Simple Solutions to Complex Issues –

Risk – Cost – Benefit (RCB) Selection of Optimum Early Warning Technologies

- ***Heavy Equipment Collisions***
- ***Highwall/Lowwall Slope Failure***
- ***Gas Outburst***
- ***Surface Subsidence***

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ABSTRACT

An ACARP funded project has developed a new, minerals industry focussed 'Risk - Cost - Benefit (RCB) Decision Support Tool' to determine **semi-quantitative to quantitative assessment** of the complex risks, costs and benefits associated with safety interventions. The practical tool assists with identifying appropriate technology, assessing whether an appropriate technology reduces that risk, considering and determining an optimal group of controls and calculating the net financial benefit associated with the appropriate technology.

The RCB Project received significant Australian mining industry support and involved five site visits (NSW and QLD), and several meetings with key industry representatives over two year period.

The project has developed two innovative NEW* methods: 1. $\boldsymbol{RCB_{GEN}}$: Risk-Cost-Benefit (RCB) Decision Support Tool; 2. Risk-Control-Effectiveness Model, $\boldsymbol{RCE_{MODEL}}$. The paper introduces these two unique methods and outlines their practical application by providing information about two case studies and examples of their Risk-Cost-Benefit analysis results.

INTRODUCTION

Potential solutions to both financial and personnel risk in the mining industry are delivered by technology and applied research. These solutions are often expensive and both the risk improvement levels and financial benefit of the alternative solutions are poorly quantified. How then does a mining company make reliable decisions to implement these expensive technologies?

A successful joint initiative, funded by the *Australian Coal Association Research Program (ACARP)*, between the *Minerals Industry Safety and Health Centre* (MISHC) and the *WH*

Bryan Mining and Geology Research Centre (BRC) has developed an innovative and unique generic *Risk-Cost-Benefit (RCB) Decision Support Tool* known as **'*RCB*$_{GEN}$'** *(Risk-Cost-Benefit Generator)***,** to determine the complex risks, costs and benefits associated with safety interventions. The practical tool defines a methodology for identifying appropriate technologies/controls, assessing whether an appropriate technology/control reduces that risk, considering and determining an optimal group of technology/controls and calculating the net financial benefit associated with the appropriate technology/control.

RCE$_{MODEL}$ Risk-Control-Effectiveness Model

Technologies generally are developed for very specific risk situations. A new* method, known as ***'RCE$_{MODEL}$'*** *Risk-Control-Effectiveness Model' (Figure 1)*, has been developed to evaluate effectiveness of controls such as Collision Avoidance & Fatigue technology effectiveness *(Kizil & Bye 2008-10[1]).* The *'RCE$_{MODEL}$'* has been successfully integrated into the *'RCB$_{GEN}$'* methodology.

