



Integrating principles of safe design and human factors engineering into the design of mining equipment

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Australian Coal Association Research Program

Acknowledgements

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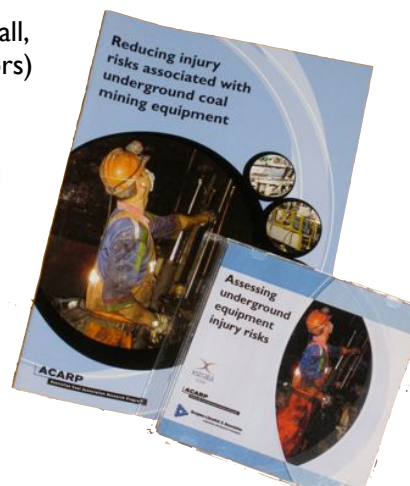
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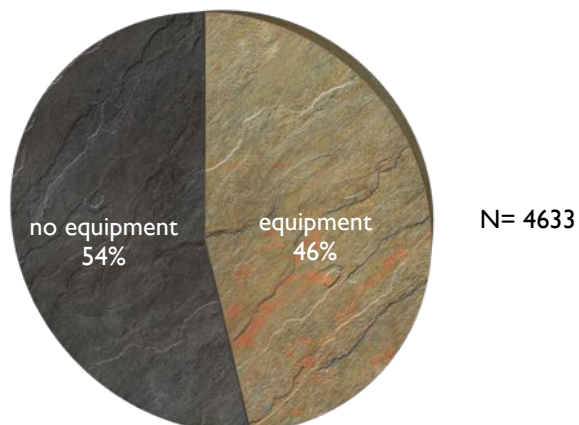


