Sustainable Built Environment National Research Centre

Project 2.7 - LEVERAGING R&D FOR THE AUSTRALIAN BUILT ENVIRONMENT

Phase 2 – Case studies

Part 2: Case 1 – Road Construction Safety

Read in conjunction with Part 1, 3 & 4

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Abbreviations:

APA – Australian Asphalt Association
ARC – Australian Research Council
BCC – Brisbane City Council
BEIIC – Built Environment Industry Innovation Council
CARRS-Q – Centre for Accident Research and Road Safety Queensland
CCF – Civil Contractors Federation
CCTV – Closed-Circuit Television
CRC CI – CRC for Construction Innovation
COO – Chief Operations Officer
CRC – Cooperative Research Centre
DG – Director General
DVR – Digital Video Recorder
ILO – International Labour Organization
MTA – Mechanical Traffic Aid
MUTCD – Manual of Uniform Traffic Control Devices
NOHSC- National Occupational Health and Safety Commission
OHS – Occupational Health and Safety
PHS – Plant Hire Services
PPE – Personal Protective Equipment
PSE – Passport to Safety Excellence
QMCA – Queensland Major Contractors Association
QPS – Queensland Police Service
R&D – Research and Development
RTA – Roads & Traffic Authority (New South Wales)
SBEnrc – Sustainable Built Environment National Research Centre
SMG - Senior Management Group
TCA – Traffic Controllers Association
TMA – Truck Mounted Attenuator
TMAQ – Traffic Management Association of Queensland
QTMR – Queensland Department of Transport and Main Roads
TRUM – Queensland Traffic and Road Use Management Manual
WHS – Workplace Health and Safety

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EXECUTIVE SUMMARY

The Queensland Department of Transport and Main Roads (QTMR) has taken a leadership role in developing a safer working environment for road construction workers. In the past decades, a range of initiatives have been introduced to contribute to improved performance in this area. A key industry-wide initiative of note is the *Construction Safety Competency Framework* project (2006) led by the CRC for Construction Innovation with QTMR and John Holland as key partners (Section 6.1). Several other initiatives have also been undertaken by QTMR as part of their overarching commitment to safety. Three such initiatives form the basis for this case study investigation, in order to better illustrate the nature of R&D investment and its impact on day-to-day operations and the supply chain. These are the development and implementation of: (i) the *Mechanical Traffic Aid*: (ii) the *Thermal Imaging Camera*; and (iii) the *Trailer-based CCTV* (camera).

This case study seeks to illustrate: (i) the nature of this leadership; (ii) the contributory role of R&D to policy development; and (iii) the dissemination and impact of outcomes in the broader industry. Issues to be explored include: defining QTMR's leadership in this field; understanding drivers for these R&D initiatives; and identifying influences of R&D from other sectors/disciplines.

A broad cross section of people from within QTMR (including the Queensland Workplace Rights Ombudsman and the Minister for Main Roads) have been identified as responsible for driving and delivering on these initiatives since 2008. These include the Director General (DG), and Chief Operations Officer (COO), and the WHS Governance group. At the initiative and operational level those involved include: RoadTek (QTMR's commercial construction business); WHS Research and Development (R&D) Senior Advisor; project teams and project implementers; and the Transport Services Division.

Section 2 presents a summary of interview data relating to the specific theme of each interview question. Section 3 presents data coded by researchers against criteria relating to organisational and innovation theories, identified as significant to this research. Section 4 discusses this data in two parts. The first part builds a better understanding of the initiatives and the context in which they were undertaken. The second part aims to build an understanding of the organisational capabilities evidenced throughout this process. Section 5 presents conclusions based on the analysis of the findings. The main capabilities made apparent during the analysis of the interview data include: (i) product and process development; (ii) coordination of the innovation process; (iii) organisation learning and the development of staff skills; (iv) customer focus and needs awareness; (v) value-creation through both the internal and external knowledge base; (vi) broad communications structures; and (vii) other non-financial benefits such as risk reduction. Criteria against which little or no coding was recorded include: a focus on time and cost advantage and/or reduction; IP creation and management; and new metrics for assessing innovation performance. These findings will be explored further: in conjunction with QTMR; in the context of the cross-case analysis; and alongside of the findings of the audit and analysis of past R&D investment in the Australian built environment.

Additional appendices provide further detail including: (i) a timeline of relevant international, national and state developments; (ii) a précis of relevant national and state strategies; and (iii) detailed interview data for those who wish to delve deeper into these findings.

This report is to be read in conjunction with Part 1 Overview. Two additional parts discuss findings of the two concurrent case studies, namely: (i) *CADD to Integrated Project Delivery* (Queensland Department for Public Works); and (ii) *Green building* initiatives (West Australian Government).

1. The initiatives

The Queensland Department of Transport and Main Roads (QTMR) has taken a leadership role in developing a safer working environment for road construction workers. In the past decades, a range of initiatives have been introduced to contribute to improved performance in this area. A key initiative of industry-wide note is the *Construction Safety Competency Framework* project (2006) led by the CRC for Construction Innovation (CRC CI) with QTMR and John Holland as key partners (See Section 6.1).

Several other initiatives have been undertaken by QTMR as a part of this overarching commitment to safety. Three of these projects are the basis for this case study investigation, aimed at better illustrating the nature of R&D investment, and its impact on day-to-day operations and the industry supply chain. These include the development and implementation of: (i) the *Mechanical Traffic Aid*; (ii) the *Thermal Imaging Camera*; and (iii) the *Trailer-based CCTV (camera).* These have been undertaken in the context of building a better understanding of Workplace Health and Safety (WHS) roles and responsibilities. The role taken by QTMR has been defined by their global, national and internal initiatives and research in this area.

This case study seeks to investigate: (i) the nature of this leadership; (ii) the contributory role of R&D to policy development; and (iii) the dissemination and impact of outcomes in the broader industry. Issues to be explored include:

- Defining QTMR's leadership in this field
- Drivers for R&D initiatives developed and implemented in the past 10-15 years
- Influences of R&D from other sectors/disciplines
- The role of collaboration

A broad cross section of people from within QTMR have been identified as responsible for driving and delivering on these initiatives from 2003. These include the Director General (DG), and Chief Operations Officer (COO), and the WHS Governance group. At the initiative and operational level those involved were RoadTek (QTMR's commercial construction business); WHS Research and Development (R&D) Senior Advisor; project teams and project implementers; and the Transport Services Division.

Additional drivers provided by the Queensland Workplace Rights Ombudsman *Report on Traffic Control* (2009), and the Minister for Main Roads have also been important.

Key industry association relationships include those with: Australian Asphalt Association (APA); Civil Contractors Federation (CCF); Queensland Major Contractors Association (QMCA); and Traffic Management Association of Queensland (TMAQ). Furthermore, QTMR's relationships with external contractors and agencies (such as Abigroup, Brisbane City Council (BCC), and Leightons), as well as consultants and suppliers (including Hi Tech Rear Vision and Mobile Camera Security) contributed significantly and have been important to these initiatives.

Three specific initiatives were selected to illustrate this case study.

1.1. Thermal Imaging camera unit

QTMR uses a number of large trucks fitted with impact attenuators to protect its workers during static and rolling construction, and maintenance works on state controlled roads. These vehicles, known as Barrier Trucks or Truck Mounted Attenuators (TMA's), are operated by QTMR staff and are used as a first line of defence to protect vehicle-based and pedestrian road workers from vehicle impacts. As a result of 14 incidents since 2003 involving vehicle strikes, barrier trucks and injury to road workers, informal research was undertaken by members of the Truck Mounted Attenuator (TMA) working group. This group found that QTMR's counterparts from the NSW Road and Traffic Authority (RTA) used rear mounted *Thermal imaging cameras* in their vehicles for the purpose of early indication of possible collision incidents.

Based on these discussions two Barrier Trucks at the Nathan Deport were retro-fitted with standard imaging cameras and digital video recorders (DVR's) in 2009. This proved unreliable, with poor quality and lacked ongoing support. After this, further options were explored including trialling new thermal imaging technology. A formal trial of thermal imaging technologies on barrier trucks was undertaken in July 2009 to assess whether this could increase the safety of workers operating in and around these specialised trucks. The 6-week trial concluded with the gathering of operator's data via a questionnaire as to their experiences. The trial included thermal imaging infrared camera, reversing camera, and a digital video recorder (DVR).

