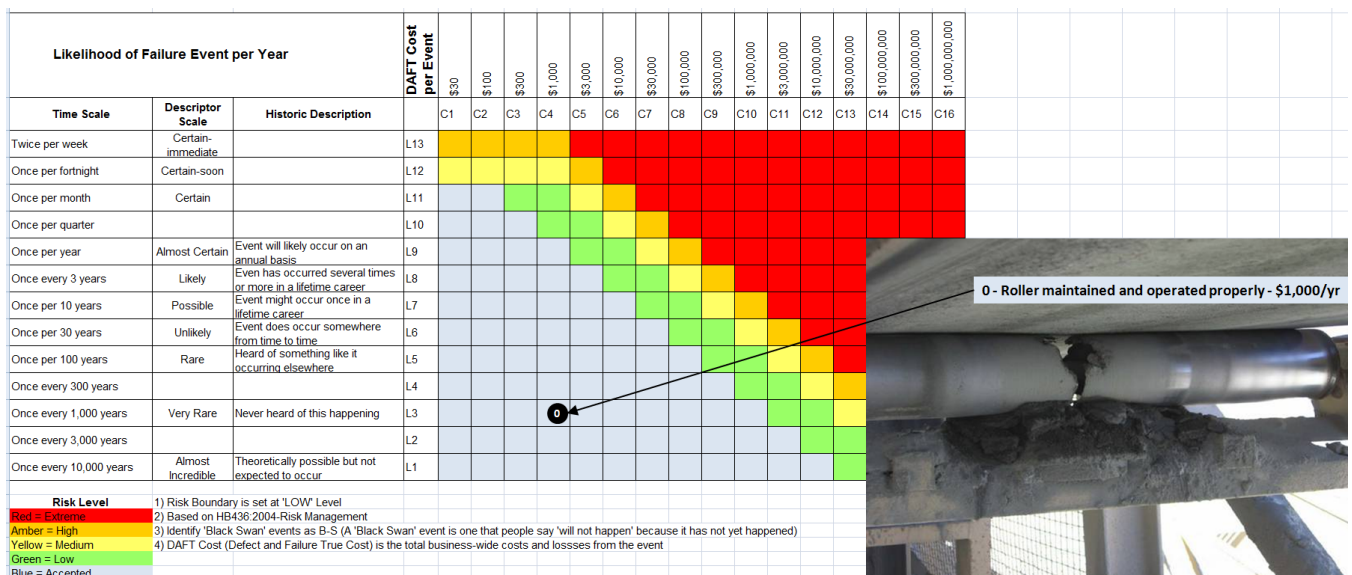
Figure 3 Risk when Conveyor Roller is Operating Properly

Should one of the roller bearings in the return roller start to fail the risk now changes because the path to a catastrophic failure has started. The new risk is shown in Figure 4. The bearing is still turning but it is running hotter because a failure mode has initiated. The cost to repair the bearing is now $12,000 and if nothing is done it is estimated that in about eight weeks time, two months, the bearing will seize.