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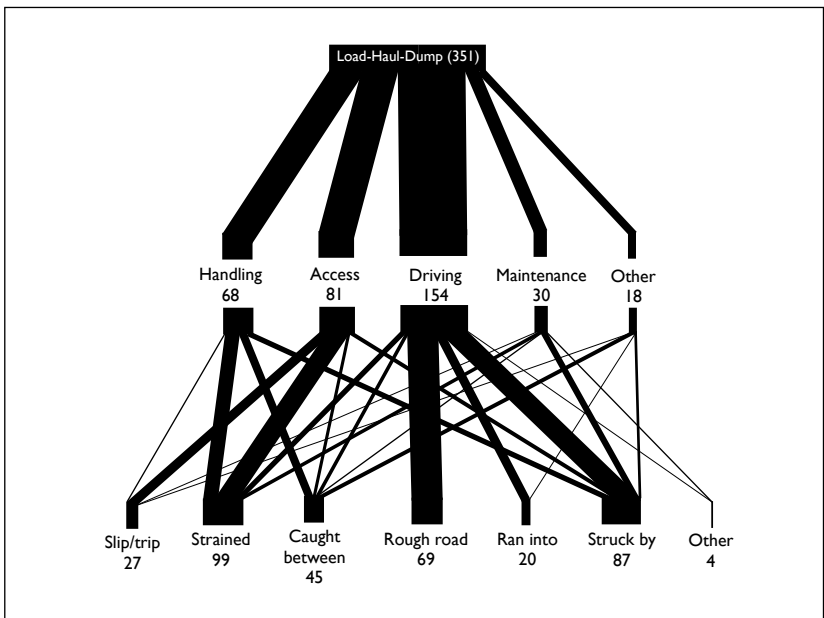
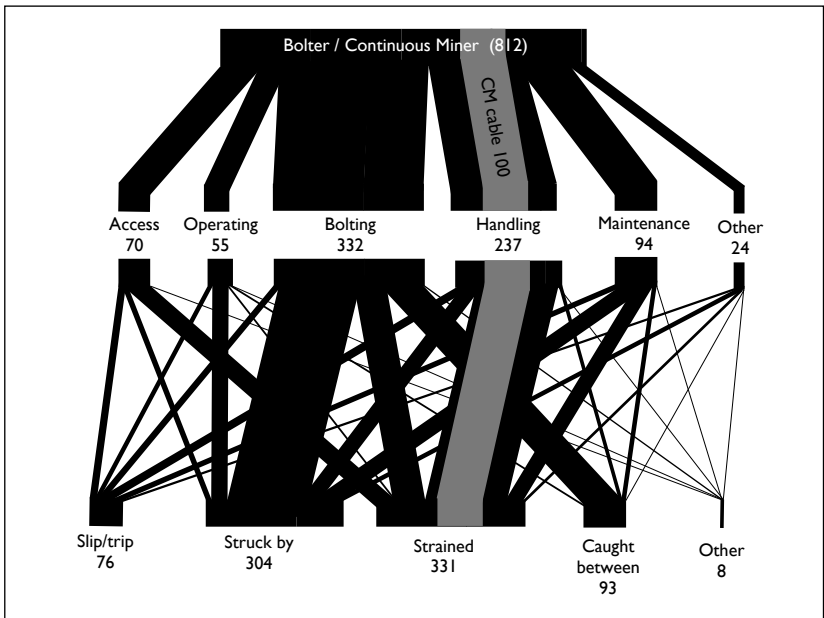
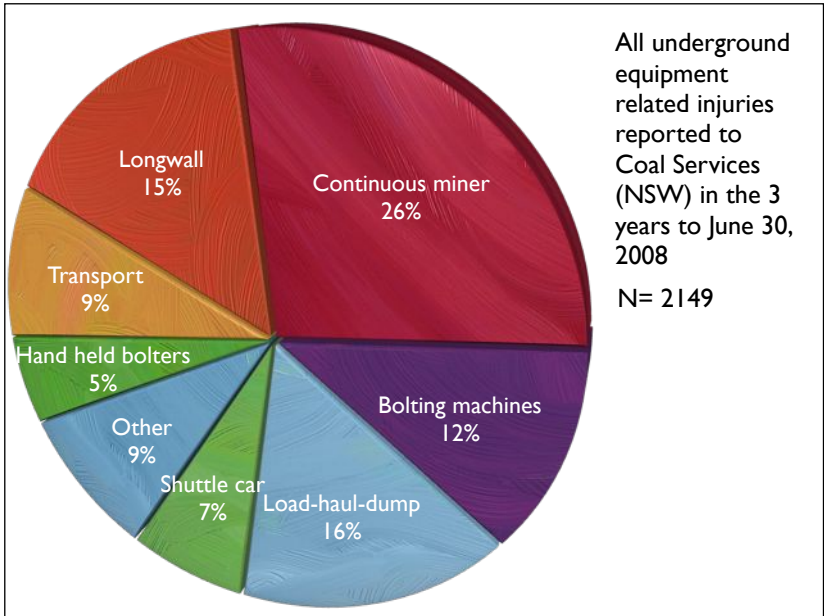