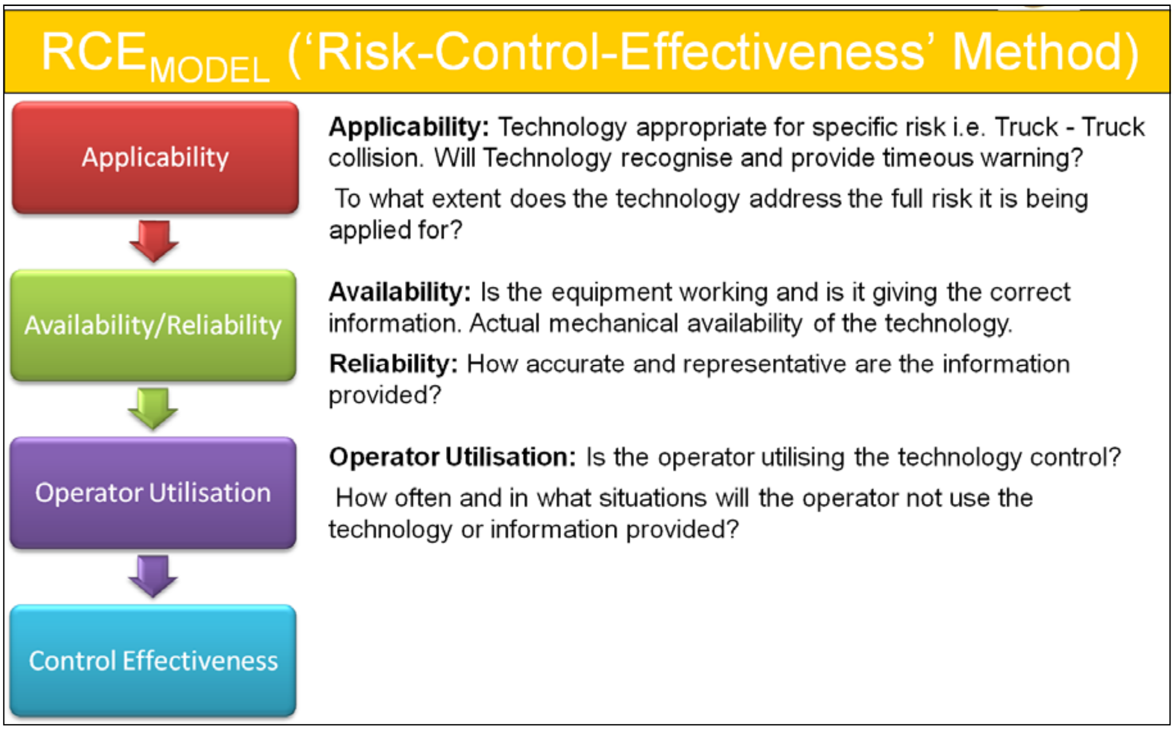

Figure 1. **RCE$_{MODEL}$** (Risk-Control Effectiveness Model) is shown *(Kizil & Bye 2008-10)*

The unique aspects of the ***RCE$_{MODEL}$*** are explained below:

- Innovative and unique in its approach to assess and evaluate effectiveness of a single control and combination of controls that allows identification of an 'optimum group of controls' for the risk considered;
- Undertakes semi-quantitative to quantitative assessment (where possible);

[1] Kizil G, Bye A & Joy J 2008-10. Development of Risk-Cost-Benefit Decision Support Tool for Mining Industry, ACARP Project

- Consists of four main Control Effectiveness categories. The questions posed for each of the control effectiveness categories have been structured to illicit semi-quantitative to quantitative information. For example;

  Availability - What are the mechanical downtime records for the Slope Stability Radar?

The authors recognised and emphasised the importance of the ‘Utilisation’ category of the ***RCE**$_{MODEL}$* as ‘poor control utilisation would/could have an impact on reducing the overall Control Effectiveness of the Control(s) examined. As such, the ‘Utilisation’ category has been treated as important as the Applicability, Availability and Reliability categories. For example, Collision Avoidance Technology, CASCAM RF, assessment involved using site based ‘CASCAM RF Survey Analysis’ results as a part of the Operator Utilisation assessment. Sample categories considered included the following areas:

- Position & Direction of Cameras;
- Position of screen;
- Quality of camera image;
- Screen configuration & Usability; and
- Ease of Use.

There are a few existing Control Effectiveness approaches and these were reviewed in detail by an ACARP Project 26202 *(Joy & Kizil 2008-09[2]).* These methods take a qualitative approach except one that uses a semi-quantitative approach. The fundamental differences between these methods and the new* ***RCE**$_{MODEL}$* include but are not limited to the following areas:

- The ***RCE**$_{MODEL}$* *(Risk-Control-Effectiveness Model),* investigates each technology/control including the reliability of the technology/control **comprehensively** by using semi-quantitative (based on extensive research on Controls, utilising high quality controls information such as industry/organisation research reports, journal articles, as well as manufacturers technology specifications and expert input) to quantitative data (where possible).
- Only model that incorporates the ‘Utilisation’ category. Significant ‘site specific data/information’ is required to fully evaluate this category.