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Once a bearing in the roller seizes the roller stops turning and the belt begins to rub across the roller wall gradually wearing it away to eventually create a knife edge where the belt touches the roller.
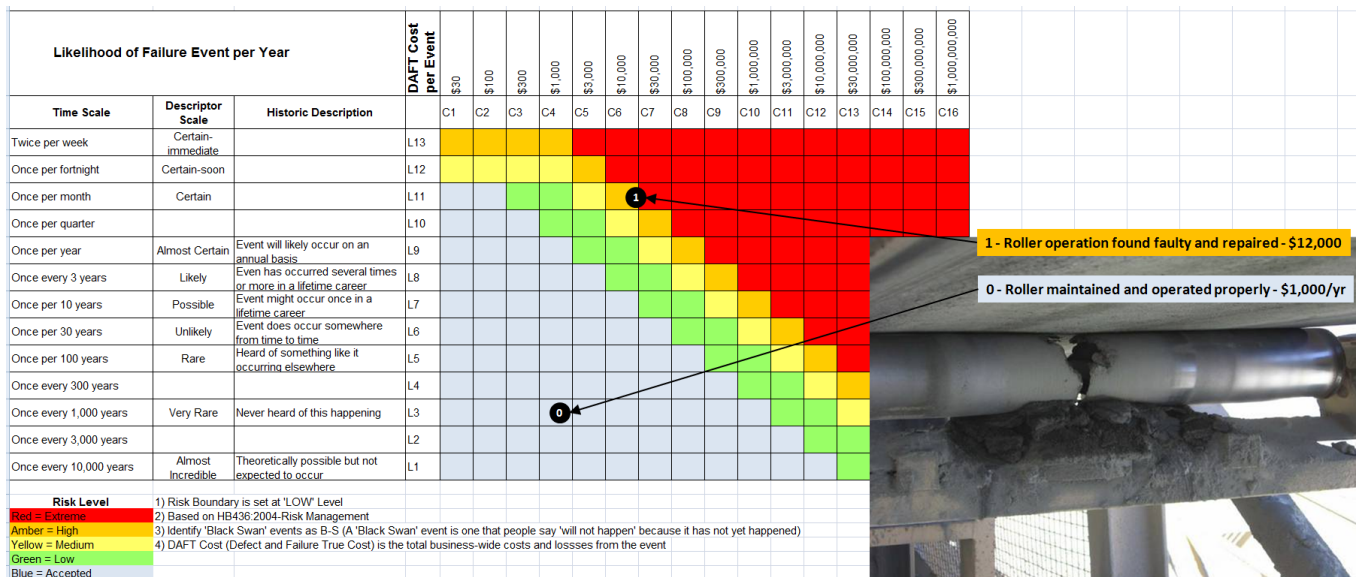
Figure 4 Risk if Bearing in Conveyor Roller starts to fail

If the roller is not replaced before the knife edge forms the conveyor belt is then at risk of being ripped its full length. This is an event that one often hears about in the mining industry and its chance of occurrence is several times in a working career. The risk of ripping a belt because of a knife edge on a roller is shown in Figure 5. The cost, should the belt rip event happen, will be a total cost of $200,000 to stop the operation for a day or two and fit a new belt.
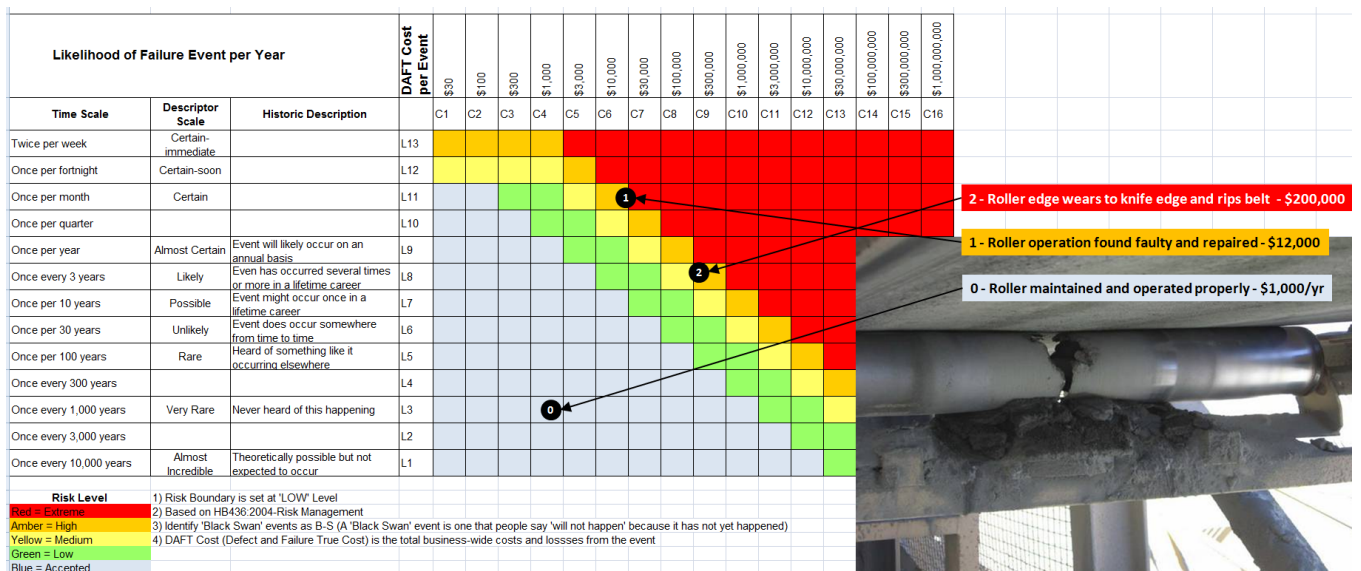
Figure 5 Risk if Bearing Seizes and Belt Rubs a Knife Edge into the Roller Wall

If the knife edge instead peels shreds of rubber from the belt and the shavings get deposited at a position to catch alight the entire operation will be stopped for months to replace machines and structures if a fire was to occur. The risk of a belt fire from shredded rubber is presented in Figure 6. Should the belt fire event happen it will be a $10,000,000 catastrophe.