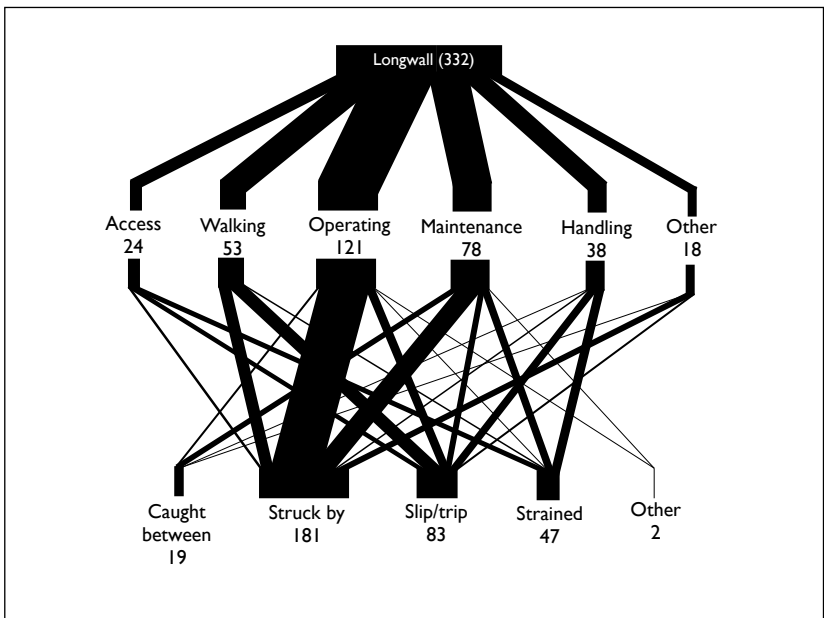
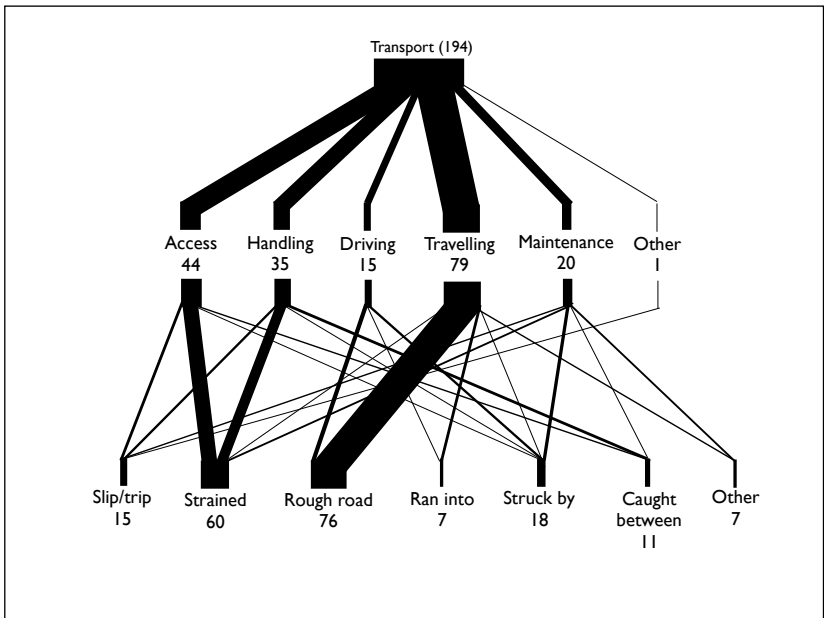
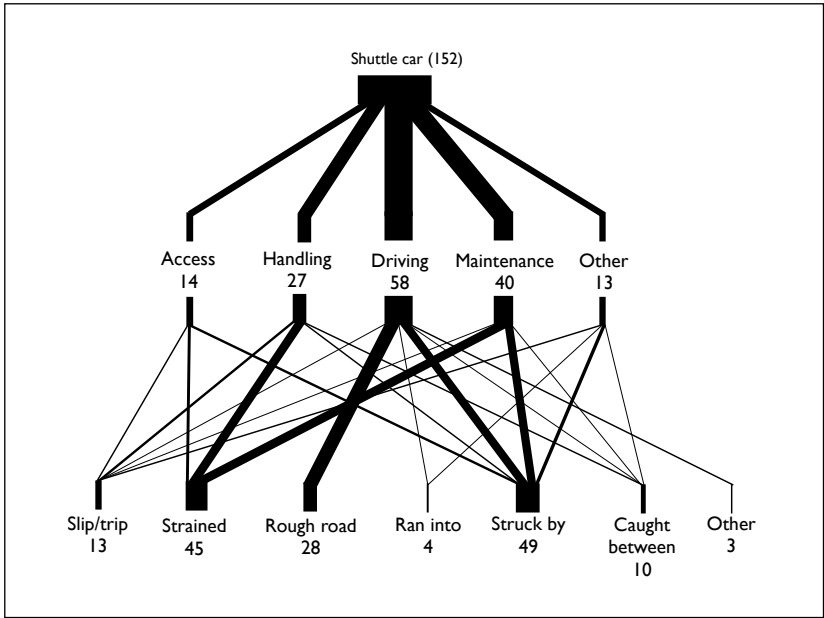
All underground injuries reported to Coal Services (NSW) in the 3 years to June 30, 2008



