Designing for health and safety in the construction industry

Centre for Construction Work Health and Safety Research

RMIT University

RMIT UNIVERSITY


Loughborough
University


lendlease


AUSTRALIAN
CONSTRUCTORS
ASSOCIATION


Virginia
Tech


Australian Government
Australian Research Council


National Institute for
Occupational Safety and Health
NIOSH


VICTORIA
State
Government


ENGINEERS
AUSTRALIA


CRC Construction Innovation
BUILDING OUR FUTURE


LEVEL
CROSSING
REMOVAL
AUTHORITY


METRO


Queensland
Government


MELBOURNE
METRO RAIL


Fonterra


Port of Melbourne
Corporation


PROPERTY
COUNCIL
of Australia


ARCADIS
Design & Consultancy
for natural and
built assets


CodeSafe
Solutions


safe work australia


CONSULT AUSTRALIA

Themes	Expertise
Workforce health and wellbeing	• Work-life balance and wellbeing • Workplace stress • Workforce health and lifestyle factors • Ergonomic and biomechanics assessment and task redesign
Organisational safety	• Culture for safety/climate/lead-lag indicators • Incident reporting • Client safety leadership • Organisation of work • Structure of work/procurement strategies
Effectiveness of regulation	• Policy, standards, regulation
Design for safety	• Process design - construction safety • Operational safety/asset management/risk • Design process mapping and analysis • Knowledge transfer • Risk perception
ICT use for safety	• Remote sensing technology • Virtual reality/gaming • Smart/responsive clothing • Real-time, wireless data collection • Internet-of-things

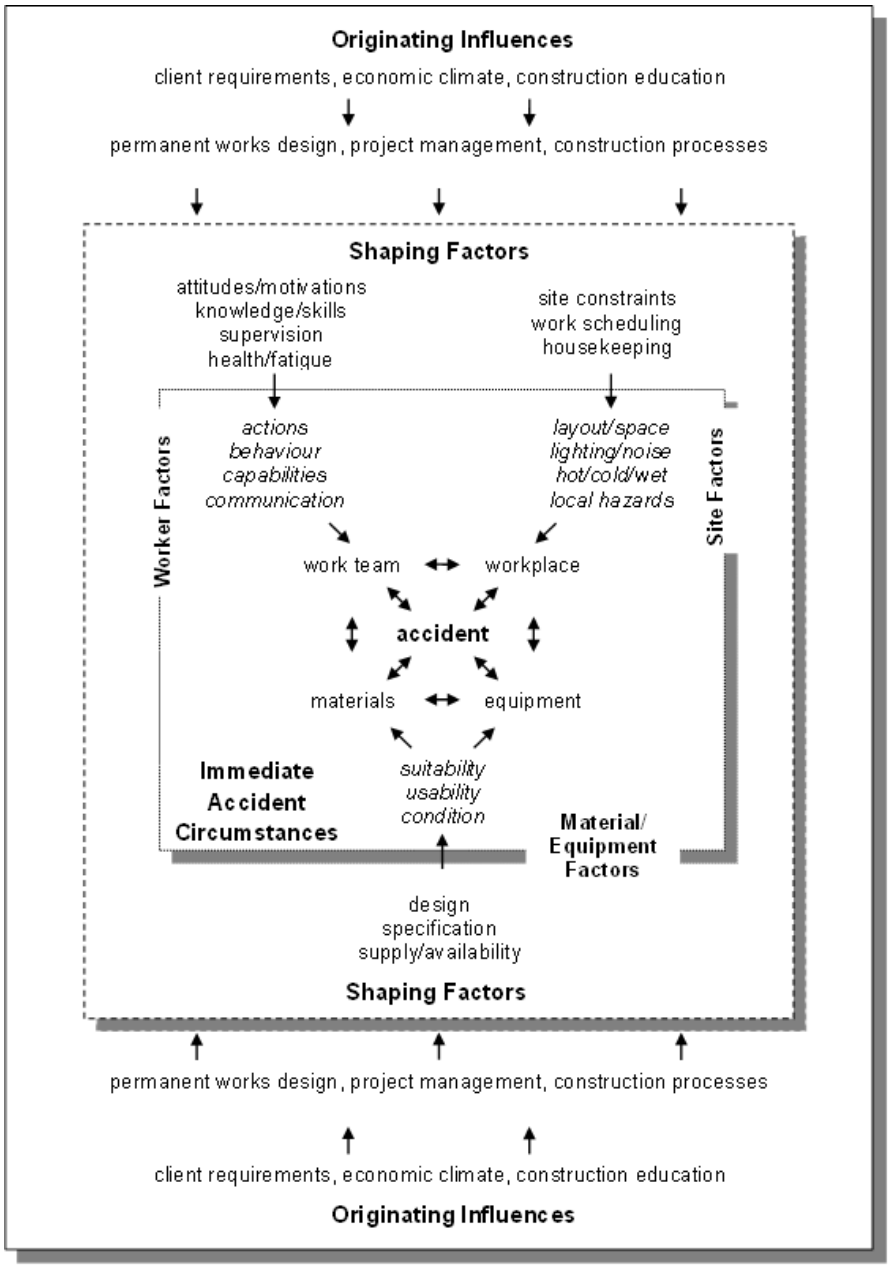
RMIT UNIVERSITY

Work design, health and safety

- Australian Strategy for Work Health and Safety 2012-2022
- Health and safety by design
  - Hazards are eliminated or minimised by design
    - Structures, plant and substances are designed to eliminate or minimise hazards and risks before they are introduced into the workplace.
    - Work, work processes and systems of work are designed and managed to eliminate or minimise hazards and risks.
- In construction there is emphasis on the first of these (CHAIR, safety in design reviews et), but not so much emphasis on the second.

"*Workers' general health and wellbeing are strongly influenced by their health and safety at work. Well-designed work can improve worker health*."

(Safe Work Australia, 2012)



Theories of construction accident causation

Evidence-informed Construction Accident Causality Model (Haslam et al., 2003, p. 59)

Designing safe and healthy products and processes

Product design

- Safety in use of the product
- Safety in operating the product
- Safety in the structural integrity of the product
- Traditional designers more comfortable with product design