Key findings of the trial results, compiled from feedback sheets and data obtained from operators, were: the reversing camera had a positive effect in reducing speed around road work sites; thermal imaging allowed the barrier truck operators to have a better visual understanding of the oncoming traffic; and the inclusion of a DVR provided better access to information for work supervisors. Finally, the trial also identified a series of options which were considered with respect to financial considerations, risks, advantages and disadvantages. The Workplace Health and Safety (WHS) program office recommended Option 3 - to fit the fleet with *thermal imaging technology, reversing camera, and DVR.* This option involved the installation of Thermal Imaging Camera system to the remaining 27 barrier Trucks within QTMR's fleet. The tender process for the supply of the Thermal imaging cameras was finalised, and the installation of the units is currently in progress at the writing of this report.

1.2. Mechanical Traffic Aid

The *2009 Ombudsman's Report into the Traffic Control Industry* revealed that the tendency to ignore reduced speed zones had reached a level where it was regarded as culture among Queensland motorists. The report provided several recommendations to help improve the road construction site safety across the state. As a result of the report, and an opportunity for improvement to enhance road worker safety, in late 2010 QTMR acquired a *Mechanical Traffic Aid (MTA)* to trial at Queensland road construction sites.

QTMR has previously trialled (conducted at Mackay in 2001) a *Mechanical SLOW Man* unit which was a cut-out of a person with a moving right hand and the left arm holding a SLOW sign. Its purpose is to alert motorists about the presence of Traffic Controller at a work zone and to encourage them to reduce their speed. It was evidenced from this trial that the presence of the device reduced the speed around the work site. The device was endorsed by the Road Safety Branch but was not implemented. Further desktop research was undertaken where QTMR identified the use of Mechanical Traffic Aids in Asia, Europe and other parts of Australia such as the Tweed Shire Council in NSW. This led to the trial of the MTA.

The device (essentially a test device only for trial purposes) is a mannequin dressed in similar clothing to a Traffic Controller that assists with calming traffic at road construction sites, through movement of a robotic arm. It was expected this device would have a significant influence on vehicle speed around road construction sites. Other research conducted overseas reflects similar issues in road construction safety.[1]

[1] A similar trial was conducted in Malaysia in 2010 of a portable traffic light system to replace manual traffic control at road construction sites. This trial was significant as it highlighted the use and deployment of what Subramiam et al. (2010) called "the automated flagman" (p.76), similar to QTMR's *Mechanical Traffic Aid* device, in conjunction with the traffic light system.

The MTA unit was trialled at three sites within Queensland for a total of 17.5 hours. During this time the deployment of the MTA did not interfere with the safe operations of the road construction sites. The results of this trial, compiled through speed check data, and operator feedback and observation sheets, showed the MTA was an effective tool in reducing speeds around the sites with results showed that for 85% of the recording time (or the 85th percentile) vehicles were not exceeding the speed limit, and a significant reduction (on average from 61% to 20%) in speeding violations. The trials found that the *MTA* was a useful method as an advance warning device around road construction sites. It found that the *MTA* should be limited to high risk construction sites involving work in close proximity to live traffic lanes. Finally, the trial report recommended that any future deployments be limited to night works and motorway construction sites only.

The trial outcomes were discussed through internal and external (industry) stakeholder briefings to assess the future deployment and operational criteria for the MTA. The test device is now currently being redesigned for use in Queensland conditions. Supporting specifications and deployment guidelines will be included in QTMR's Traffic and Road Use Management Manual (TRUM).

1.3. Trailer-based CCTV

Road congestion is a by-product of road construction work which often leads to road-user aggression targeted at construction workers, especially traffic controllers. In January 2010 a 3-month trial was conducted on major project sites utilising two methods: (i) video monitoring and road signs; (ii) and a Trailer Camera (TrailerCam) system. This initiative was based on the 2009 Ombudsman report which identified driver behaviours around road construction sites as a significant contributor to accidents and fatalities at those sites.

The trial used signage approaching road work sites notifying road users that their behaviour may be monitored. Additionally, a trailer-based CCTV unit was stationed within the site to record activities leading up to and through the road work site. This system used the CCTV capabilities of monitoring large areas and recording footage to on-board hard drives. The intent of the trial was to determine whether the presence of the *TrailerCam* and the associated road signs had a positive effect of road user aggression and speed through the five road work sites, and if the TrailerCam can be successfully operated in live road works environment.

The trial highlighted four outcomes: (i) the presence of the TrailerCam and associated signage proved to be an effective tool in improving driver behaviour; (ii) the use of CCTV allowed the Queensland Police Service (QPS) to investigate road traffic breaches; (iii) the report recommended that Plant Hire Services (PHS) purchase the TrailerCam system for use on state controlled roads; and (iv) the deployment of the TrailerCam be dictated by local risk assessments and traffic management planning considerations. It can be reported that the TrailerCam system has been approved for implementation with supporting deployment guidelines being incorporated within QTMR's systems. PHS has purchased one TrailerCam unit for deployment as needed, and is supported with an instruction guide for the operation and deployment of the unit.

2. Illustrating the case - interview findings

This report is to be read in conjunction with Part 1 – Overview, which provides details of the research methods and tools used to gather the following data.

Data for this case has been gathered from interviews undertaken with 10 people from both within QTMR and external to the organisation but with a high level of awareness of green building initiatives (Table 1).

Table 1 - Interviewees

Role	Case 1
Executive (internal)	1
Champion (internal)	1
Project Leader (internal)	1
Implementer (internal)	1
Allied Agency (internal)	2
Supplier (external)	2
Industry Rep. (external)	1
Researcher (external)	1
	10

The following tables (Table 2 to Table 10) provide a summary of data gathered relating to the specific theme of each interview question.

Table 2 – Key drivers

Risks to road workers & travelling public
Vehicle Safety – vehicle and road worker
Current research projects
Implementation of new technology
Road work operations & efficiency
Other state government reports & initiatives

Table 3 – Key implementation activities

Deployment and implementation guidelines
Communication and stakeholder participation
Procurement requirements
Alignment to MUTCD[2], other regulations, policies, Acts, and codes
Funding requirements
Legal and privacy issues
Staff education and training

Table 4 – New processes

Education and training within QTMR
Communication within the industry
Project management
Program governance and management
Implementation, operational, and work practice guidelines
MUTCD and TRUM[3] updates
Traffic management, and IT requirements for video feeds
Collaboration, coordination and stakeholder engagement
Communication with the travelling public

Three types of impacts are being discussed: (i) impacts on the culture and values of the organisation; (ii) on the supply chain and industry; and (iii) the impact of major external changes on the development and delivery of the initiatives.

[2] Manual of Uniform Traffic Control Devices
[3] Queensland Traffic and Road Use Management Manual

Table 5 – Impact on values and culture

QTMR's cultural change program
Benefits of new technology
Road work site deployment, work patterns, and contractor expertise
Building awareness and understanding
R&D initiative process
Education and training, and communication within QTMR
Budgets for new technology

Table 6 – Impact on supply chain and industry

Shared knowledge across the industry and supply chain
Workforce and union implications
Availability of technology locally
Industry funding
Better work site management

Table 7 – Major changes impacting on initiative

National and state regulations, Acts, codes, and policy updates
Implementation, deployment, and process documents
Training and education for new technology
Internal funding, e.g. funding for trials
Design changes

Table 8 – Successes

Better risk identification and early warning system
Greater awareness within the industry
Changed driver behaviours
Improved safety around road work sites

Table 9 – Barriers

Lack of time and resources, e.g. cost implications
Internal awareness of initiatives
Negative perceptions and lack of interest
Speed of research
Broad concerns surrounding technology deployment
MUTCD requirements
Design and manufacturing issues
Internal delays and procurement requirements

Table 10 – R&D activities and engagement

Departmental R&D funding
Better technology, technical solutions and outcomes
Role of WHS Senior Advisor in R&D
Benefits for the industry
Better innovation
Greater role for academics
More R&D can increase road worker and travelling public safety

3. Links to theory

The following tables (Table 11 to Table 21) present data coded by researchers against specific criteria related to the three areas of theory identified as significant to this research (i.e. dynamic capabilities, absorptive capacity and innovation). The tables highlight the number of interviewees in five categories (i.e. Majority = >80%; Several = >50% but < 80%; Some = <50% but >20%; Minority = <20%; None) who were considered by the research team to have raised concepts related to the criteria indicated on the following graphs.

3.1. Dynamic capabilities

Teece, Pisano and Shuen (1997) define dynamic capabilities 'as the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments' (p.516). Criteria for providing evidence of an organisation's have been drawn from several papers in this field including Lawson and Samson (2001), Teese and Pisano (1994), Eisenhardt and Martin (2000), Davis and Walker (2009).