RCB$_{GEN}$ & RCE$_{MODEL}$: MINING SITE BASED APPLICATIONS

Open-Cut & Underground

Once the ***RCB**$_{GEN}$* is configured for a specific application, the ***RCB**$_{GEN}$* enables assessment for different risks within the mine and the selection of the appropriate group of control mechanisms required. The *RCB$_{GEN}$* utilises the ‘*Bow Tie Analysis (BTA)*’ risk analysis technique***.***

The ***RCB**$_{GEN}$* has been applied to a range of key areas related to Open-Cut and Underground Mining operations to improve safety performance / productivity as well as environment related areas as follows:

1. **Truck Collisions;**

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[2] Joy & Kizil 2008-09. *Acceptable Risk: A Matter of Establishing Adequate Control*, ACARP Project 26202 Report

2. **Highwall / Lowwall Failures;**
3. **Gas Outburst;** and
4. **Surface Subsidence.**

The roles of significantly expensive risk reduction measures have been specifically researched. The project has received significant industry support; each case study involved a number of site visits and 'considerable amount of data gathering' and 'Data Analysis'. Two of the case studies and associated examples of RCB analysis results, based on identified typical incident scenarios, are provided below.

Truck Collisions & Risk-Cost-Benefit Selection of *Collision Avoidance & Fatigue Technology*

The comprehensive **'Heavy Equipment Collisions'** industry project gathered and reviewed significant amount of Australian and global mining industry mobile equipment related accident/incident data from the period 2004-2007 (approximately 1500 cases), and focused on heavy equipment collisions (364 cases) (Figure 2). Associated accident investigation reports were gathered and thoroughly reviewed, and all gathered data was analysed. The project also collated a considerable amount of industry data in relation to proximity detection and fatigue detection technologies.

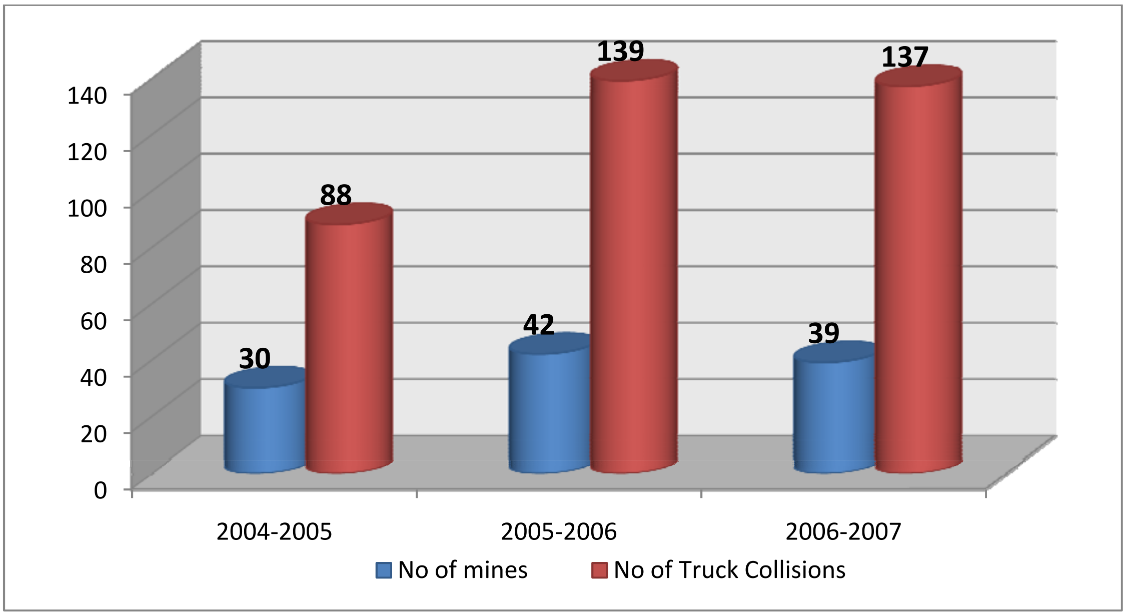

Figure 2. In total, 364 Truck Collisions were identified, reviewed and analysed *(Kizil & Bye 2008-10)*.

Truck Collision project examined Collision Avoidance and Fatigue technology, such as *CasCam RF, Optalert, 360° Radar, Autonomous Truck and a combination of controls*.