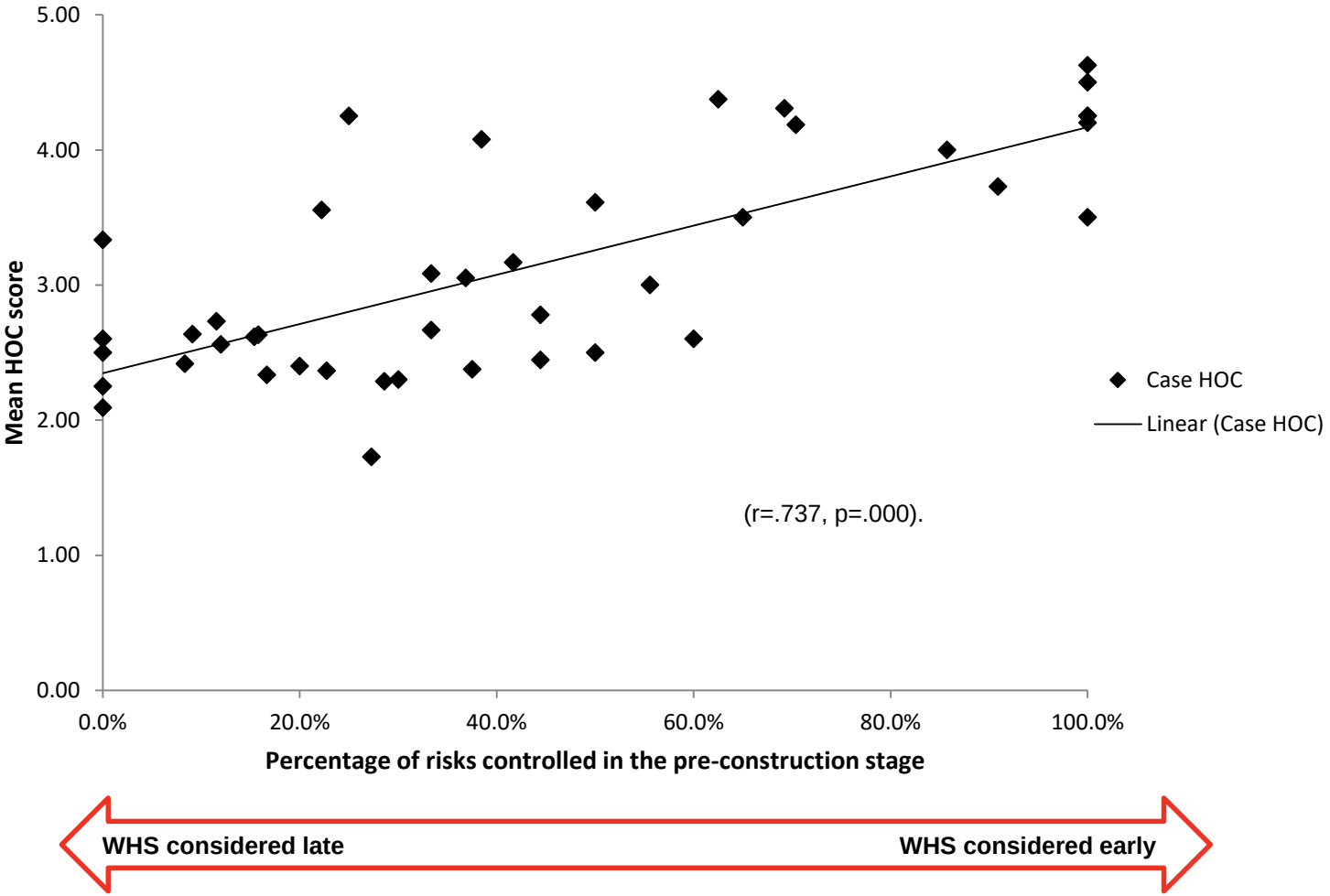
Process design

- Safety in the manufacture, transport, installation and commissioning of the product
- Safety in maintaining the product
- Assumption that constructors can control any hazards
- Designing safe processes requires construction knowledge

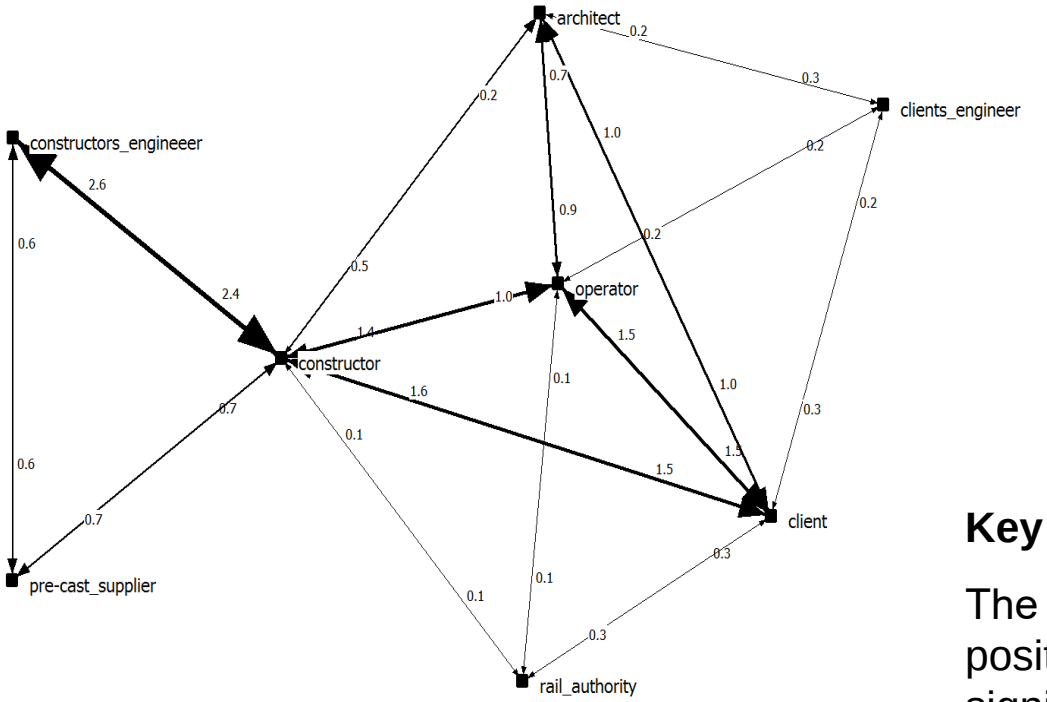
Five year benchmarking study – safety in design

- **Research Partner**: Center for Innovation in Construction Safety and Health at Virginia Tech.
- **Funding body**: US Centers for Disease Control/National Institute of Occupational Safety and Health
- **Scope:** Data collection
  - 23 construction projects (9 in Australia, one in NZ and 13 in US)
  - 288 interviews were conducted (185 in Australia and 103 in the USA)
- **Research-to-Practice report**
  - How can we ensure that WH&S are better considered in “upstream” decision-making, i.e. in project planning and design?
  - How can we measure and improve the quality of WH&S and better control WH&S risks?

Timing of risk control decisions (US, NZ, and Australian data)



Construction knowledge



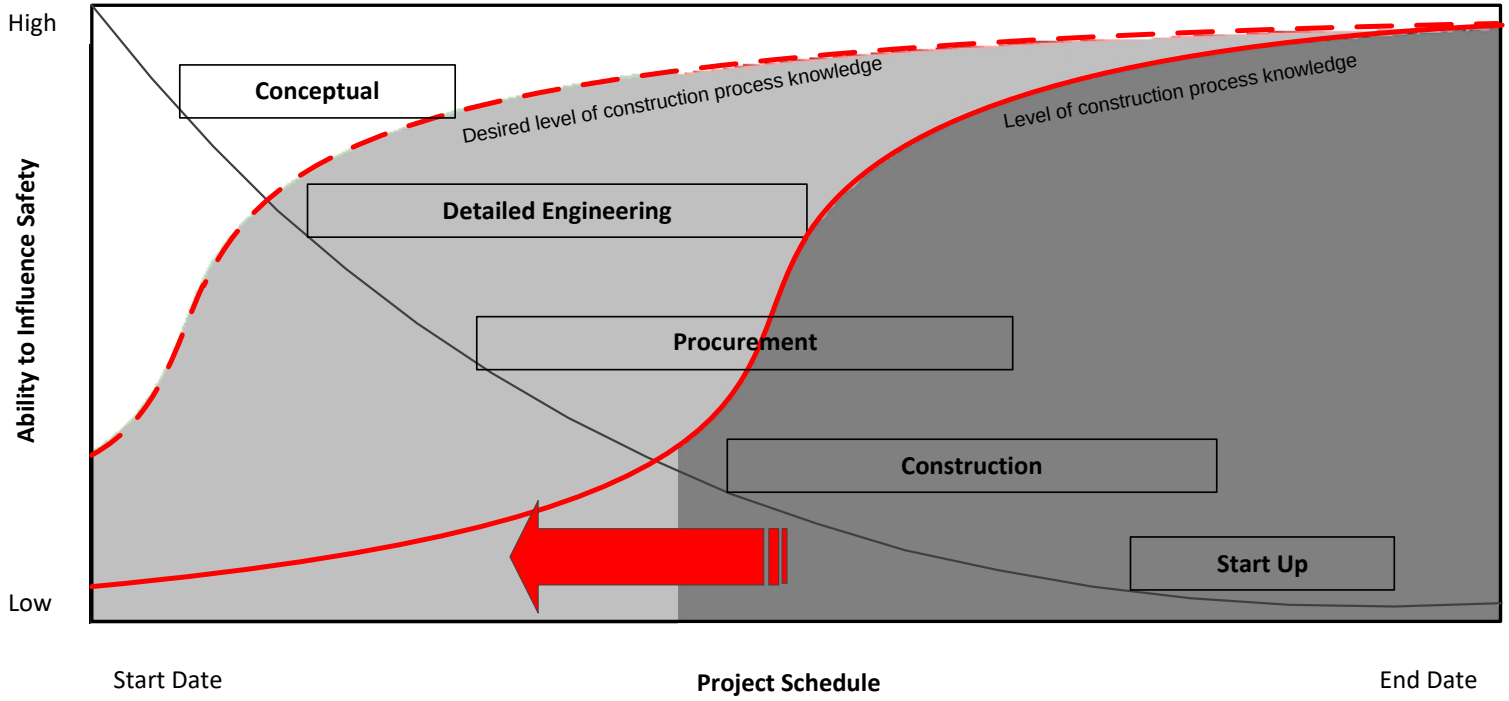
Key finding

The construction contractor's position in decision-networks was significantly higher in cases with high quality risk control outcomes.