3.1.1. Evidence of dynamic capabilities

Comments during interviews were attributed to characteristics of the following dynamic capabilities (Table 11). For example, this is useful in the context of QTMR's ability to integrate and take advantage of safety-related innovations.

Table 11 - Interviewees who discussed issues related to organisational dynamic capabilities

Majority	Product or process development Organisation learning Customer focus Alliancing Technology transfer Internal R&D engagement
Several	External R&D engagement Product or service differentiation
Some	Strategic decision making
None	Cost advantage through increased market intelligence Cost advantage through less waste IP creation

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

3.2. Absorptive capacity

3.2.1. Evidence of inbound absorptive capacity

Cohen and Levinthal (1990) introduced the concept of *absorptive capacity* as a 'firm's ability to recognise the value of new, external information, assimilate it, and apply it to commercial ends' (p.128). They argue that absorptive capacity is 'largely a function of prior related knowledge' (p.131) that has been accumulated through effort, as prior knowledge facilitates the assimilation of new knowledge. Key criteria, which shed light on the absorptive capacity of an organisation, have been drawn from key literature in this field (Cohen and Levinthal 1990), Zahra and George (2002), Nieto and Quevedo (2005), Flatten et al. (2011)).

This is relevant in terms of further understanding QTMR's capacity to value, assimilate and take advantage of safety-related knowledge.

Table 12 –Interviewees who raised issues relevant to evidence of inbound absorptive capacity

Majority	Exploitation of knowledge Assimilation of knowledge into organisation Transfer of knowledge
Several	Knowledge acquisition – internally generated Knowledge acquisition from external sources

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Measures of absorptive capacity

The following measures of absorptive capacity have been derived from Cohen and Levinthal (1990), Zahra and George (2002), Nieto and Quevedo (2005), Flatten et al. (2011).

Table 13 – Interviewees who raised issues relevant to measures of absorptive capacity

Majority	Effort put into development of new products Staff skills - Investment in training Awareness of customer needs Capacity for technology development
Several	Awareness of competitors' technologies Noteworthy economies of scale
Some	Range of staff training Capacity to adapt technologies from other sources
Minority	High level of technology specialisation
None	Effort put into cost reduction

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

3.3. Innovation

Chesbrough (2004) defines the *open innovation* paradigm as an assumption 'that firms can and should use external as well as internal ideas and internal and external paths to market, as they look to advance their technology' (p.23). He proposes that this increases the number of possible sources of innovation.

This approach better enables an organisation (in this instance QTMR) to deal with the unknowable, and manage the risks associated with experimentation.

Chesbrough et al. (2005) was used as the source for the *features* of 'open innovation' presented in these case reports. Huizingh (2011) was the source for the criteria which have been used to illustrate the *nature* of open innovation exhibited in the delivery of initiatives. Categories of *factors resulting in benefit from innovation* project and team have been drawn from Ling (2003). Bossink (2004) discussed an extensive array of *drivers for construction innovation*. These have been used alongside interview responses to categorise drivers within each case study organisation.

3.3.1. Features of open innovation

Chesbrough et al. (2005) was used as the sources for significant features of open innovation (Table 14).

Table 14 – Interviewees who raised issues relevant to significant features of open innovation

Majority	Abundant underlying knowledge landscape Purposive outbound flows of knowledge & tech.
Several	Business model focus on converting R&D into commercial value Equal importance given to external knowledge, in comparison to internal knowledge
None	Proactive and nuanced role of IP management Rise of innovation intermediaries New metrics for assessing innovation capability and performance

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

3.3.2. Nature of open innovation

Key relevant academic literature was the source for the following criteria which have been used to illustrate the nature of open innovation exhibited in the road construction initiatives within QTMR (See Part 1 Overview).

Table 15 – Interviewees who raised issues relevant to the nature of inbound innovation

Majority	Exploitation
Several	Outbound innovation (external exploitation of internal knowledge Retention Non-pecuniary Knowledge Acquisition
Some	Pecuniary re acquiring, sourcing, selling, and revealing
None	Coupled activities

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 16 –Interviewees who raised issues relevant to effectiveness of innovation

Majority	Nonfinancial benefits Decreasing risks
Several	Enhancing technological effectiveness Access to new markets
Some	Less waste
None	Shorter time to market Number of innovations Other measures Lower costs Stimulating growth Financial benefits

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

3.3.3. Benefits of open innovation approach

The benefits of this approach for the project and team have been drawn from key academic literature (See Part 1 Overview). Those identified in Table 17 relate to the working environment.

Table 17 – Interviewees who raised issues relevant to benefits of open innovation approach

Majority	Working environment Level of interest of project team members Formation of task groups
Several	Capabilities of the people involved in the innovation

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

3.3.4. Drivers for construction innovation

The academic literature discusses an array of drivers for construction innovation (See Part 1 Overview). These have been used to thematically code data from interviews.

The following tables (Table 18 to Table 21) highlight areas where interviewees raised issues relevant to construction innovation in the context of QTMR's road construction initiatives. Table 18 highlights the environment pressures which are considered to have existed.

Table 18 – Interviewees who raised issues relevant to benefits of construction innovation – environmental pressures

Majority	Market pull industry wide
Several	Governmental clients with innovative demands
Some	Innovation stimulating regulations
None	Government guarantee for markets for innovative firms Subsidies for innovative applications and materials

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 19 highlights issues associated with technological capabilities relating to the implementation of these initiatives.

Table 19 – Interviewees who raised issues relevant to benefits of construction innovation – technological capability

Several	Programs promoting access to technology Technology push
Some	Technology leadership strategy Finance the pilot projects Technology fusion
None	Product evaluating institutions

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Table 20 highlights issues related to the exchange of knowledge (such as the on-site training of workers) raised by interviewees when discussing QTMR initiatives.

Table 20 - Interviewees who raised issues relevant to benefits of construction innovation – knowledge exchange

Majority	Training of workers on the site Stimulation of research Broad view of risk
Several	Lateral communication structures
Some	Effective information gathering Programs promoting collaboration Creation of knowledge networks
None	Integrated & informal R & D function

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20%

Finally, Table 21 presents data related to 'boundary spanning' which may also be considered as crossing over traditional boundaries (such as organisational silos).

Table 21 – Interviewees who raised issues relevant to benefits of construction innovation – boundary spanning

Majority	Involvement of the client Strategic alliances in long-term relationships
Several	Mechanisms sharing financial risks and benefits Explicit coordination of the innovation process Innovations from suppliers
Some	Coordination of participating groups Integration of design and build
Minority	Empowerment of innovation leaders* Empowerment of innovation champions*

Majority = >80% Several = >50 but < 80% Some = <50% but >20% Minority = <20
*The implementer and the project leader (safety innovation leaders) provide reports on the safety initiatives directly to QTMR's COO (safety champion).

4. Discussion

The above data has been gathered and analysed in order to illustrate and better understand the QTMR's road construction safety initiatives and the environment in which they were implemented.

As per the data presented in the previous section, this discussion is presented in two parts. The first part is designed to build a better understanding of the initiatives themselves. This draws directly from responses to each of the interview questions (Table 2 to Table 10). The second part has used a set of criteria from academic theory relating to dynamic capabilities, absorptive capacity and open innovation to thematically code data. This has been done to build a deeper understanding of the organisational capabilities QTMR have exhibited in the course of these activities, and of those capabilities which may not have been evident, but which may contribute to better outcomes into the future.

4.1. Understanding the initiatives

In summary key *drivers* of these initiatives include: reducing risk to road workers and the travelling public; vehicle safety; current research projects (for example Fatigue Glasses and Digital Speed Indicating Devices); implementation of new technology such as the deployment of the *TrailerCam* at major road construction sites in Gympie and Tungun by QTMR engineers; better and more efficient road work operations; and state government reports and initiatives (for example the Ombudsman *Report on Traffic Control* (2009)).

Key *implementation* activities related to these initiatives involved: the development of trial deployment guidelines; communication and stakeholder participation; procurement requirements; alignment to MUTCD and other regulations, policies, Acts, and codes; allowing for funding requirements, legal and privacy issues; and staff education and training on the new technology through formal training sessions and briefings, group discussions, and documented guidelines.

New *processes* required to deliver on these initiatives included education and training within QTMR; communication within the industry; project management processes; program management and governance arrangements; implementation, operational, and work practice guidelines; MUTCD and TRUM updates; traffic management data and IT requirements for video feeds; collaboration, coordination and stakeholder engagement; and communication with the travelling public.