Figure 3. CAS CAM RF

Figure 4. Optalert

Figure 5 demonstrates the RCB analysis results for Truck Collisions at mine sites *(based on industry accident/incident data (Australian & global), site specific data, technical reports, research publications, expert views and others)*. Technologies used to reduce '*Human Error*' (HE) and '*Blind Spot*' related Truck Collisions were identified and investigated in-depth including their technical characteristics and site implementation.

The 'Probability of Truck Collisions due to Human Error', **PoC HE**, is shown on the vertical axis, whereas the cost of the technology is shown on the horizontal axis. Each symbol in Figure 5 represents an impact of a technology or combination of technologies on reducing the risk level shown on the vertical axis.

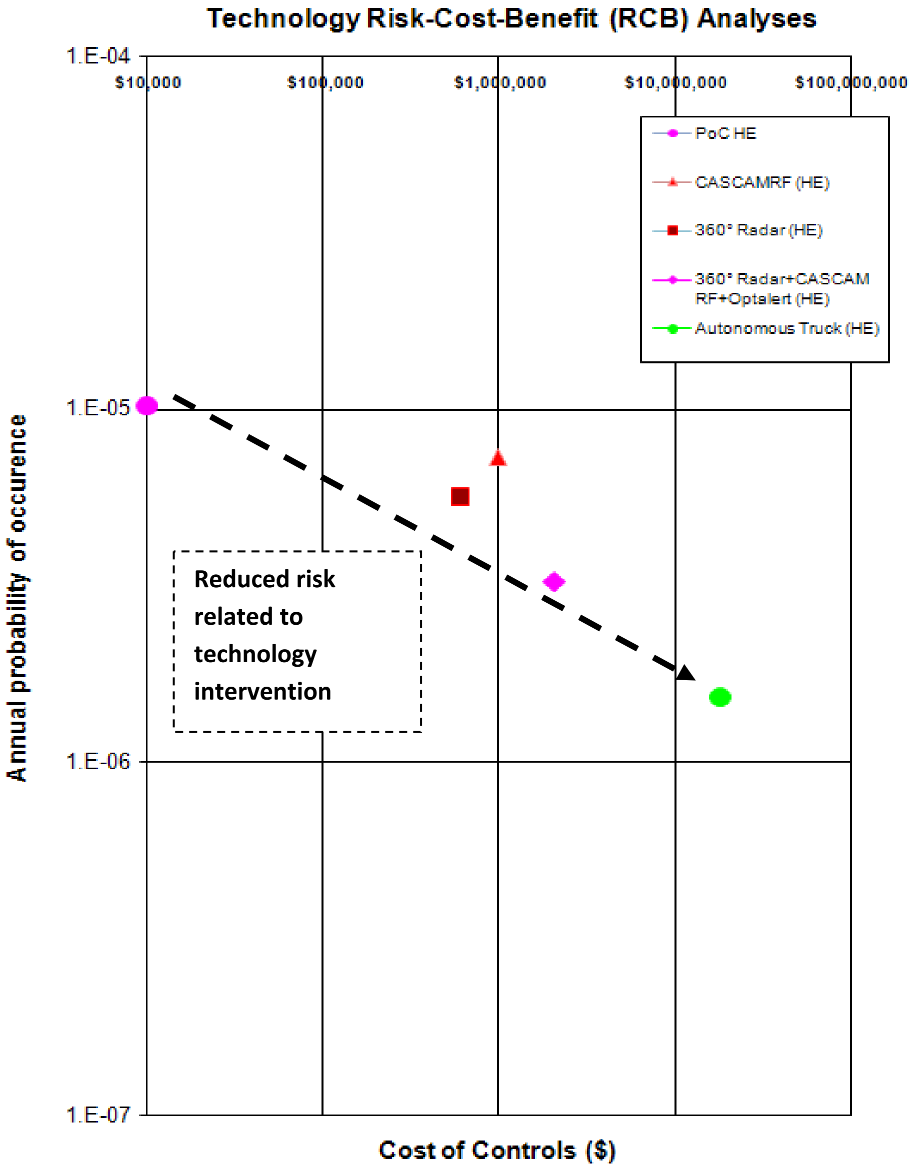

Figure 5. Risk-Cost-Benefit scenario to illustrate the benefit of implementing Collision Avoidance T**echnology** *(Kizil & Bye 08-10)*.