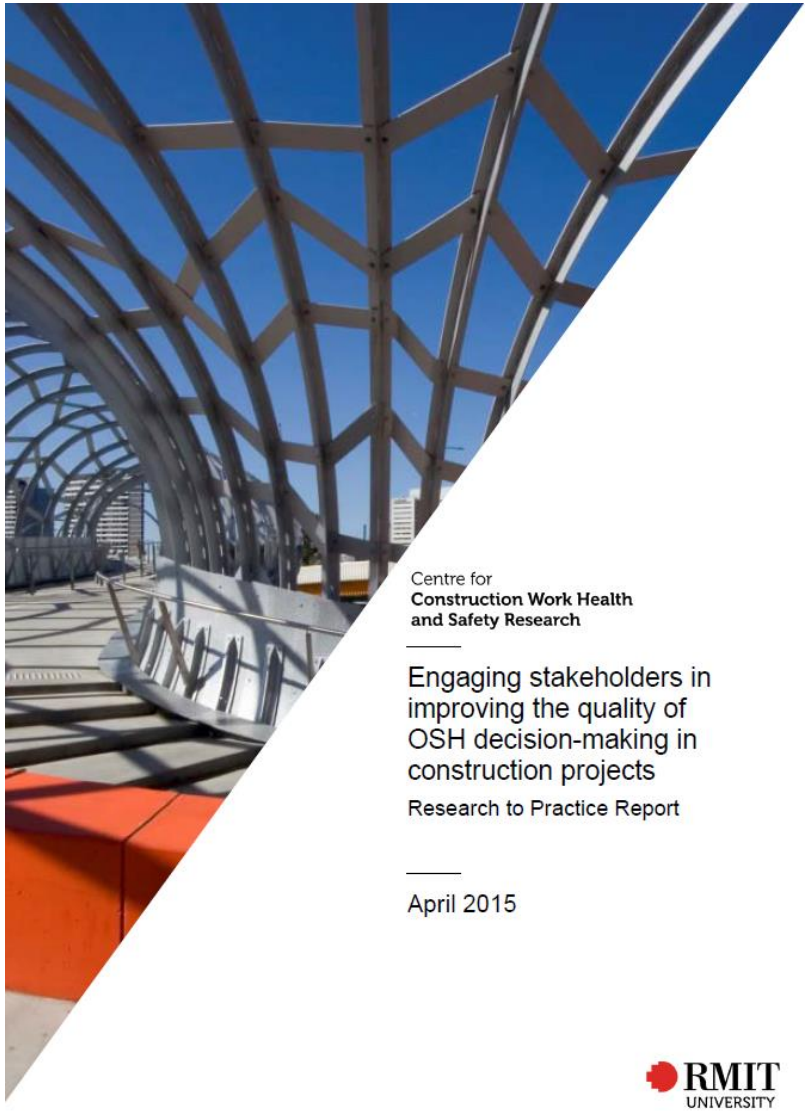
High quality outcomes = 14.2

Low quality outcomes = 5.4

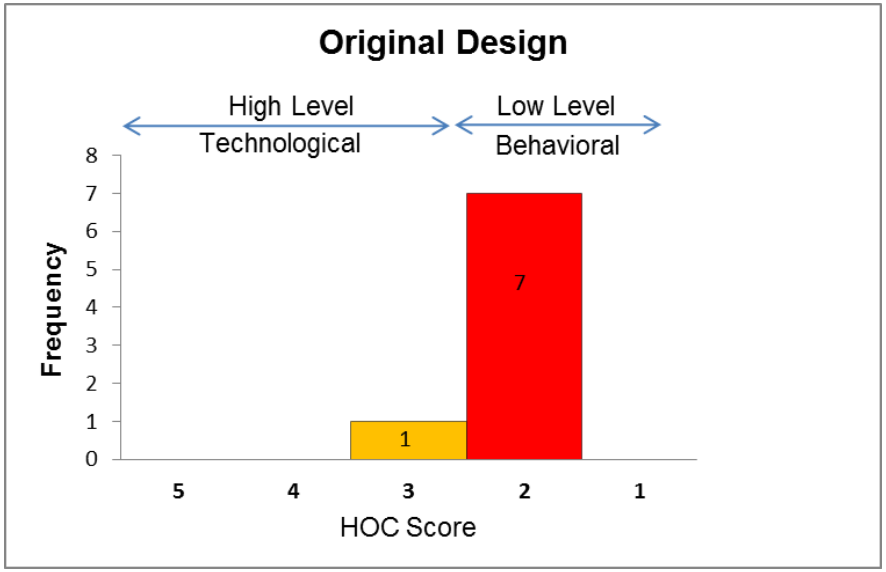
Process knowledge transfer



Research to Practice Report



A tool to evaluate and compare risk control outcomes



Average HOC score 2.13

Average HOC score 4.25

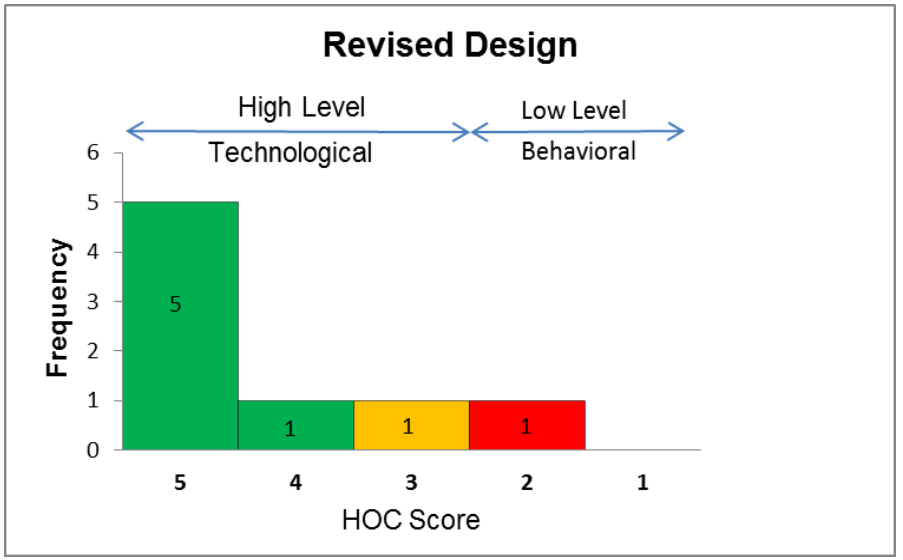


Image-based tool

F01

Description: Precast concrete panel system for housing
Source: By courtesy of Mark Vines of RMIT University