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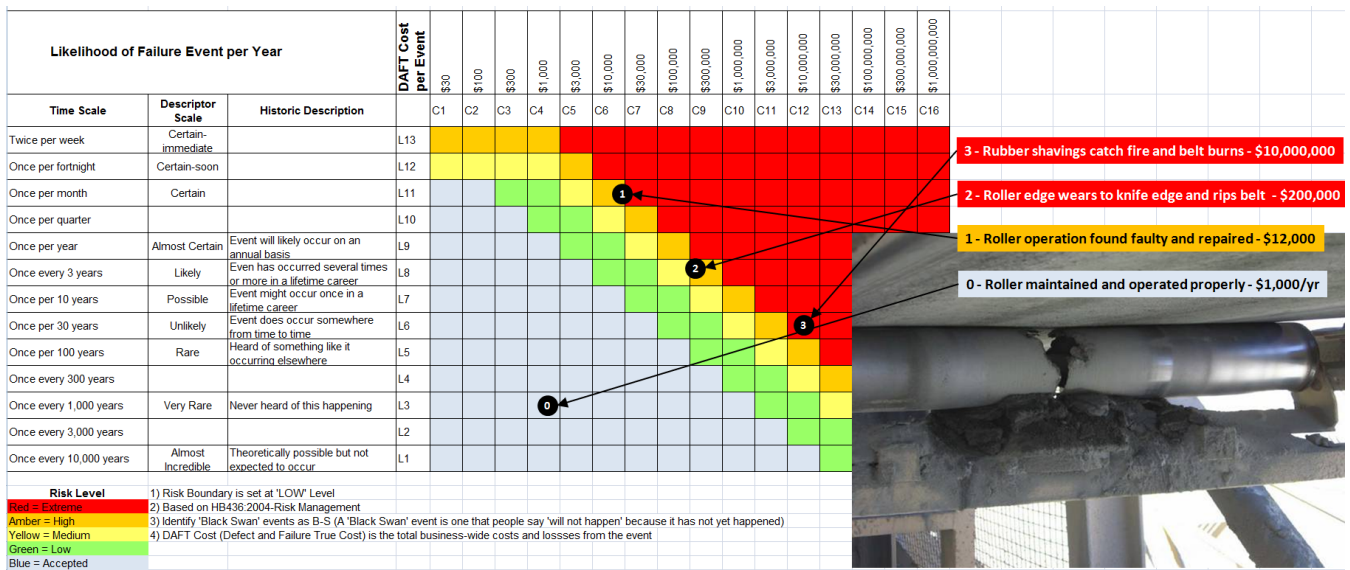| Likelihood of Failure Event per Year			DAFT Cost per Event	$30 C1	$100 C2	$300 C3	$1,000 C4	$3,000 C5	$10,000 C6	$30,000 C7	$100,000 C8	$300,000 C9	$1,000,000 C10	$3,000,000 C11	$10,000,000 C12	$30,000,000 C13	$100,000,000 C14	$300,000,000 C15	$1,000,000,000 C16
Time Scale	Descriptor Scale	Historic Description																	
Twice per week	Certain-immediate		L13																
Once per fortnight	Certain-soon		L12																
Once per month	Certain		L11																
Once per quarter			L10																
Once per year	Almost Certain	Event will likely occur on an annual basis	L9																
Once every 3 years	Likely	Even has occurred several times or more in a lifetime career	L8																
Once per 10 years	Possible	Event might occur once in a lifetime career	L7																
Once per 30 years	Unlikely	Event does occur somewhere from time to time	L6																
Once per 100 years	Rare	Heard of something like it occurring elsewhere	L5																
Once every 300 years			L4																
Once every 1,000 years	Very Rare	Never heard of this happening	L3																
Once every 3,000 years			L2																
Once every 10,000 years	Almost Incredible	Theoretically possible but not expected to occur	L1																

3 - Rubber shavings catch fire and belt burns - $10,000,000
2 - Roller edge wears to knife edge and rips belt - $200,000
1 - Roller operation found faulty and repaired - $12,000
0 - Roller maintained and operated properly - $1,000/yr