Note: PoC_{HE} - Probability of Truck Collision due to Human Error.

Highwall/Lowwall Failure & Risk-Cost-Benefit Selection of Optimum Group of Early Warning Technology

The second case study concentrated on investigating Highwall and Lowwall failures, likely consequences of such failures, relevant controls including controls implemented at the site where case study was conducted, the potential costs of these controls, and the likely economic benefits from risk mitigation.

The comprehensive **'Wall Failure'** industry project gathered and reviewed a significant amount of site based incident data from the period 2005-2007, and identified and analysed 107 failures (Figure 6).

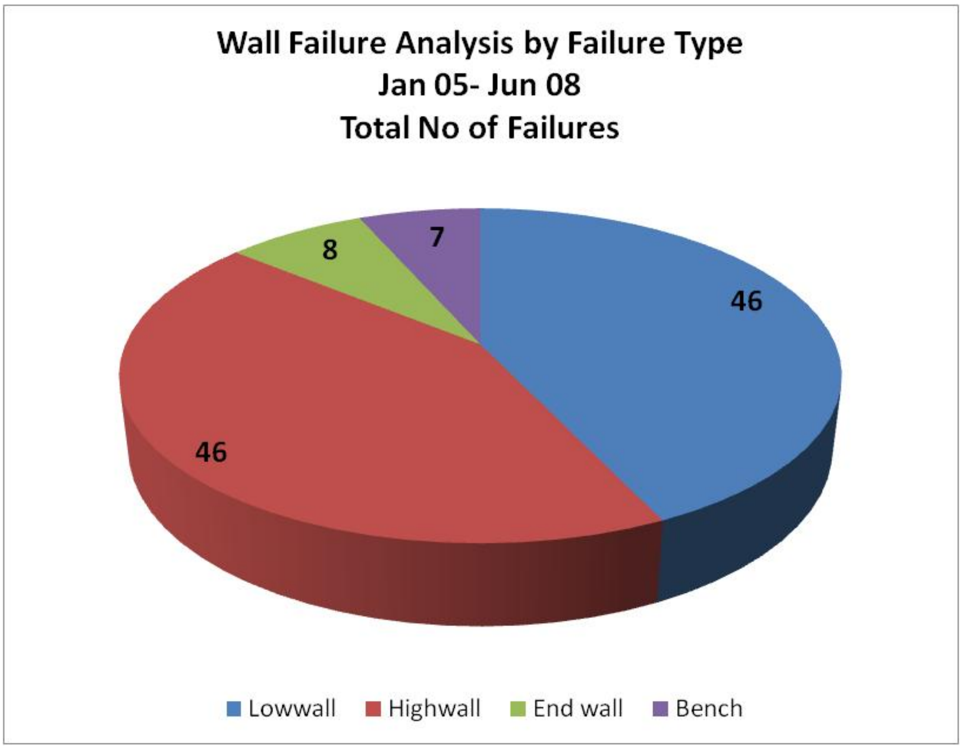

Figure 6. In total, 107 Wall Failures occurred over a three and a half year period *(Kizil & Bye 08-10)*.

In particular, the case study focused on '**Early Warning Technology'** including, Slope Stability Radar (SSR), Laser Survey Instruments, and Extensometers. The study clearly highlighted the most cost and safety effective group of technologies needed to reduce the

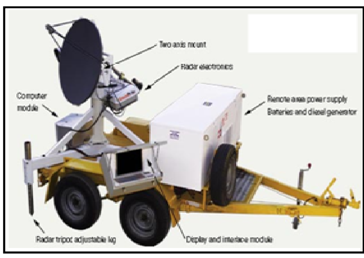

Figure 7. SSR (Slope Stability Radar)

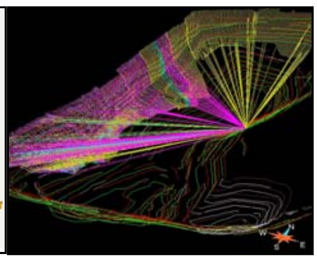

Figure 8. Laser Survey Instrument

risks associated with Highwall and Lowwall failures. The Control Effectiveness analysis also included **Visual Inspections.**

Data gathering, as a part of the SSR Effectiveness analysis, included Radar data readings (Figure 9). These were analysed to investigate Radar Availability and Reliability.