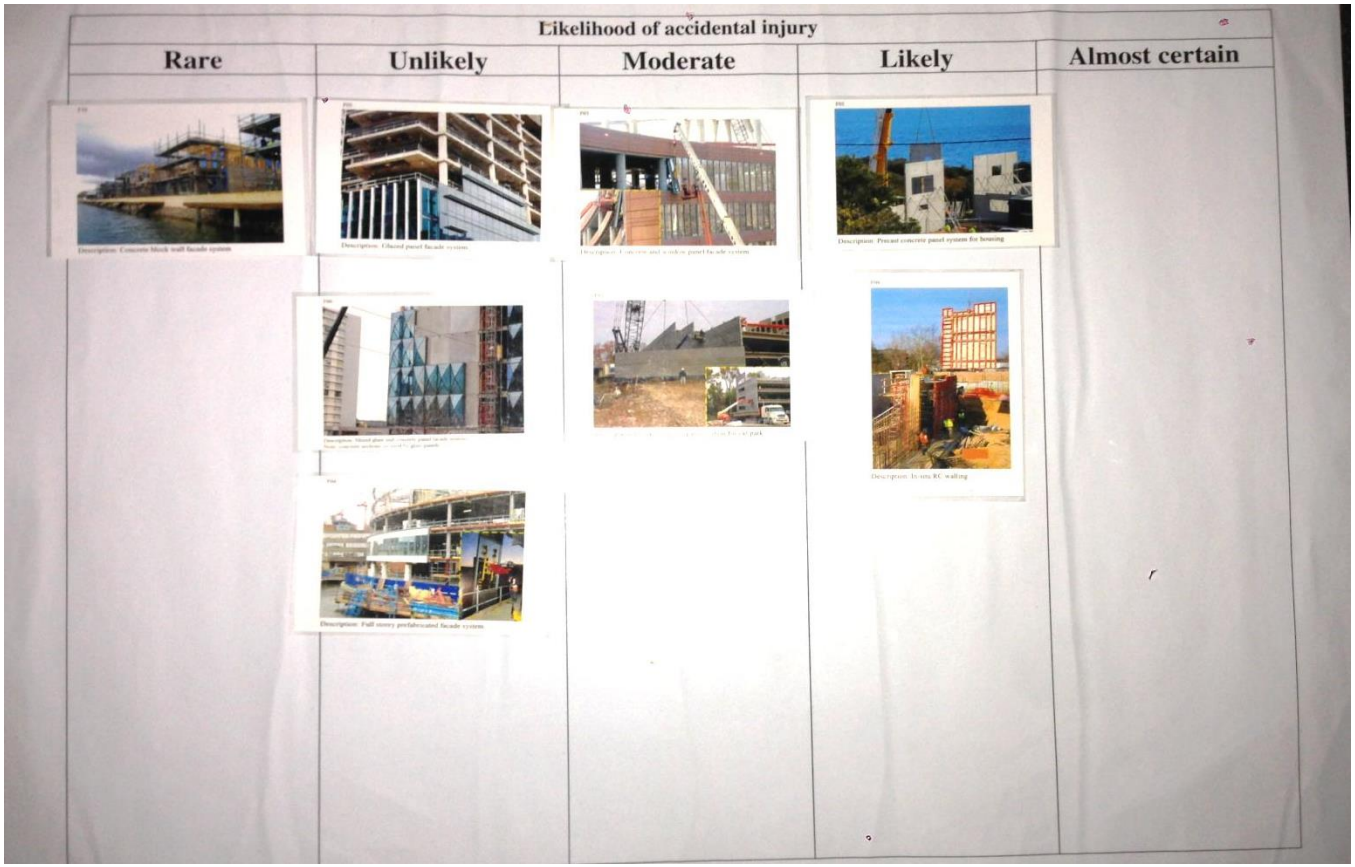
R10

Description:Prefabricated roof systems for offsite built classrooms
Source: CRC for Construction Innovation

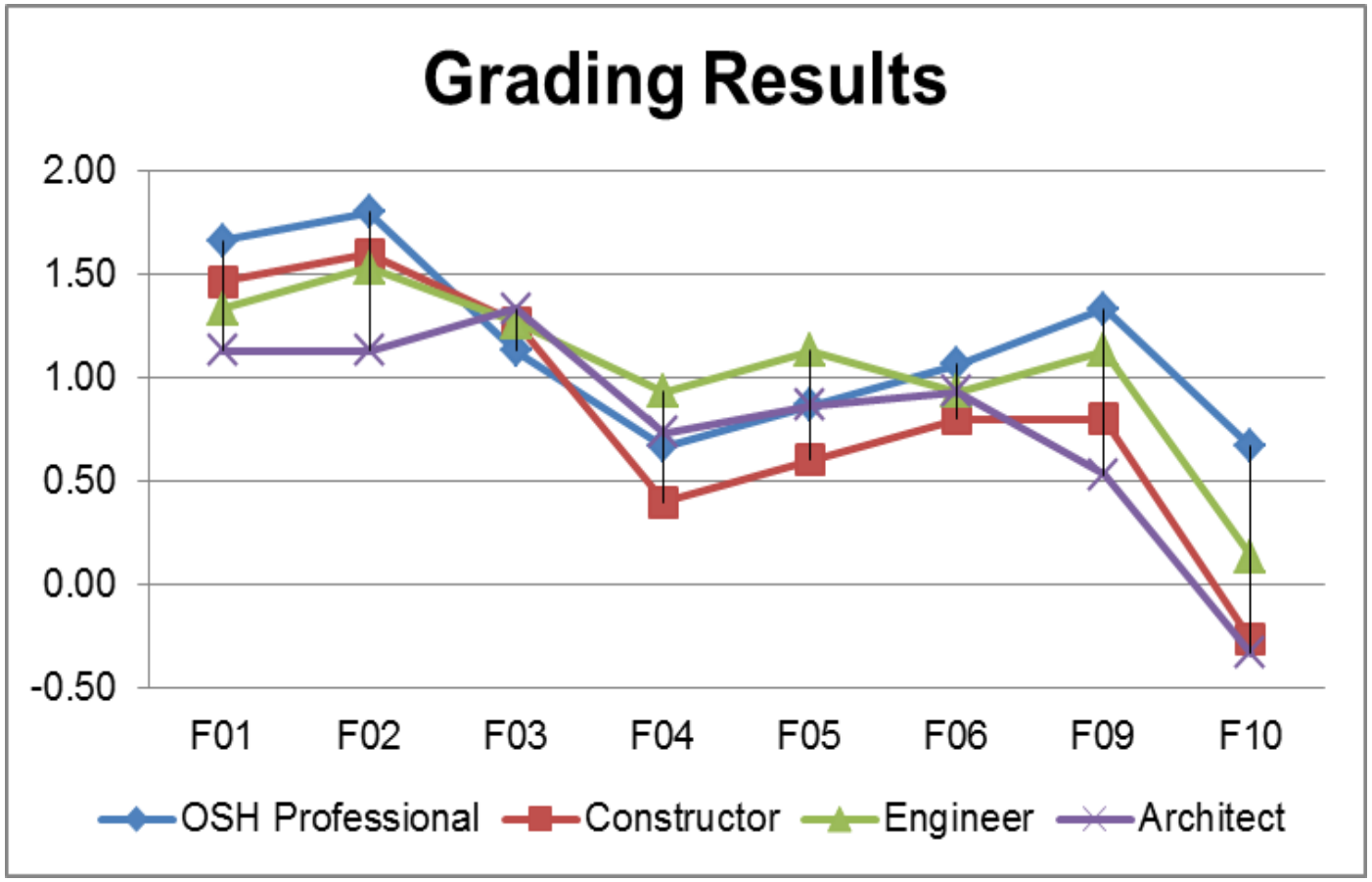
S04

Description: Precast reinforced concrete columns, beams and slab panels.
Source: CRC for Construction Innovation