A significant number of *required new processes* were also identified including:

- project management documentation
- new processes and guidelines that aligned with the new operating requirements of the technology
- new work method statements with updated policies and regulations to capture the operating procedures of the new technology
- technical notes included in TRUM
- new signage which incorporates the new technology.

Impacts were observed both internally on organisational culture and values, and externally on the supply chain. Internal impacts included: QTMR's cultural change program; benefits of the new technology; site deployment, work patterns, and contractor expertise; building awareness and understanding within QTMR; R&D initiative process; education and training, and communication; budgets for new technology. Impacts seen in the supply chain include: shared knowledge across the broader supply chain and industry through industry seminars and briefings; workforce and union implications with respect to working hours and operation of equipment; availability of technology locally; increased funding is needed in the industry to further develop the *MTA*; and better work site management.

External impacts as a result of the trials conducted of these initiatives included: national and state regulations, Acts, codes, and policy updates; the fact that new projects will stipulate the use and deployment of the *Thermal imaging camera* and the *MTA*; design and deployment processes to support the new technology; education and training in the new technology; impacts on internal funding, for example sufficient funding being made available for trials; and redesign and reconfiguration of the *MTA* unit for Australian right hand driving conditions.

Key *successes* which were highlighted include: better early warning and risk identification; greater awareness within the industry; changed driver behaviours; and improved safety around road work sites. The trials of the three initiatives provided clear evidence of: (i) reduced vehicle speeds when entering the road work sites; (ii) the units were user friendly;

(iii) observed changes to driver behaviours around road work sites; and (iv) positive feedback from operators, QPS, and industry.

Considerable *barriers* were also identified including: lack of time and resources (e.g. funding); insufficient internal awareness of the initiatives; negative perceptions and lack of interest within QTMR; the time taken for research outcomes to be achieved (in particular getting the new equipment to the field staff in a timely manner); concerns surrounding technology deployment and its associated safety practices could *increase* the risk to road workers and as such the new practices combined with existing practices could get in the way of other regulations; MUTCD requirements; design and manufacturing issues for the *MTA* unit; and internal procurement delays through Plant Hire Services (PHS).

In terms of *R&D engagement and activities* key issues which emerged included: allocation of departmental R&D funding to support the trials and subsequent purchasing of new equipment; better technical solutions and outcomes; the WHS Senior Advisor is a key role in the R&D process; increased benefits for the industry; better innovation practices; a greater role for academics; and the idea that more R&D can increase the safety of road workers and the travelling public.

4.2. Exploring the links to theory

Based on an analysis of interview responses, QTMR has *embedded dynamic capabilities* which have facilitated their approach to road construction safety in that state. These include: product or process development; organisation learning; customer focus; alliancing; technology transfer; and internal R&D engagement (e.g. other internal QTMR research projects such as liaising with OPTALERT in the Fatigue Glasses trial, and the role of Plant Hire Services (PHS) in procurement and deployment).

These latter capabilities are further reinforced with evidence of *inbound absorptive capacity* through: the exploitation, assimilation and transfer of knowledge into and within the organisation (i.e. discussions between QTMR and NSW RTA with respect to the *MTA* and *TrailerCam* units). Issues identified from analysis in relation to measures of absorptive capacity reinforce the effort put into: development of new products; staff skills (and investment in training); awareness of customer needs; and the capacity for technological development (for example safety cultural change program, purchasing and procurement requirements for PHS, and staff education and training programs).

In terms of issues relevant to *features of open innovation*, the majority of interviewees discussed:

- the abundant underlying knowledge landscape - for example: working with CARRS-Q on other safety projects; the trial of the BodyGuard™ Proximity Sensor unit; and liaison with OPTALERT in the current trial of Fatigue Glasses
- useful outbound flows of knowledge & technology – as evidenced in: better awareness and risk identification such as the inclusion of technical notes to align with MUTCD's technical requirements, and the application of *TrailerCam* units in other industries such as mining)

Several interviewees discussed: the business model focus on converting R&D into commercial value; and the equal importance given to internal and external knowledge (for example software and IT requirements for viewing *TrailerCam* video feeds).

Regarding the *nature of this open innovation*, the exploitation of external knowledge for internal benefit was the most frequently coded interviewee response. This is evidenced through: engagement in other safety research projects with CARRS-Q and private organisations (e.g. OPTALERT); new traffic management plans and guidelines required the incorporation of the new technology; and the interest shown from other organisations in these R&D initiatives. Additionally, the *effectiveness of this open innovation* is apparent in nonfinancial benefits and decreasing risks such as better identification of high risk activities. It should be noted that at this stage there would seem to be no impact on QTMR's Risk Management System, but rather the risks discussed in this study are related to the specific trials. Benefits of this approach for the working environment were clearly apparent from interviewee responses in relation to the level of interest of project team members and the formation of relevant task groups.

Construction innovation drivers were coded according to environmental pressures, technological capability, knowledge exchange and boundary spanning criteria. The most commonly coded responses in terms of environmental pressures related to: industry-wide market pull (vehicle safety, reduction in road worker fatalities, risk reduction around road work sites); governmental clients with innovative demands (both QTMR and RTA); and the involvement of the client. In terms of technological capability reference to programs promoting access to technology (extension from previous research to increase the use of technology) and technology push were most often coded. Regarding the exchange of knowledge: the on-site training of workers (with external firms contracted to deliver new technology training to unit operators); stimulation of research (other R&D research projects within QTMR); and taking a broad view of risk (i.e. protection of road workers and travelling public) were the most commonly coded. Finally in terms of boundary spanning the most coded references are:

- Lateral communication structures - as seen in industry wide briefings, communications and education with such groups as Queensland Major Contractors Association (QMCA), Traffic Management Association of Queensland (TMAQ), and Traffic Controllers Association (TCA)
- Strategic alliances in long-term relationships - with other agencies including ABI Group, Brisbane City Council (BCC), Civil Contractors Federation (CCF), and Leightons
- Mechanisms for sharing financial risks and benefits such as cost and funding requirements within the business areas
- Explicit coordination of the innovation process and the pivotal role of the WHS Governance Group
- Innovations from suppliers such as new innovations for Trailer Camera operations.

Those criteria which were not referred to by interviewees and thus not coded in relation to dynamic capabilities include: cost advantage through increased market intelligence; IP creation; and cost advantage through less waste. The latter is reinforced with regards to absorptive capacity with no coding in relation to the effort put into cost reduction; this finding may be attributed to the recent and trial nature of these three initiatives.

With regards to features of open innovation criteria those least coded include: proactive and nuanced role of IP management; the rise of innovation intermediaries; and new metrics for assessing innovation capability and performance. Regarding the nature of inbound open innovation, coupled activities was not coded. In terms of the effectiveness of innovation those criteria not coded include: shorter time to market; lower costs; financial benefits; innovation stimulating growth; and the number of innovations. Again the recent trial nature of these innovations is a likely explanation for the lack of reference to time, cost and growth stimulation. With regards to the lack of references to new metrics, WHS metrics have been long established and accepted industry wide.

The least coded of the construction innovation criteria are: government guarantee for markets for innovative firms; subsidies for innovative applications and materials; product evaluating institutions; integrated & informal R & D function (the trials were conducted on a formal basis in a structured environment); and the empowerment of innovation leaders and champions (the project leader and implementer for these safety initiatives are considered as the innovation leaders - they provide reports directly to the COO who is considered as QTMR's innovation champion).

5. Conclusions

These initiatives within QTMR have been driven by an on-going commitment by both the Department and the industry to safer conditions for road construction workers. The trials of these initiatives can be characterised and based on a combination of both informal and formal R&D processes. This has included desktop research; discussions with NSW RTA on similar technologies (e.g. the MTA unit); options analyses as reflected in the Thermal Imaging trial; pilot trials of the technology and their assessment (through surveys of users and operators, and a review of performance and options as evidenced with the TrailerCam system). Finally, it was found that the MTA and TrailerCam trials were as a direct result of the Ombudsman Report on the Traffic Control (2009) which highlighted the need to reduce speed and change the behaviour of drivers at and around road work sites.