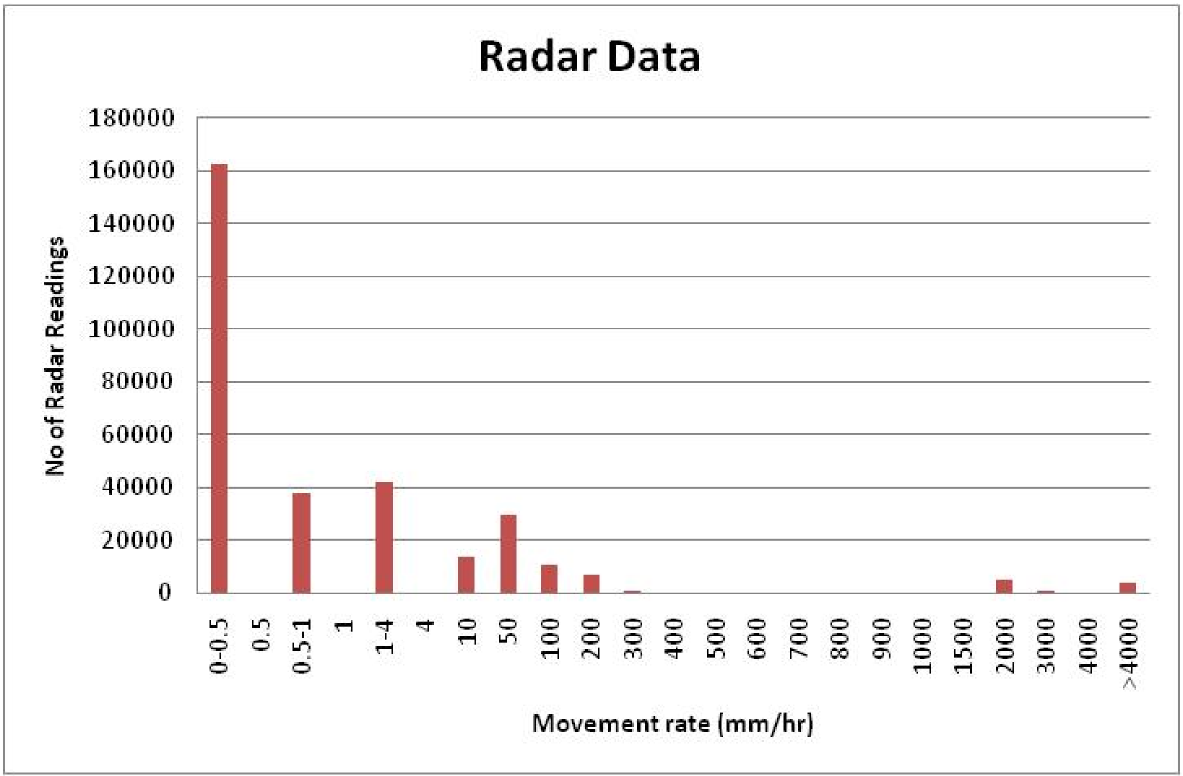

Figure 9. 313,269 wall movement rates (mm/hr) were taken by the SSR during the period of Oct 2007 - Jul 2008 *(Kizil & Bye 08-10)*.

Figure 10 demonstrates the RCB analysis results for Lowwall Failures at an open-cut mine site *(based on industry accident/incident data, technical reports, research publications, expert views and others)*. The annual 'Probability of Loss of Life', **pLoL**, due to Lowwall Failures is shown on the vertical axis, and the cost of the Early Warning Technology is shown on the horizontal axis. Each symbol in Figure 10 represents an impact of a technology or combination of technologies on reducing the risk level shown on the vertical axis.