Risk Level
Red = Extreme
Amber = High
Yellow = Medium
Green = Low
Blue = Accepted

1) Risk Boundary is set at 'LOW' Level
2) Based on HB436:2004-Risk Management
3) Identify 'Black Swan' events as B-S (A 'Black Swan' event is one that people say 'will not happen' because it has not yet happened)
4) DAFT Cost (Defect and Failure True Cost) is the total business-wide costs and losses from the event

Figure 6 Risk of a Belt Fire

The Risk Changes as Events Occur

The above scenarios show risk of events from the point in time a bearing has a problem that can cause its failure. If the bearing does not seize there will be no catastrophic failures because their cause could not occur. But as each stage of possibilities take place and an event happens the risk no long stays the same as it was before the event—it rises sharply. The risk of disaster once a knife edge is formed in the roller is vastly greater than before there was an edge present. In the risk scenarios above we were looking into future risk from when the bearing had started to fail. There was plenty of time ahead of us to correct the problem because there was no knife edge to create a believable failure event—there was no opportunity for failure. Once a knife edge developed the opportunity for disaster was ever present and from that point onward a belt failure became certain. In Figure 7, Point 1 is the risk of a belt rip once there is a knife edge. Now the potential of belt rip is present because the opportunity is always there. All that is left to save us is the chance of the rip starting. If we wait long enough you can almost guarantee the belt will get ripped.
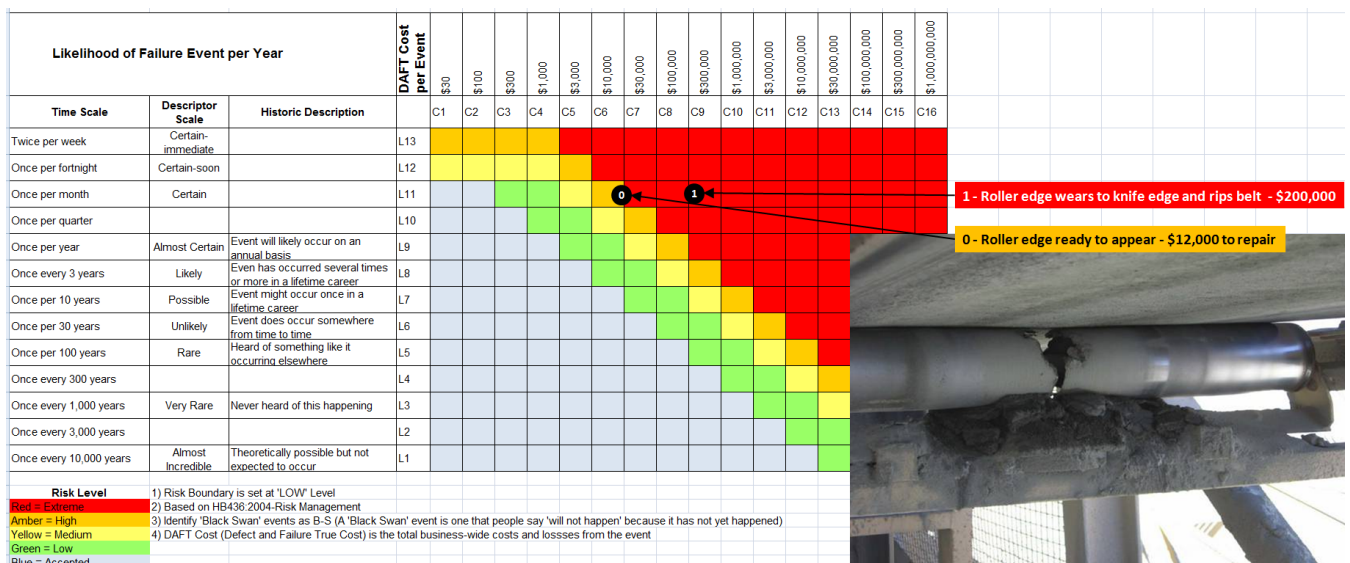
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1 - Roller edge wears to knife edge and rips belt - $200,000
0 - Roller edge ready to appear - $12,000 to repair

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Figure 7 Risk at the Point the Knife Edge appears in the Roller Wall