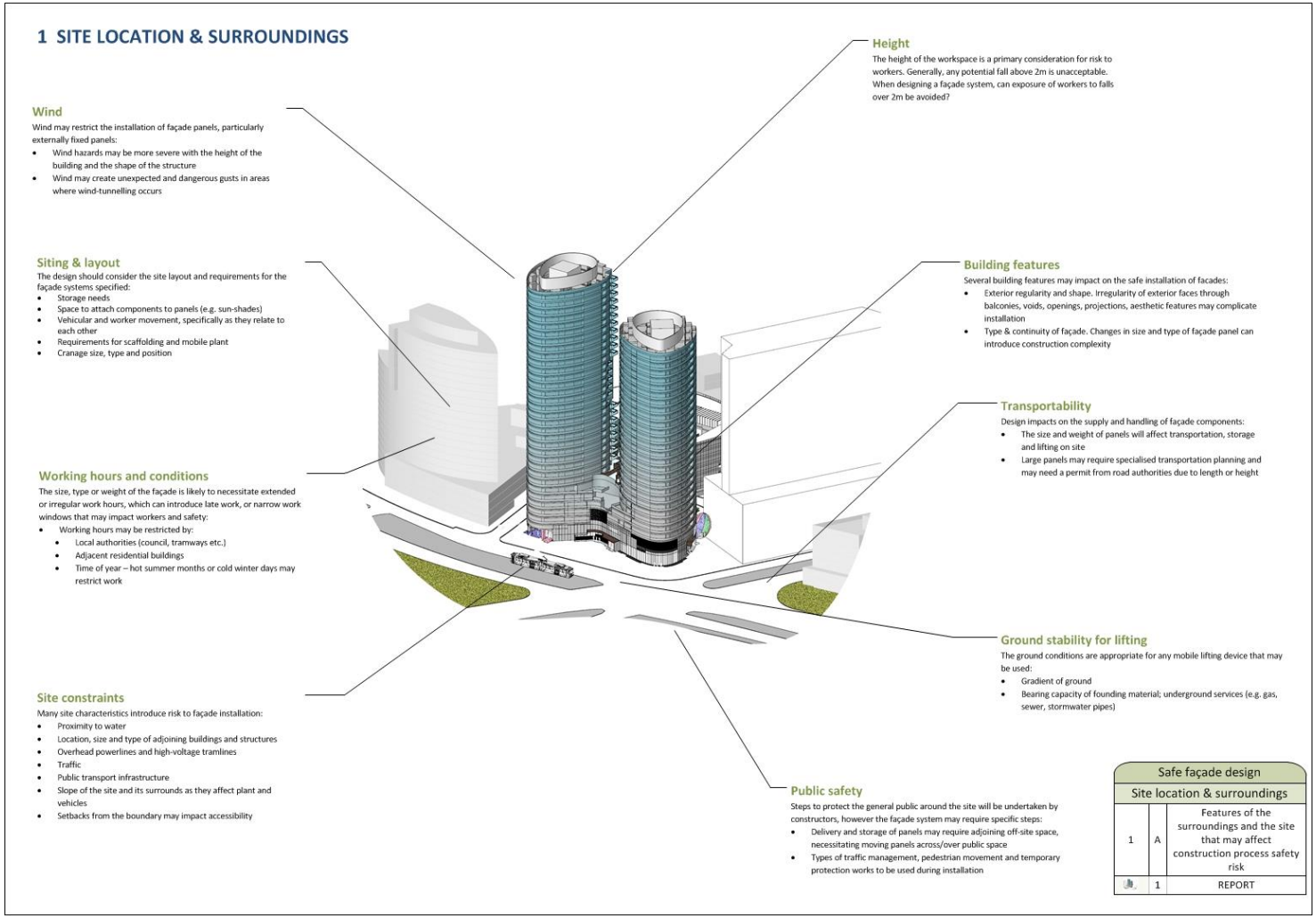
Exploring stakeholders' perceptions of WHS risk



Differences of perception



Infographics to aid safety in design



Site level detail

2 CONSTRUCTION SITE

Panel procurement

- The level of detail on drawings and specifications has a significant impact on manufacture and construction. Panel identification with detailed specifications helps avoid errors, rework and rectification on site
- The lack of sufficient installation detail provided on façade drawings may affect the installation process onsite – this may be particularly severe for internationally procured products
- Degree to which design drawings are complete may impact the degree of control the design team have over the construction process
- The language in which specifications are originally written may affect translation and quality of the product – needs to be monitored when using internationally procured products
- The location of the manufacturer will determine the level of QA visits that can be undertaken; and needs to be specifically considered for internationally procured products
- Facades may need very long lead times that may need planning to minimise disruption and delays which put pressure on crews

Cranage

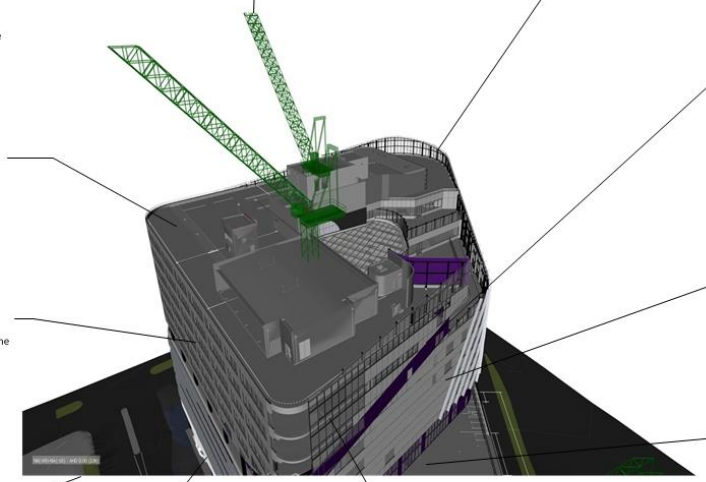
Level and type of cranage required should be considered:

- Whether a system is externally or internally fixed
- Reach and capacity restrictions of cranes
- The need for complex manoeuvres, such as dual lifts should be avoided

Internally fixed, externally fixed or both

The most important façade installation decision is related to whether it is internally or externally installed as this has the most significant safety implications. Options and implications for installation include:

- All works can be done internally
- Panels can be installed internally but façade finishes (e.g. sealing) requires external access
- Both internal and exterior perimeter access is required for panel installation and façade finishes
- The façade will be installed on the exterior of the structure (either from above, or ground level)



Work platform or surface

- For externally fixed systems, elevated platforms (e.g. scaffold) may be required. These platforms require specific design for erection, dismantling, height, fixing to the structure etc.
- Use of elevated work platforms (EWPs) such as scissor-lifts (whether internal or external) need an appropriate surface finish and of sufficient strength (especially suspended slabs)
- Edge-protection is critical – does the selected façade system provide or require protection?

Workspace

The immediate workspace on each level where the façade will be installed needs to be carefully considered:

- If internally fixed, designers need to ensure that the suspended slabs can carry the temporary loads of panels and mobile plant. If externally fixed, is dedicated storage required?
- Consideration should be given to the need for work exclusion zones during installation as this imposes significant restrictions to construction works on the rest of the site

Manual or mechanical installation

- Size and weight of panels will determine whether panels can be installed manually or require mechanical lifting devices
- Consider ergonomic hazards - level of burden or effort, ease of access, time to complete tasks, body position etc.

Panel features

- Panels spanning less than 1-floor height will require multiple operations for the façade, whereas 1 or more-floor spanning panels may reduce the number of lifts, but may also be larger and heavier
- Uniform panels enhance quality control in manufacturing and familiarity in installation
- The material combinations of the façade and the size of panel will impact the lifting options available for the façade, due to the weight/size ratio

Exposure of workers and others on site

- Number of workers required to install each component or panel, as this will determine the number of workers exposed to hazards
- The likelihood of multiple trades in the same area, or beneath the installation zones
- The 'density of installation activities' will also impact exposure of workers to risk. Generally, large complete panels reduce exposure when compared to repetitive process with numerous small components

Construction sequencing

Sequencing of installation is often dictated by the façade system specified:

- Some will require completion of one floor on one side of a building at a time and others one floor across the building
- Do finishes and accessories need to be fixed before or after placement?
- Does the system require external sealing/painting/caulking/cleaning/ protection removal after installation?

Delivery of panels

The batching and delivery of panels should be specified to coordinate with installation. This relies on detailed panel specification in the design stage

PPE requirements for façade installation

- Consider whether substantial or specialised PPE may be required for the façade system specified e.g. fall arrest device etc

Safe façade design		
Construction site		
2	A	Building-level construction process safety risks
	1	REPORT

Panel level detail

3 FAÇADE DETAILS

Panel weight
- The material and therefore weight of each panel has a very significant bearing on the installation process
- Large, heavy panels may require dual lifts

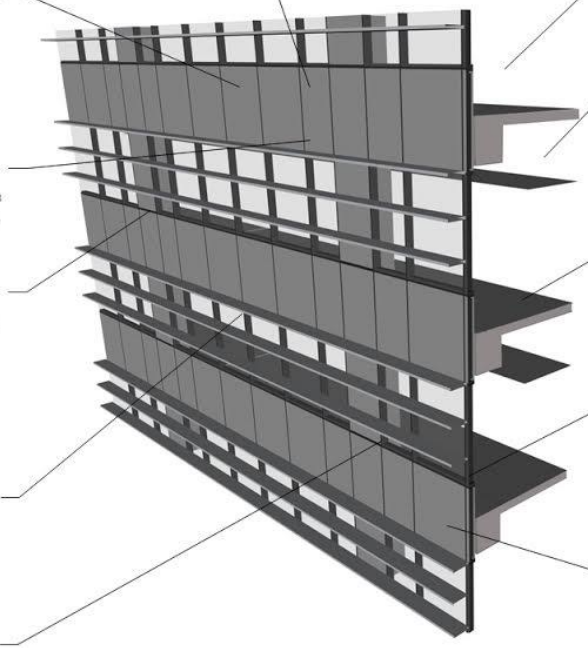
Panel maintenance & repair
Access to the façade for cleaning, maintenance and repair requires a detailed risk analysis. The two systems are not necessarily compatible.
- Cleaning facades externally from above (e.g. ropes) may not be appropriate for repair of seals for instance, and is probably wholly inadequate for panel replacement (e.g. failed glass panels)
- External replacement from ground level may not be feasible due to height or inadequate space or substrate for mobile crane
- Internal access should be considered wherever possible/practicable