The analysis of organisational characteristics highlighted above illustrates the nature of the capabilities which exist in the organisation and led to these successful trials. It also highlights those capabilities least or not apparent. There was a high level of focus on several criteria (not prioritised):

- Product and associated process development (both internally and with suppliers) and their transfer for application
- Coordination of the innovation process – including design, project management, implementation, and testing
- Organisational learning and the development of staff skills (including on-site training) in terms of: safety cultural change; new technology; and internal awareness of research initiatives
- Customer focus and awareness of their needs - evidenced by supplier's efforts to align with QTMR
- Value-creation through both the internal and external knowledge base including R&D and its exploitation, both within QTMR and externally. Of key importance is that R&D outcomes meet operational requirements, are technically excellent and credible in terms of application
- Broad communications structures including strategic and long-term relationships with industry associations was evidenced (such as the Australian Asphalt Association - APA, and TMAQ); external contractors and agencies (e.g. Abigroup and BCC) as well as consultants, and suppliers (e.g. Hi Tech Rear Vision)
- Non-financial benefits such as risk reduction were a focal point, in line with these initiatives being focussed on worker and public safety.

Potential areas for enhancing outcomes relate to those criteria least including: a limited focus on time and cost advantage and/or reduction; IP creation and management; new metrics for assessing innovation performance. This may be expected given the trial nature of these initiatives.

These findings will be explored further: in conjunction with QTMR and in the context of the cross-case analysis. Further verification (through additional and follow-up interviews) and analysis (through separation of internal and external interviewee findings) of these findings would yield additional knowledge, and may be possible in the context of Case Study 4. Findings will be further considered in the context of Phase 4 of the current project, in establishing policy guidelines for future investment in the built environment.

6. Appendices

6.1. Construction Safety Competency Framework

Between 2005 and 2009, the CRC for Construction Innovation led health and safety-based research projects in an effort to address this critical national issue. Workplace fatalities in Australia's construction industry cost the nation $3.6 billion each year. Research also shows that 20-24 year olds in the building and construction industry are four times more likely to have a fatal accident than those in other industries.

Three main projects were undertaken to improve safety in Australia's construction industry being: (i) *Construction Site Safety Culture;* (ii) *Safer Construction*; and (iii) *Safety Effectiveness Indicators.* To achieve this, the CRC for Construction Innovation brought together multi-disciplinary project teams with participants from across industry, government and research. The teams also worked collaboratively with employers and employees to ensure the best possible outcomes. Two key outcomes of the *Construction Site Safety Culture* project were: the *Construction Safety Competency Framework* (launched 2007); and *A Practical Guide to Safety Leadership* (launched 2009).

The *Construction Safety Competency Framework* promotes a consistent national standard to improve occupational health and safety (OHS) competency for key safety positions within an organisation. Implementing the framework enables staff such as project managers, supervisors, OHS advisors and engineers to effectively execute tasks needed to better manage OHS. The framework directly addresses the industry's safety culture and provides a process for significant cultural change and the reduction of injury and incident rates. Through collaboration with the *Office of the Federal Safety Commissioner* and the CRC for Construction Innovation network, this project was responsible for an ongoing cultural change based on the industry working together to improve safety.

The follow-up publication *A Practical Guide to Safety Leadership* converts the principles of the framework into more accessible and practical solutions for small to medium businesses. Again developed in consultation with the *Office of the Federal Safety Commissioner*, it provides a step-by-step approach to creating and maintaining a positive safety culture. Through its concise and hands-on approach it explains: (i) the safety critical positions and safety management tasks that companies should implement; and (ii) provides industry case studies of the competency framework implementation.

The outcomes of these safety projects have been implemented in organisations including John Holland, Queensland Transport and Main Roads, Bovis Lend Lease, Joss Group, and Laing O'Rourke. Approximately 14,000 construction workers have undertaken safety training based on this framework.

6.1.1. The John Holland story

John Holland has been a core partner of CRC for Construction Innovation since its inception, reflecting its commitment to improving safety in its workforce and in the industry as a whole. In 2008, John Holland used *A Construction Safety Competency Framework* to develop its own *Passport to Safety Excellence Program*. The program was designed to help supervisors and/or managers to manage their safety tasks within the safety competency framework and to help participants build skills and competencies to manage safety in their workplace. Between September 2008 and early 2010 over 220 programs were delivered to approximately 3200 participants. This contributed to a dramatic decrease in Workers Compensation Claims from 20 claims per 1,000 workers in 2003 to less than 4 claims per 1,000 workers in 2009-10.

John Holland was the lead agent in the initial development of the *Certificate IV in Safety Leadership (OHS) – Construction,* following extensive research into what constitutes effective and safety competency across diverse roles and responsibilities within the company and the construction industry. This qualification was nationally accredited in 2008. It aims to provide construction personnel and contractors in safety critical positions with the skills and knowledge required to complete their work effectively and to deliver safe outcomes for the workforce and clients.

6.1.2. The QTMR story

As part of its commitment to Zero Harm, QTMR recognised the need to build and further develop their systems and resources to better manage safety, and strengthen the safety culture within the Department. Research was conducted by the WH&S Branch to look at best practice methodologies for improving safety performance. As a result of that research, three providers – DuPont, Precision Technologies and the Cooperative Research Centre for Construction Innovation (CRC) were invited to brief the WH&S Governance Committee on 14 March 2008 to outline their approaches to improving organisational safety performance through cultural change. Following these briefings, the Committee agreed to follow the CRC's approach as the way forward for the department.
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A set of training modules were developed for the QTMR program by Safety Dimensions (an accredited training provider). This program was aimed at providing employees with the competencies, knowledge, and behaviours to proactively support a Zero Harm safety culture. Following a preliminary workshop in August 2008 the program was initially rolled out within RoadTek in late 2008. It was then extended to the rest of QTMR as part of a 3 year training program. The program consists of ten core and elective units which individuals can undertake and ultimately result in the award of a *Certificate IV in Safety Leadership*.

Key outcomes included:

- To date 5,820 people have attended courses covering the ten units, with a completion rate of 56%. Seven people have attained the *Certificate IV in Safety Leadership (OHS)* award (in order to complete the qualification an individual must demonstrate a shift in the culture of the workgroup).
- Around 1,600 workplace related projects have been completed which range from office based electrical cords through to major projects like rewriting tender specifications for subcontractors.
- Safety is now part of the individuals' role and not just the safety advisors, with a majority of leaders now considering safety as part of their role and responsibility, with increased ownership at a senior management level of the whole strategy.
- A reduction in the number of people being reported as injured; along with increased levels of reporting in both lead and lag indicators; an increase in the number of observations and incident investigations; and an increase in near miss and hazard reporting.

Additional benefits include: improved team engagement through the use of conversation techniques; an improvement in communication processes (e.g. tool box talks, pre-start meetings); a more positive approach to safety; a better understanding of QTMR's Zero Harm roles and responsibilities. Industry dissemination is also proving effective with suppliers modelling their own programs on QTMR's; and QTMR's leadership taking learnings to alliance leadership teams.

6.2. Timeline

The following timeline (Figure 1) is an effort to place QTMR road construction safety initiatives in the context of significant global and national developments in this field.

Figure 1 Road construction safety developments

Date	International	National incl. Australian Government	Qld Government / agencies	Other Australian states/organisations
1985	R&D activities commence into robots being used for construction in Japan.			
1992	Robots introduced on building construction projects in Japan.			
1995			QLD Transport Operations Road Management Act includes road control and management provisions.	SA Occupational Health, Safety, and Welfare Regulations including traffic control are developed.
1997		John Holland group wins 5-star safety award for site safety.		
1998	US National Institute for Occupational Safety and Health data on fatalities and serious non-fatal injuries - led to efforts to protect construction workers.			
1999				NSW Road Transport Safety and Management Act, and Regulation developed which include traffic control plans.
2002		AS1742.3 standard - Manual of Uniform traffic control devices (Part 3) issued. National 10-year OHS Strategy established by National Occupational Health and Safety Commission (NOHSC).	*Mechanical Traffic Aid* device tested in Mackay to test whether the device can slow traffic at road construction sites.	WA Traffic management for works on roads Code of Practice issued which includes road and traffic management.
2003		National Certificate III in Civil Construction (Road Construction) implemented.	QLD adopts national code of practice - Manual for Uniform Traffic Control Devices.	
2004	OHS strategy for construction industry developed in UK reports on 100 construction accidents highlight design reduce risk (Gibb et al. 2004)	CRC CI-led safety research projects commence. Bill Wild (former John Holland Managing Director) receives National Engineer award for safety.		Victorian Road Management Act - defines role of codes of practice and functions for roads. Tasmania Traffic control at work sites developed.
2005	International Labour Organisation (ILO) reports 60,000 fatalities in	John Holland leads CRC CI safety. Engineers Australia and CRC CI	Queensland adopts the National Standard for *Construction Work*	