(excludes injuries on surface at underground sites and deafness claims)

Report available at burgess-limerick.com/download/c18012injury.pdf





CM/bolter - access/egress - slip/trip



While stepping up onto c/miner platform he strained his knee

While climbing onto c/miner work platform his foot slipped & fell backwards onto the ground straining his lower back

When he stepped back on c/miner platform to read methane monitor he slipped off the edge of c/miner platform fracturing his lower leg

While stepping off c/miner from top platform to bottom platform he slipped and sprained his ankle

Controls

- single level platform
- ladder/stair access
- hand rails
- improved platform lighting

Bolting - struck by (esp hydraulic fluid & rock)

When powering up c/miner with remote he was struck with oil under high pressure into his r/eye

While installing roof bolt, on tensioning the installed bolt one of the hoses from the drill pot host pack burst spraying face with hydraulic oil injuring his eyes

While roofbolting a piece of rock slid off mesh & hit his head and shoulder causing bruising

While roofbolting he looked up & was struck by a stone causing open wound - facial injury & cervical spine injury

Controls

- replace hydraulic hosing with piping
- cover hosing
- eliminate manual bolting...

Bolting: strained

While roofbolting work with r/shoulder above head height caused pain - rotator cuff tear

Repetitive drilling & lifting drill rods he injured his l/wrist - tenosynovitis

While installing an 8m mega bolt as he pushed the bolt into the roof he felt pain in his groin



Controls

- mast mounted controls and north-south rigs
- “side-entry” headplates
- redesign bolting controls to improve access
- eliminate manual bolting...

Handling: strained (esp CM cable, bolting supplies)

While flitting c/miner he bent down to lift c/miner cable above his head into a cable roller straining his lower back

While unloading c/miner cable from side of c/miner he dislocated his r/shoulder

While twisting to pull sheet of mesh on top of c/miner he strained his lower back

While loading c/miner with roof bolts he strained his lower back



Controls

- monorail / FCT
- bolting supply cassettes
- mesh carrier
- spray on mesh substitute
- manual tasks risk management

Maintenance: strained

While assisting to remove shuttle car tyre the wheel suddenly fell straining his shoulder

While overreaching changing hoses in the bottom of c/miner he strained his neck

While removing plug from transmission cooler on Eimco in an awkward position he strained his r/wrist

While lifting drum of oil to the fitter when replenishing c/miner hydraulic oil he strained his lower back

Controls

- reduce hydraulic hosing
- improved equipment design for access for routine maintenance (ie, from ground)
- manual task risk management eg., shuttle car tyre change tool
- bulk oil solution?

Bolting: caught between - intentional operation

During drilling operations he put his hand on the drill rig to balance himself as the drill mast was coming down & caught his r/hand on the plate - crush injury r/ring and middle fingers

While installing 1.8m rib bolts the second stage of hydraulic bolter activate jamming his l/middle finger between the top of second stage and top of the rig on Eimco causing traumatic amputation

While bolting on c/miner trying to put chemical in roof when timber jack was lowered his r/middle & ring fingers were caught between timber jack and ram block causing crush injuries

While drilling ribs using c/miner rib bolter his l/hand was caught between timber jack and second stage ram on bolter - crush injuries

Controls

- two handed operation
- drill guides
- crush cone innovation & soft guarding
- eliminate manual bolting...

Bolting - Inadvertent operation

While undoing drill steels using 2 shifters & dollies when his light cord activated the bottom rotation levers bruising his l/shoulder

While removing drill steel from drill rig when sleeve of jacket came in contact with feed lever causing drill steel to hit timber jack smashing his thumb between steel & rig

Controls

- two handed operation
- guarding
- eliminate manual bolting...