Number of placements per floor level
- The number of steps involved in installing a façade system
- Use of multiple steps to install panels, e.g. panels followed by mullions and shading panels increases exposure
- Awnings, seals, painting or other fixtures should be installed at ground level before lifts if at all possible

Hazardous substances
- Impact of any hazardous substances that may have been used during the manufacture or installation of the façade, e.g. silicones, protective films on panels etc.
- Compatibility of adjoining materials (e.g. when sealant comes into contact with façade lining) needs to be considered as some may emit toxic/dangerous by-products during construction

Façade connections to the structure
The location and design of connection to the structure are important to safety:
- Are connectors cast insitu, drilled/cemented, welded etc.
- If cast or drilled, are siting of holes nominated on plans with adequate clearance from reinforcing steel and edges of structural support?
- Are specialised mechanical tools required for installation?

Location of connections on panels
The location of connections should be considered as these carry different levels of risk for workers connecting panels to the structure. For instance are connectors:
- Internally accessible at ground/floor level
- Internally accessible with the aid of a EWP or similar
- Connections located on the exterior face of the building structure at ground level
- Connections located on the exterior face of the building structure above shoulder height



Level of panel specification and detail
- The level to which each panel is clearly identified with detailed specifications to aid the installation process
- General notations of type/material of panels with no size specifications may mean on-site cutting is highly likely

Installation knowledge
- Is the product selected commonly used, or does it require specialised trades or knowledge? Long learning curves may be required as crews learn to use the system safely
- The use of uncommon systems with open competitive tenders may introduce risk. The use of specialised trades familiar with product installation should be considered

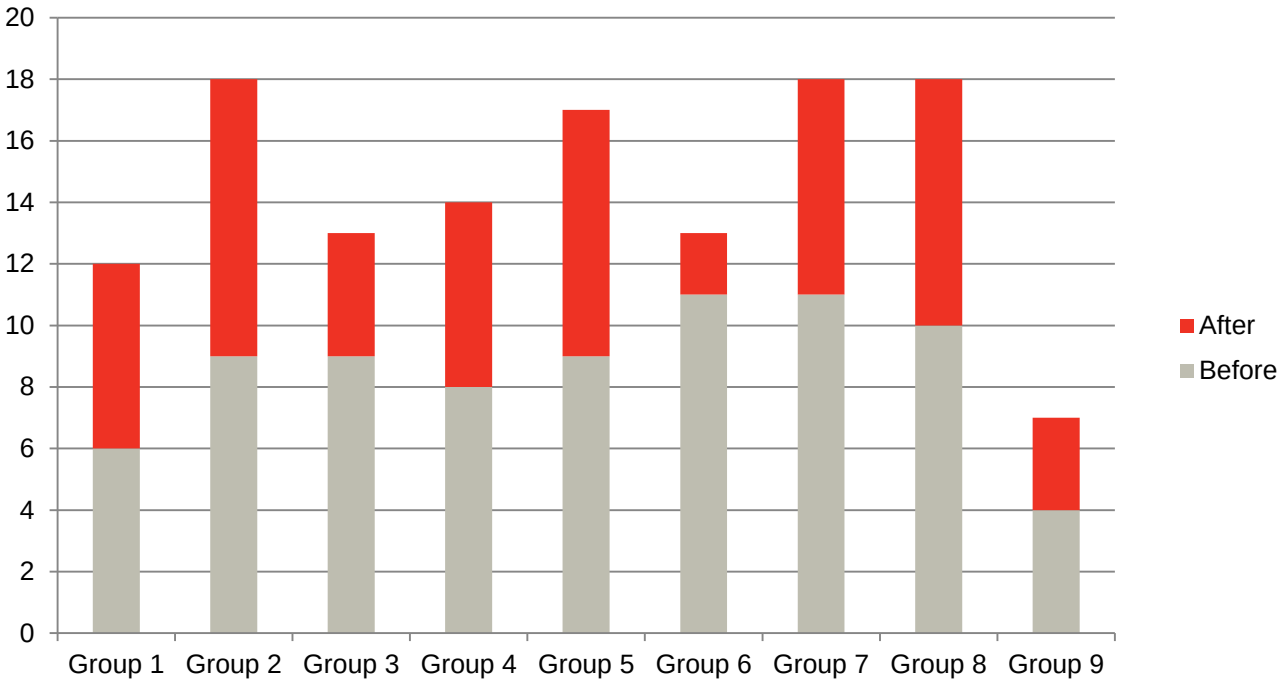
Structural integrity of panels for construction
- Full lifting point, support bracket and restraint connection design should be undertaken on panels to assist construction
- Lack of such detail introduces risk for constructors and the potential for panel failure or damage during lifting and transport
- Limitations to lifting and storage of panels should be clearly specified
- Ensure that any exterior features such as panel shades are able to withstand live loads during construction

Façade material
- Whilst panel materials may suit the building performance, panels that consist of materials vulnerable to damage while transporting or lifting will often result in additional work for crews on site
- Determine and specify the level of protection required around panels during transport and lifting
- Compatibility between different façade panel materials should be considered to avoid deterioration that will necessitate high levels of maintenance and repair
- Consider any health risks arising from cutting or drilling that may be required with panel installation

Accessibility and adjustment of panels
Are panel connections easily accessed and adjusted during installation?
- For instance, methods may include slotted holes, site drilled holes, welding, shims and packing

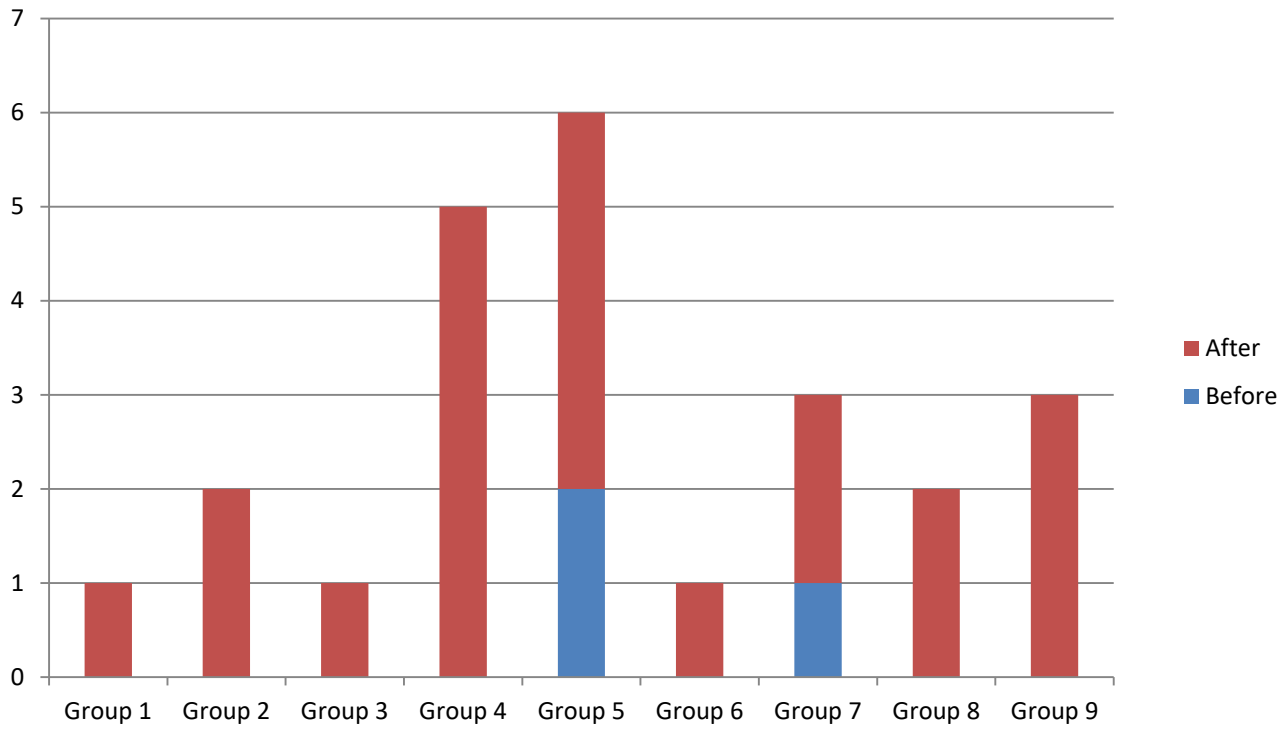
Safe façade design		
Façade		
3	A	Facade-level construction process safety risks
1		REPORT