Date	International	National incl. Australian Government	Qld Government / agencies	Other Australian states/organisations
	construction every year.	establish national steering committee on safety. National Standard for Construction Work (NOHSC) 1016:2005 released	*(NOHSC) 1016:2005.* *Stop Think Go* safety campaign at RoadTek.	
2006	Research in Holland by *van den Berg Infrastructure* to understand crash risk for road construction workers – led to safety promotion materials being developed.	CRC CI, John Holland Group and industry develop the *Construction Safety Competency Framework.*		
2007		*Guide to Best Practice for Safer Construction: Principles* developed. National steering committee on safety disbanded. Research shows average of 1 fatality per year in construction in Australia (Fraser).	QLD Traffic Controller accreditation scheme developed and managed by QTMR covers two areas: traffic control, and road signage.	SA workbook, curriculum, and field guides for Workzone traffic management developed. NSW RTA construction practices issued. Bovis Lend Lease adopts new safety management system incl. roles and responsibilities; education and training program.
2008		*Practical Guide to Safety Leadership* launched - guide for SMEs to develop a safety culture. National Certificate IV in Safety Leadership developed focusing on core skills required within construction.		Leighton contractors develop a national Safety Health and Environment (SHE) Leadership program. Delfin supply chain management process adopted to promote safe work sites. John Holland Passport to Safety Excellence (PSE) program developed.
2009	US Federal Highway Authority identifies the risk and safety of road workers, implements program of training, planning, and high-visibility apparel.	Biomotion requirements for High visibility safety garments into the draft standard - AS/NZS 4602.1 Austroads Research report – National Approach to Traffic Control at Work Sites released. Focuses on traffic control at work sites.	Road side digital speed signs, *Speed Indicating Devices (SIDs),* trialled with Road Safety branch to reduce speed related crashes at road construction sites. Trial of *Thermal Imaging Camera* to protect road workers operating	Study conducted regarding visibility benefits of retro-reflective strips for motion at road worker sites (Wood et al. 2009).

Date	International	National incl. Australian Government	Qld Government / agencies	Other Australian states/organisations
		Development of the National Work Health and Safety Act. Safe Work Australia is established - to progress the harmonisation of WHS laws with states and territories.	ahead of truck. RoadTek trial *Reversing Camera technology* to reduce incidents with mobile plant. QTMR trials the *Mechanical Traffic Aid* - not implemented.	
2010		Safe Work Australia and the Office of Best Practice Regulation develop methodology proposed by Access Economics to conduct analysis and consultation for the National Harmonisation of WHS.	*Zero Harm* statement and policy developed. First time QTMR has a statement on safety – aligns with the Zero Harm at Work philosophy. Initial proposal for trial of *Fatigue glasses.* *Portable radar suitcases* proposal for proximity technology initiated to reduce reversing accidents. Trial of *Trailer-based CCTV unit* to reduce road construction congestion and aggression toward workers.	Joss Group adopts the *Practical Guide to Safety Leadership* to aid practices and procedures to comply with regulations and Acts.
2011		Consultation document on National Harmonisation of WH&S Regulations and Codes of Practice released for public comment.	*Stop Think Go* safety campaign launched at QTMR. Review and implementation of Harmonised WHS Legislation. WH&S management system implementation.	NT road safety program recognises safety near road construction sites.

6.2.1. Road construction strategies

Table 22below provides a summary of the key and most relevant road construction strategies in place across Australia, as well as identifying the key literature within the field.

Table 22 - Road construction safety strategies

Initiatives	Date	Aim and Objectives
National		
Manual of Uniform Traffic Control Devices (MUTCD) – Part 3	First issued 2002	It specifies the traffic control measures and devices to be used to warn, instruct and guide road users in the safe negotiation of road work sites. It is also applicable to traffic guidance schemes for road and bridge construction; provides guidance for the planning, design, installation and operation of traffic control arrangements together with requirements for maintaining a safe workplace.
National Road Safety Strategy 2001-2010	2003	The strategy is aimed at reducing death and injury on Australian roads. It has a target of 40% reduction in road fatalities by the end of 2010. The strategy's objectives included road construction systems, improved road user behaviour, and improved vehicle design.
Certificate III in Civil Construction (Road Construction)	2003	This qualification was developed to inform road workers in theory and practice to prepare them to operate in the road construction environment. The qualification includes areas such as safety around work sites, installing road barriers and signs, and traffic management through construction areas.
National Standard for Construction Work (NOHSC)	2005	The national standard aims to protect individuals from the hazards associated with construction work. It assigns responsibilities to individuals to identify these hazards and either eliminate or, minimise the risks these hazards may pose.
Construction Safety Competency Framework	2006	The CRC CI, led by John Holland Group with input from industry, developed this framework. It provides the information required by safety managers, senior managers and executives to implement a safety culture approach to best suit their organisational requirements.
Guide to Best Practice for Safer Construction	2007	The guide provides a framework to improve safety performance on construction projects and covers all stages of a project from planning to post-construction. Its overarching objective is to reduce the number of accidents and deaths on construction sites and to improve the ability of the industry to deliver safer construction projects and healthier employees.
Practical Guide to Safety Leadership	2008	This is a follow-up to *A Construction Safety Competency Framework* (2006). It was developed with significant input from the construction industry. It was designed as a tool to help industry apply the principles of a safety culture within their organisations.
Passport to Safety Excellence Program	2008	John Holland used *A Construction Safety Competency Framework* (2006) to develop this program. The program was designed to help supervisors and/or managers to manage their safety tasks within the safety competency framework. Specifically, the program helps participants to build the skills and competencies to manage the safety in their workplace.
Certificate IV in Safety Leadership (OHS) – Construction	2008	The qualification was initially developed in 2006 by John Holland Group, following extensive research into what constitutes effective and safety competency across diverse roles and responsibilities within the company and the construction industry. It was nationally accredited in 2008. It was designed for workplace leaders to create and maintain a safety culture and a new way forward by introducing a more stringent standard of OHS competency and compliance.

Initiatives	Date	Aim and Objectives
National Approach to Traffic Control at Work Sites	2009	Austroads commissioned ARRB Group to review traffic control at work sites documentation, including relevant legislation, from each state and territory in Australia. The aim was to identify and document the differences between jurisdictions in their approach to standard setting for traffic control at road work sites, and to analyse the extent of those differences to highlight measures that may be taken to achieve a national approach and recommended strategies and actions.
National Harmonisation of Work Health and Safety Regulations and Codes of Practice	2011	Safe Work Australia and the Office of Best Practice Regulation (OBPR) issued this consultation document for public comment. The aim of this legislation is for uniform national codes and standards for OH&S across all states and territories.
ACT		
Road Safety Strategy and Action Plan	2006	The strategy and plan is a high level set of policies and principles, aimed at specific activities to achieve the goals and targets outlined in the National Road Safety Strategy. The strategy and action plan is aimed at road safety programs in four key areas: education, encouragement, engineering, and enforcement.
New South Wales		
Road Transport Safety and Management Act, and Regulation	1999	The Act and Regulation that was developed makes allowances for traffic control plans.
Road construction practices	2007	This provides a set of road construction practices were issued by the NSW RTA which, aligns to industry best practice for managers and supervisors, in safety design, risk management, and communication.
2010 Road Safety framework	2009	The framework sets out the intent to halve the road toll, saving 2,000 lives by the year 2010. It also promotes community understanding and involvement in road safety initiatives and strategies. The focus of the framework is on all road users, whether as drivers, cyclists, pedestrians or passengers.
Northern Territory		
Road works safety program	2009	The NT government developed a road works safety program which was aimed at improving safety when working on or near roads. It outlined practices which covered areas traffic management systems, the interaction of plant and personnel, traffic signalling and signage, barriers, and training and induction strategies.
Queensland		
Transport Operations Road Management Act	1995	The Act includes and makes provisions for road traffic control and management.
2004 - 2011 Queensland Road Safety Strategy	2003	This strategy was aimed to encourage community participation in achieving a safer road environment. It focused on the areas of alcohol and drug driving, fatigue, speed, seat belts, inexperience, inattention, single vehicles, intersections, and serious casualties.
Manual of Uniform Traffic Control Devices (MUTCD)	2003	Queensland adopted the national code of practice of Manual for Uniform Traffic Control Devices (MUTCD) for traffic control, guidance, and signage arrangements.