Bolting - Selection errors

While operating LHS walk through bolter when using 12" shifter to dismantle rope drills he pulled the wrong handle to rotate chuck & spanner hit his cheek causing laceration - stitches

While bolting bottom rib bolt on c/m he reached over to advance drill motor holding drill steel at the same time grabbed wrong lever & closed clamps lacerating little finger

While installing roof bolts he placed his left hand on the dolly to remove it. He pulled the wrong lever, crushing his left ring finger.

While putting a roof bolt to the roof he pulled the wrong lever which brought the timber jack down, trapping his right arm between timber jack and manifold.

While putting rib support in, the drill steel stuck and pulled out of chuck. As he reached back to fine tune alignment of drill rod he pulled the wrong lever, pushing timber jack out and crushing left hand against rib.

While operating rib borer, guiding steel into rib, hit wrong lever crushing his left hand between timber jack and bolting rig.

Controls

- shape coding?
- eliminate manual bolting...



“The bolter rotation and bolter raise control handles are located beside each other but are differing shaped handles. *The handle shape was not consistently applied to all control stations on the machine...*

The injured mineworker reported that the bolter rig drill motor head was slowly dropping and required frequent drill rig alignment corrections.”

(NSW DPI Summary Investigation Report, 2009 emphasis added)

Shape coding must be consistent, and maintenance errors prevented

eg., “Shape-coded knobs and handles shall be positively and non-reversibly attached to their shafts to preclude incorrect attachment when replacement is required” MIL-STD-1472F (5.4.1.4.4.e)

Bolting - Direction errors

While installing roof bolt steel he went to raise timber jack, pulling handle the wrong way, pinning his right arm between timber jack and top of rig

While on c/m rig 6' hole drill steel became bogged he lowered the chuck operated feed handle in wrong direction bending the drill squashing his r/thumb - fracture

Controls

- ensure directional control-response compatibility
- eliminate manual bolting...

Directional Control-Response Compatibility

"... Consistency of Movement - Controls shall be selected so that the direction of movements of the control will be consistent with the related movement of an associated display, equipment component, or vehicle."

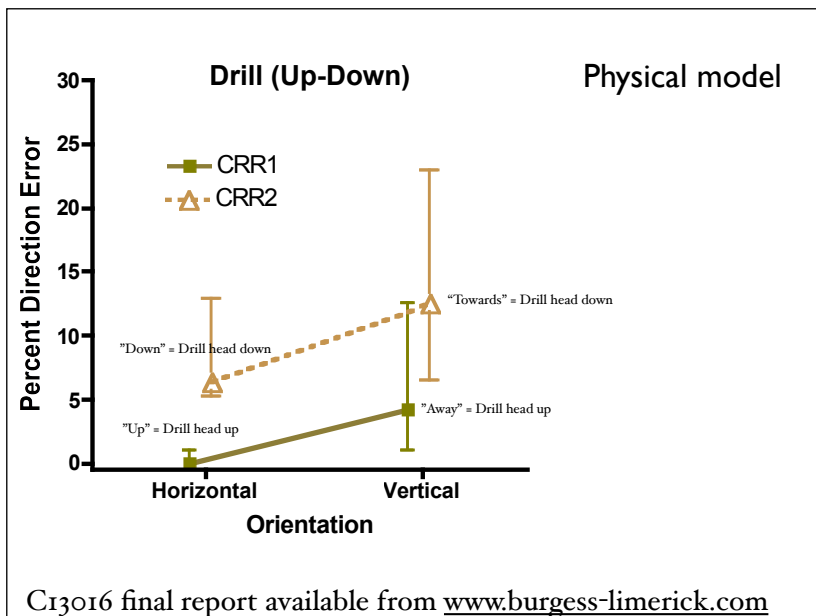
NASA-STD-3000 Man-Systems Integration Standard, 1995.