Evaluation workshop



Number of safety issues inherent in a scenario façade design identified before and after participants were provided access to the infographics

Upstream safety issues



Number of upstream safety issues inherent in a scenario façade design identified before and after participants were provided access to the infographics

Designers' comments

- "*I suppose at a glance you can see the whole environment. Whereas when something's in writing you just focus on the one issue and not the whole environment. It's a much more global thing*".
- *[The infographics] brought to the fore the risks and got you to look a bit deeper into a situation…because people do have different backgrounds, different ways of looking at things."*
- *"[The infographics] may make a difference to somebody who's less experienced…and provide some trigger for them…They don't think about all the possibilities. They've got a narrow field of expertise on which to draw from."*
- "*I think at that stage of a project…when we don't have everything fully resolved, these things will be very useful for a project team to look at to try to understand some of the issues the builder will encounter when they are actually erecting and constructing the scene*."

Context is important – understanding the way work is done

- "*To place a straight ladder at the 1:4 ratio just doesn't work, you can't get a body in there as well because it blocks off the access and you have to contort yourself to actually get in [to the ceiling space].*"
- The routine violation of the SOP (gap between procedure and practice) was identified

Standard operating procedure required a straight ladder to be placed at a 1:4 ratio, and extend 900mm beyond the step off point.

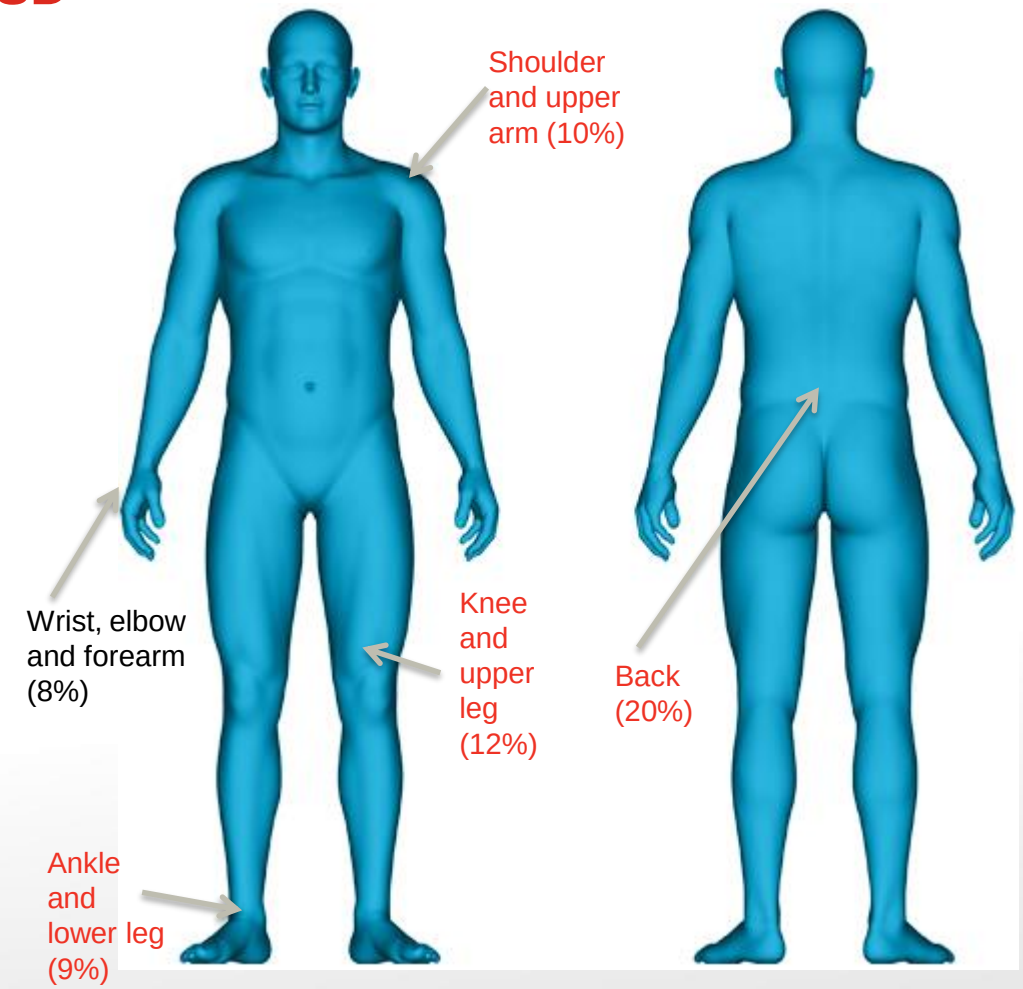
To use an A-frame ladder workers had to stand on the top rung and haul themselves into the Ceiling space

Design of work

- *Good design can eliminate or minimise the major physical, biomechanical and psychosocial hazards and risks associated with work. Effective design of the overall system of work will take into account, for example, management practices, work processes, schedules, tasks and workstation design.*
- Safe Work Australia, 2012b, p. 7

Designing work to reduce WMSD

- Construction involves frequent exposure to awkward body postures and movements, e.g.
  - lifting,
  - bending,
  - twisting,
  - kneeling (often for over extended time periods).
- 20 per cent of serious workers' compensation claims in construction are for back injuries
- Body stressing accounts for 37 per cent of compensation claims in construction
- Musculoskeletal disorders are linked to work disability and diminished mental health
- Up to two thirds of construction workers retire early due to work disability (Arndt, 2005)



Data sourced from Safe Work Australia, 2016

RMIT UNIVERSITY

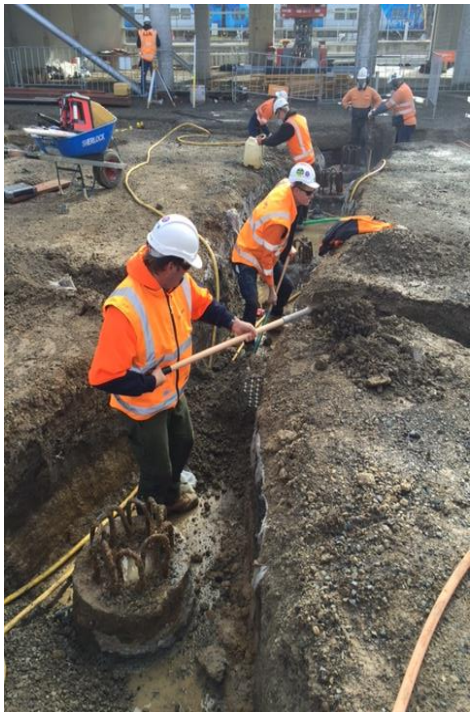
Seven high risk tasks have been identified for analysis

- shotcreting,
- jack-hammering,
- steel fixing,
- cable pulling,
- hole drilling,
- concrete cutting,
- shovelling