Initiatives	Date	Aim and Objectives
Adoption of National Standard for Construction Work	2005	Queensland adopted the National Standard for *Construction Work (NOHSC) 1016:2005.*
Traffic controller accreditation	2007	Traffic Controller accreditation scheme was developed and managed by QTMR and covers two areas: traffic control, and road signage.
South Australia		
Occupational Health, Safety, and Welfare Regulations	1995	This set of regulations includes management and control of all road traffic.
Workzone traffic management guide	2007	A set of curriculum, workbooks, and field guides are developed for road work site traffic management.
Tasmania		
Traffic Control at Work Sites Code of Practice	2004	Traffic control at work sites was developed, and based on national standard for traffic control. It sets out the requirements for traffic control arrangements around road work sites.
Victoria		
Road Management Act	2004	The Act was developed to define the roles of codes of practice and functions for roads and road work sites.
Arrive Alive 2008-2017	2007	This strategy sets out how the Victorian Government will continue its leadership in road safety to deliver a safer system for all road users and make a significant reduction to road trauma. The strategy addresses three critical elements: roads and roadsides, vehicles, and road users.
Western Australia		
Traffic management code of practice	2002	The Traffic management for works on roads Code of Practice includes road and traffic management arrangements around road work sites.
Towards Zero road strategy	2009	The road safety strategy for 2008–2020 is aimed at ensuring that road safety policies in Western Australia. It is based on shared responsibility between the WA Government, the police, road authorities, vehicle manufacturers and the community. The strategy, addresses four key elements for a safe road system: safe road and roadsides, speed, vehicles, and road use.

6.3. Interview data

6.3.1. Understanding the initiatives

6.3.1.1. Drivers

Identified by internal interviewees

- Better identification of high risk activities;
- Agitated travelling public and road rage;
- Fatalities, incidents and near misses; Enhanced safety for road workers, traffic controllers and the travelling public; Reduction in road worker fatalities;
- Smarter road works with respect to (1) road worker safety, (2) road user safety, (3) road operation efficiency; Congestion on the roads;
- Management of heavy, and over-sized vehicles;
- Vehicle safety; risk reduction around road works to the public; Increased risks to road workers;
- Need for systematic signage at road work sites; and

- Extension from previous research to increase the use of technology; safety needs identified from the Ombudsman report; Liaise with QLD Police Service (QPS) for speeding violations and traffic infringements around work sites.

Identified by external interviewees

- Road worker safety; To save lives; Better WHS and worker safety;
- Increase in accidents at road work sites; Drivers not showing due care around road work sites;
- Better traffic management around road work sites; Driver and worker protection;
- Better productivity at road construction sites;
- Research and development into road construction safety; Technology support for road safety; and
- Improvement to the road systems.

6.3.1.2. Delivery - implementation activities

Identified by internal interviewees

- *Stop-Think-Go* approach to safety;
- Good communication for better awareness and risk identification;
- Outcomes and success factors of the initiatives;
- Deployment and procurement of new technology within QTMR through Plant Hire Services (PHS)
- Deployment and implementation:
  - of new equipment; new equipment as standard issue within QTMR;
  - they become part of road construction standards;
  - site specific implementation guidelines ensure it does not breach any regulations, policies, Acts, and codes;
  - proper placement and deployment of signage at road work sites; and
  - trial coordination, implementation, and site determination with Allied agency;
- Requirements check of MUTCD;
- Liaise with QPS with regards to traffic management requirements; and
- Funding requirements for trials; resource availability for implementation; time needs to be allowed for trial periods and data collection.

Identified in external interviewees

- Design and testing of the units prior to their deployment;
- Staff training and education for proper implementation; correct process for set-up and configuration of units;
- Key implementation steps included:
  - discussion of research objectives;
  - technology customisation to meet the needs ;
  - design to fit the site conditions;
  - additional equipment installation;
  - trial site selection;
  - and implementation and deployment of units.
- Promote participation of all stakeholders with a view to the bigger picture instead of just technical testing; and
- Possible implications for QPS with respect to legal and privacy issues.

6.3.1.3. Processes

Identified by internal interviewees

- Training and notes to support stronger awareness of workplace risks and the need for safety;
- Education and communication across the industry; Liaison with areas such as signage and regulations within the industry;
- Project management, governance and program-wide view:
  - processes for the trials and implementation;
  - updates and revisions for simpler implementation on work sites (i.e. pictures than words);
  - implementation guidelines;
  - work team arrangements for implementation;
  - work method statements;
  - communication and training;
  - change processes;
  - owners assigned to new technologies; and
  - state-wide business systems, policies and procedures
- Operating requirements of new technology:
  - MUTCD updates of new processes and guidelines; and
  - updating policies and regulations to capture the new operating procedures of technology.
- TRUM (Transport Management Regulations manual) updates;; and
- Engagement required with private traffic management centre and QPS for video review and data releases; Liaise with traffic management steering committee.

External interviewees

- Internal process changes for mandatory testing requirements
- Stakeholder engagement; Communication to and with the travelling public;
- Legislation and MUTCD processes;
- Procurement methods;
- Driver awareness of the units around road work sites;
- Education and training of QTMR staff ;
- Funding identified in budgets for safety initiatives;
- Signage to take into account new technology; Traffic management plans and guidelines to incorporate new technology;
- IT requirements for the viewing of video feeds;
- Guidelines, site plans and implementation plans; and
- Training and education for road workers.

6.3.1.4. Impacts

Three types of impacts are being discussed: (i) impacts on the culture and values of the organisation; (ii) on the supply chain and industry; and (iii) the impact of major external changes on the development and delivery of the initiatives.

Culture and values-based impacts

Identified by internal interviewees

- QTMR's safety culture:
  - cultural change program;
  - alignment to QTMR's 5-year cultural change process for WHS; and
  - develop a safety culture within QTMR.
- Benefits of technology implementation with respect to safety;
- Vehicle speed measurement and warning signs at road work sites;
- New processes for deployment;
- Communication packs, one-on-one conversations, toolbox talks and group discussions; Communication required to disseminate trial results and to keep people informed;
- New improvements through technology which assist people; and
- Standard R&D initiative process.

Identified by external interviewees

- Balance required between road worker safety and travelling public's inconvenience at road work sites;
- Contractors expertise and experiences in the field;
- Budgets allowed for the implementation of safety initiatives and new technology;
- Education and training;
- Work pattern changes; and
- Communicating advantages and strategies to road workers.

Impacts of initiatives on supply chain and industry

Identified by internal interviewees

- Workforce and union implications; Possible changes to work practices;
- Information requests from organisations such as BCC and QTMR's alliance contractors and partners (i.e. - CCF, QMCA, and TMAQ); Interest shown from the signage, and traffic control industry;
- *Thermal Imaging Camera* unit added to truck mounted attenuators (barrier trucks);
- Shared information of initiatives within the industry;
- More funding needed in the industry;
- Technology (*Mechanical Traffic Aid*) sourced from Asia; Units are not mass produced;
- PHS involvement with procurement process; and
- Possible national implication with other states (NSW, and Victoria) having shown some interest in the technology.

Identified by external interviewees

- Better traffic control at road work sites; Shift towards smart environment with improved safety planning;
- Deployment and decommissioning processes;
- Outcomes report to PHS for procurement requirements;
- Engineering designs incorporated at road work sites; and

- Impact and implication for other industries such as mining, security companies, metal management;
- Broader industry interest shown in *Thermal Imaging Camera* unit.

Major changes impacting on initiative

Identified by internal interviewees

- New guidelines and changes in WHS Officer roles;
- Consultation with key stakeholders for initiative set-up and key success elements;
- Processes for new technology;
- Funding requirements for trials and equipment;
- Regulation, Acts, and policy updates; MUTCD and TRUM updates, approvals and technical notes;
- Project implementation processes; Documentation for deployment of new units; and
- Training and education.

Identified by External interviewees

- Design changes for transportation; and
- Funding of new projects.

6.3.1.5. Successes

Identified by internal interviewees

- Driving impacts:
  - reduction of wild driving around and at road sites;
  - changed driver behaviours; and
  - reduced speeds at road work sites;
- Construction and road work sites impacts:
  - increased safety for road workers and traffic controllers improved awareness of road workers;
  - early warning and camera monitoring indications for road workers;
  - early vehicle detection;
  - better warning times;
  - reduced risk levels at night;
  - better risk identification; and
  - reduced likelihood of collisions at road work sites.

Identified by external interviewees

- Better vehicle and driver recognition; Increased safety for drivers and workers;
- Workers operating in safer working conditions;
- Promote industry discussions; Dissemination of trial findings and technology benefits; Endorsement within the industry; and
- Reduction of speeds at all trial sites, and improved driver behaviour.