"...the movement of the lever shall produce a movement of the controlled component in the same direction."

ISO 447-1984 Machine Tools - Direction of operation of controls

"The direction of operation of manual controls should be consistent with the direction and response/movement of the actuator or the plant, where practicable"

MDG 35.1 "Guideline for bolting and drilling plant in mines. Part 1: Bolting plant for strata support in underground coal mines" (NSW DPI, 2009)



Driving/travelling - rough road

While driving s/car hit a pot hole in wheeling road causing drivers seat to bottom out jarring his lower back

While driving s/car he hit a bump & bounced hitting s/car canopy straining his neck

While driving Eimco he hit a pothole causing him to hit his head on the roof jarring his neck

While driving PJB he hit a pot hole hitting his head on PJB roof landing on his light battery straining his neck and lower back

While sitting in PJB travelling to pit bottom hit a large bump launching him into the roof then back down jarring his heck and lower back

Controls

- roadway maintenance
- shuttle car suspension
- weight adjustable suspension seats
- auto-adjusting seats
- forward facing transport seating

Limitations of injury frequency analysis

Fails to direct attention to low probability / high consequence hazards

Different causal factors eg., Interactions between mobile equipment and pedestrians

NB - Decreased LTIFR does not indicate decreased fatality risks

Equipment - pedestrian interactions

While he was walking past left side of c/miner it turned forcing him into rib jamming him between the c/miner & rib bruising l/thigh

He was at the hydrant washing c/m remote when a front loader heading outbye suddenly came back inbye and ran into him spun him around the wheel passed over his lower leg and fractured L/ tibia

While standing behind Eimco observing the gear being unloaded the Eimco reversed & pinned him between work platform & bucket spraining his L/ankle

While working as a cable hand on c/miner he turned to see a s/car approaching he slipped into s/car wheel rut & L/foot was run over by s/car causing crush injury

While training to drive s/car from bootend to c/miner he was crushed between the s/car & the rib causing crush injury to his l/ hand

While standing in the rib as a s/car was passing he slipped on loose surface his r/foot went under s/car wheel causing bruising.

Controls

- proximity detection
- reduce obstructions to visibility
- height adjustable LHD cab
- lighting
- video cameras
- shuttle car steering compatibility
- FCT
- non-line-of-site CM remote control

Conclusions

Design and operational risk assessments should address identified injury mechanisms

Encourage “safety by design” by OEMs - EMESRT

Share your innovations (and adopt others!)

Identify & investigate high potential incidents (regardless of actual outcome), control risks, and share

Automated bolting, in conjunction with monorail and non-line of sight remote control will eliminate many injury risks - high priority step change

Proximity detection an emerging technology of potential value

post script

MDG9 Design Guidelines for the Construction of Electric Powered Shuttle Cars for Use in Coal Mines

2.2.1 *“All relevant ergonomic aspects of the shuttle car shall be addressed by the manufacturer in the design and manufacture of the shuttle car. A suitable person shall review the ergonomic aspects to ensure compliance with good practice.”*

MDG15 Guideline for Mobile and Transportable Equipment for Use in Mines

3.6 *“All relevant ergonomic aspects of the equipment should be addressed by the Manufacturer in the design and manufacture of the equipment. A suitably qualified person should review the ergonomic aspects of the equipment to ensure compliance with good practice. A report should be prepared by this person and supplied to the Operator before delivery.”*

MDG35.1 Guideline for Bolting and Drilling Plant in Mines. Part 1: Bolting Plant for Strata Support in Underground Coal Mines

3.2.2.5 ... *An ergonomic assessment on the layout of all operator controls should be carried out. The assessment should be carried out by a suitably competent person.”*

MDG41 Guideline for Fluid Power System Safety at Mines

3.5.5.2 *“An ergonomic assessment on the layout of all fluid power controls and operator gauges should be carried out. The assessment should be carried out by a suitably competent person.”*