Shotcreting

Jack- hammering

High risk tasks for MSDs

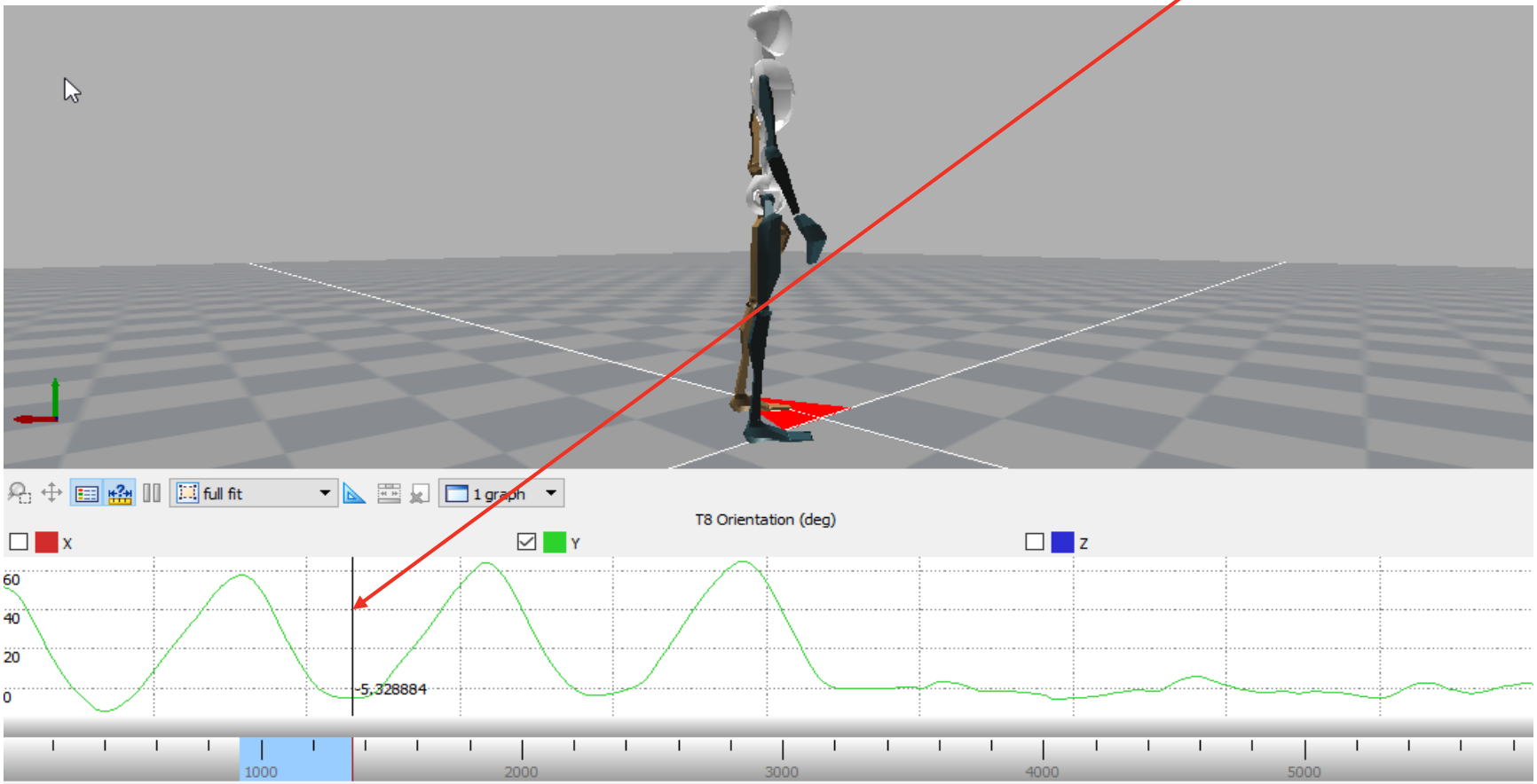


What we are doing

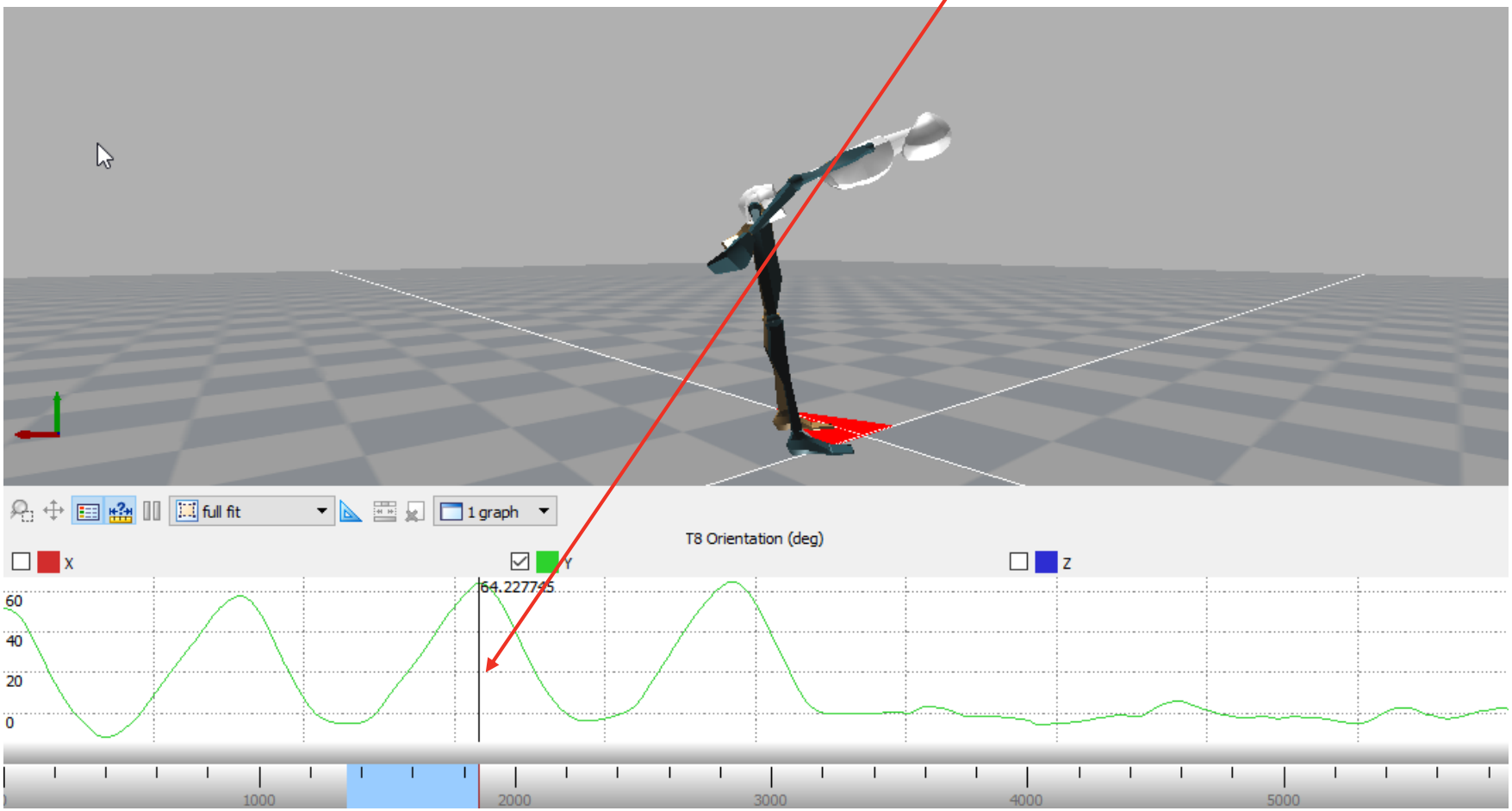
- Inter-disciplinary team of construction WHS, sports and exercise scientists, bio-mechanists and ergonomists – even fashion and textiles!
- Undertake a baseline assessment of tasks using observational and video techniques combined with advanced motion sensing technologies (Xsens motion tracking technology)
- Using a participatory ergonomics approach, develop alternative ways of performing these tasks
- Implement changes in a site-based environment and re-assess the tasks
- Develop practical guidance and video-based training materials for industry dissemination and impact

Example of bending forwards

Back-front angular position of the lower back (shown by vertical line) while standing upright



Back-front angular position of the lower back (shown by vertical line) with back bent



Questions?

For more information please visit

http://www.rmit.edu.au/research/research-institutes-centres-and-groups/research-centres/cwhsr/

The Research to Practice report can be downloaded from

http://www.rmit.edu.au/research/research-institutes-centres-and-groups/research-centres/cwhsr/publications/