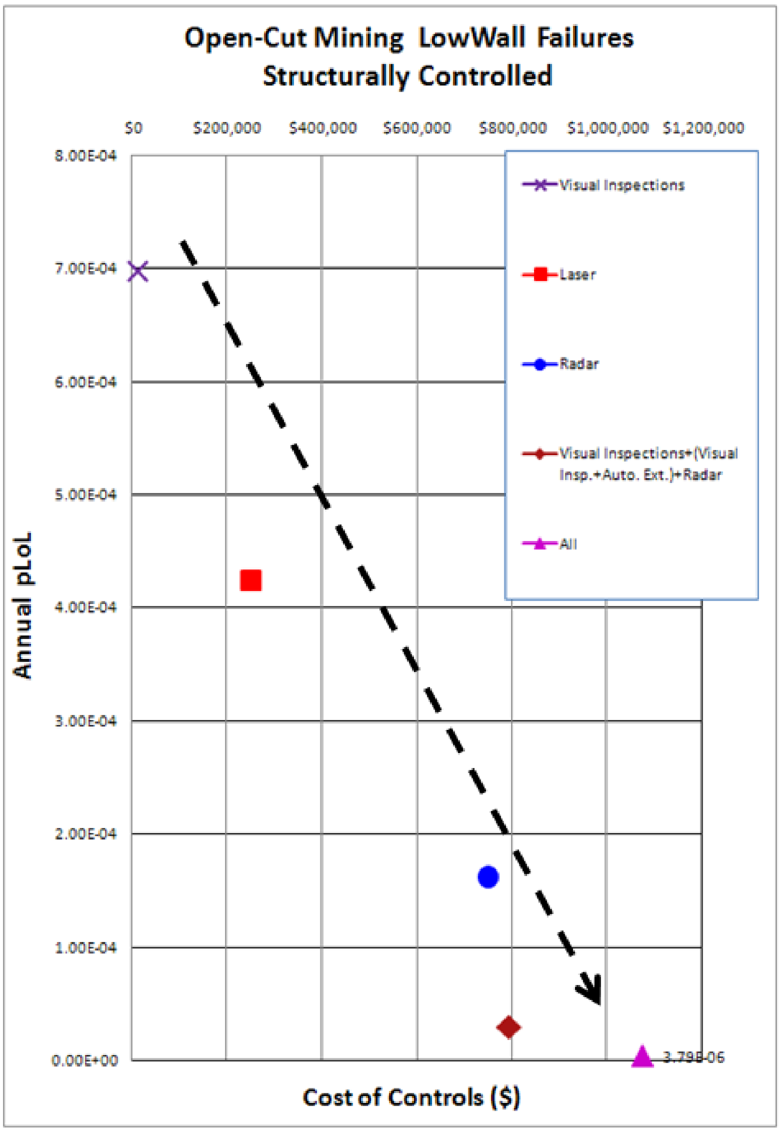

Figure 10. Risk-Cost-Benefit scenario to illustrate the benefit of implementing Early Warning Technology *(Kizil & Bye 08-10)*.

Note: pLoL - Probability of Loss of Life' due to Lowwall Failures

CONCLUSIONS

In summary, ***RCB$_{GEN}$*** is a Decision-Making-Aid aimed at helping the user to select the most appropriate safety solution; usually an optimal group of controls, by assessing complex risks, costs and benefits by using semi-quantitative to quantitative (where possible) data.

A key message from the in depth study is that the ***RCB$_{GEN}$*** has proven to be a valuable tool for selecting the optimum combination of appropriate technologies to reduce risk, to assist with achieving ALARA.

High risk industries such as petroleum, oil, chemical and gas industries have shown a high utilisation of cost-benefit approaches. But the authors have not so far come across a similar method that integrates RISK, COST and BENEFIT, and CONTROL EFFECTIVENESS. There are a lot of similarities between mining and the high risk industries in relation to the risks that are faced in day to day operations. The $\boldsymbol{RCB_{GEN}}$ can be adopted not only by the mining industry but other high risk industries too. One of the uses of this method would be as a ***'pro-active scenario analysis tool'*** to examine various accident/incident scenarios.