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Having the knife edge present all the time raised the risk of belt rip to a near certainty—the only unknown was when it would happen or if the situation could deteriorate to a belt fire. The consequence was always $200,000 should a belt rip happen. Once a knife edge appears opportunity is always there, and the rip is not long to happen. Point 2 in Figure 8 is the risk of a belt fire once the knife edge is worn into the roller. In this stage the opportunity to have shavings is lower than that of a belt rip and the chance of a heat source that starts a rubber fire is also low, though possible, as belt fires are often heard about in the mining industry. The consequence of a belt fire is always $10,000,000, the opportunity is always present once the knife edge develops, leaving the chance of failure as the only variable—i.e. luck. The conveyor ought to be immediately stopped and the roller replaced, otherwise you would have to start hoping only for a ripped belt and not a fire.
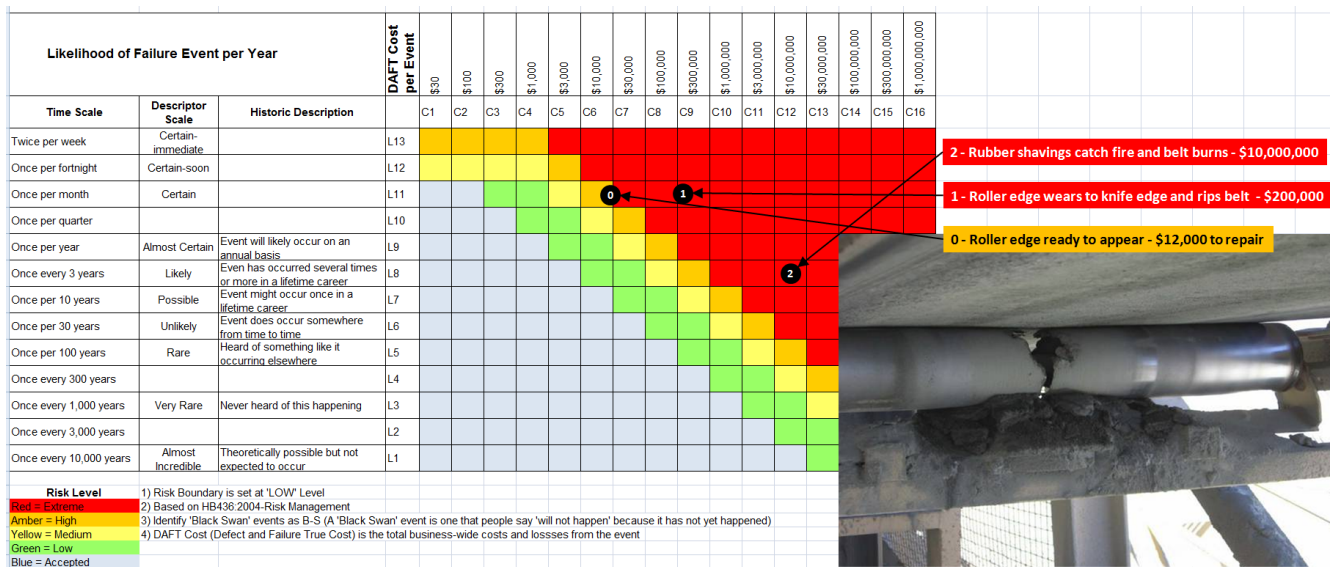
Figure 8 Risk of Belt Fire once Conveyor Roller has Knife Edge

Determining Risk with a Risk Cost Calculator

You can model risk scenarios with a risk cost calculator such as the one in Figure 9. All the risk situations previously shown on risk matrices could have been worked through using a risk cost calculator developed in a spreadsheet.

Figure 9 A Risk Cost Calculator is Used to Model Risk Scenarios

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The risk cost calculator lets you investigate the short-term and long-term implications of your choices. It is a great tool for modelling risk situations so that you can better understand what sensible decisions in the circumstances are.

In the case of our seized return roller, it clearly is not sensible to let it deteriorate to the knife edge. If you decide to wait six weeks to the shutdown and replace the roller you are risking your operation on the toss of a coin (a 50-50 chance). If you want to wait six weeks you must reduce the 50-50 chance of failure by doing something to prevent a knife edge forming. You want to reduce the odds to less than one percent that the belt will rip in the next six weeks. Even then you will watch the roller every second to make sure you stop the belt the instant a knife edge appears.

Would it not have been far easier and much better business just to make sure that the bearings in the roller were always in good health.

My best regards to you,

Mike Sondalini
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