6.3.1.6. Barriers

Identified by internal interviewees

- Lack of time and resources; resource limitation and requirements within QTMR means a prioritisation of work and trials; technology; Costs and funding resistance within the business areas;
- Lack of interest and care from business management people;
- Research speed takes time; field people would like to have new technology and PPE;
- MUTCD regulations and required exemptions;
- Design issues – units need to be reconfigured, designed, and/or manufactured for Australian right hand driving conditions;
- Negative perceptions of the initiatives;
- Lack of:
  - awareness within the organisation of research initiatives;
  - connection to strategic objectives and program;
  - awareness of the initiatives;
  - standard project or technology implementation processes across the organisation; and
- Internal delays for procurement, and due diligence requirements; PHS concerns of investment versus perceived business outcomes, and cost-benefit analysis.

Identified in external interviewees

- Technology concerns:
  - may cause some unknown or unconsidered risks to road workers;
  - possible loss of jobs where technology may replace or reduce manpower at road work sites or to make people redundant;
  - does not address the root cause of the problem;
  - may not fit with informal and non-documented construction practices;
  - could undermine the road worker's expertise;
  - may replace or reduce manpower at road work sites, or make people redundant; and
  - unreliability;
- Placement of technology may provide additional safety concerns when equipment is located very close to the road work sites and other construction operations.

6.3.1.7. Research and development

Identified by internal interviewees

- Research and development (R&D):
  - saves lives;
  - into using technology for WHS improve;
  - protects road workers, and the travelling public;
  - can provide better engineering solutions;
  - linked to the role of the WHS R&D Senior Advisor; and
  - can lead to technically excellent outcomes.
- Feedback loop required to R&D;

- Greater academic involvement required; Good research outcomes should support additional future R&D.

Identified by external interviewees

- TMAQ's industry role focused on industry impacts in areas such as PPE, licensing, traffic management, and MUTCD updates;
- More R&D required if funding allows;
- New LED display for speed control; Innovations for camera operation at road work sites;
- CARRS-Q research projects:
  - better communication and feedback travelling public and use of new technology;
  - new ways to measure speed at road work sites; and
- Impact analysis of new technologies.

6.3.2. Links to theory

6.3.2.1. Dynamic Capabilities

Table 23 - Summary of comments from interviews considered relevant as evidence of organisational dynamic capabilities

Dynamic Capability	Examples
Internal R&D engagement	– Responsibility rests with ***(DG)***; Leadership role of Workplace Health Safety (WHS) ***steering group*** – ***responsibility*** from works and line managers in operational areas at RoadTek depots – R&D to meet ***operational*** requirements – Plant Hire Services (PHS) ***procurement*** for deployment – role of ***RoadTek*** in trial coordination and implementation site determination – role of ***Project leader*** in project management implementation, guidelines and site selection – ***previous research*** to increase the use of technology – outcomes and success factors – future implications and innovations: – State Government agenda on road work safety; and – R&D links to technology for WHS improvements – future ***system***s deployment – ***industry information*** on QTMR initiatives – development of ***technical*** solutions
Product or process development	– Lack of ***Time, and resource*** requirements within business areas – ***new*** guidelines, deployment, and implementation processes – work method and regulation ***updates*** – new industry standards – ***funding*** for trials and equipment – design, project management, implementation, deployment and testing ***processes*** – signage and allocation ***plans*** – due diligence and ***procurement*** – new traffic management plans – additional software and IT requirements – legal and privacy issues; QPS for evidence support
Alliancing	– Workforce, union, and training implications – information requests from other agencies (i.e. – BCC) and QTMR's ***alliance contractors*** and ***partners*** (i.e. - CCF, QMCA, and TMAQ), and ***other states*** (NSW and Victoria) – interest from signage, and traffic control industry – ***research alliances*** with CARRS-Q, and OptiAlert – ***outside contractors*** expertise and experiences in the field – impact and implications for ***other industries*** such as mining, and security companies

Dynamic Capability	Examples
	– ***procurement*** implications
Customer focus	– Identified ***risks***, and risk reduction to road workers and travelling public – ***reduction*** in road worker fatalities – ***management*** of congestion around work sites – ***smarter*** road works and road operation efficiency – ***technology*** to better support workers at road work sites – communication processes
Organisation learning	– Better ***awareness*** and ***risk*** identification – benefits of technology implementation – ***communication*** packs, one-on-one conversations, toolbox talks and group discussions – awareness within the ***organisation*** of research initiatives – ***staff education and training*** on safety cultural change and new technology – future implications/innovations: – training notes for better awareness of workplace risks and needs for safety; – shared safety information through the industry; – changes to work patterns; and – communication of advantages and strategies to road workers
Technology transfer	– ***Research implications***: speed, other QTMR R&D projects, and other CARRS-Q research projects, and research objectives – ***new technology*** and PPE deployment – ***MUTCD*** regulations, technical notes, and exemptions – ***redesign and manufacturing*** for Australian driving conditions – standard project, testing, and implementation ***processes*** across the organisation – technology ***customisation*** to meet needs – ***trial*** site selection and implementation – ***travelling public*** behaviour analysis
External R&D engagement	– Engagement with industry and alliance partners – involvement in ARC linkage projects and other ***academic research*** projects with CARRS-Q – ***Ombudsman*** report on road worker safety – ***traffic management*** steering committee – ***Minister*** for Main Roads – QLD Police Service (QPS) – ***industry changes*** in areas such as PPE, licensing, and traffic management plans – ***MUTCD*** and ***TRUM*** changes
Product or service differentiation	– Identification of ***high risk*** activities – ***enhanced safety*** for road workers, traffic controllers, and the travelling public – ***standard R&D*** process in QTMR – better ***traffic management*** and productivity at road work sites
Strategic decision making	– Involvement with ***academic*** and ARC linkage projects – identification of ***high risk*** activities – better ***traffic management*** around road work sites – promote ***participation*** with and from ***industry*** stakeholders – future implications/innovations: – balance between road worker safety and travelling public's inconvenience; – look at bigger picture as opposed to technical testing

Table 24 - – Number of interviewees who discussed issues considered related to organisational dynamic capabilities

Organisational dynamic capability	Observed Yes/No
Internal R&D engagement	10 of 10
Product or process development	10 of 10
Alliancing	8 of 10
Customer focus	8 of 10
Organisation learning	8 of 10
Technology transfer	8 of 10
External R&D engagement	5 of 10
Product or service differentiation	5 of 10
Strategic decision making	4 of 10
Cost advantage through less waste	0 of 10
Cost advantage through increased market intelligence	0 of 10
IP creation	0 of 10

6.3.2.2. Evidence of absorptive capacity

Table 25 – Summary of comments from interview considered relevant to providing dimensions of absorptive capacity

Dimensions of absorptive capacity	Examples
Transfer of knowledge	– Better ***awareness*** and risk identification – ***engagement*** and feedback loops with suppliers and vendors – ***training and notes*** for workplace risks and need for safety – ***field people*** with new technology and PPE – project management, implementation, deployment and site selection ***guidelines*** – ***consultation*** with key stakeholders – interest from ***other organisations***, alliance contractors, and other states on R&D initiatives – shared ***information*** communicated across the ***industry*** – staff education and training – ***technology*** and new improvements – extension from previous ***research*** – ***MUTCD*** technical note updates – advance ***warning*** for drivers – ***communication***, work pattern changes, one-on-one conversations, toolbox talks and group discussions with road workers
Assimilation of knowledge into organisation	– Executives and safety champion know of the initiatives – WHS steering group – Allied Agency (RoadTek) know of the initiatives – ***implementer*** is engaged with researchers – ***technology*** may cause unknown consequences – supplier ***engaged with researchers*** to design and develop technical safety solutions – ***technology customisation*** to meet the needs and fit site conditions – lack of ***time and resources***
Exploitation of knowledge	– New ***federal guidelines*** supersedes state-based workplace safety laws – ***technology*** interacts with environment and its setting – ***R&D*** – meets operational requirements, technically excellent and credible outcomes – greater ***academic R&D*** for better engineering solutions – ***supply and demand*** requirements for PHS – ***engagement*** with private traffic management centres and QPS – more R&D required if ***funding*** allows – new ***traffic management plans*** and guidelines to incorporate new technology – promote ***participation*** from all stakeholders for trials – better ***communication*** and ***feedback*** with drivers on road work sites – new ways to ***measure speed*** at road work sites

Dimensions of absorptive capacity	Examples
	– better ***impact and analysis*** of new technologies – ***software requirements*** for video surveillance and data outputs
Knowledge acquisition from external sources	– ***CARRSQ*** research projects – ***private R&D*** organisations – Ombudsman's report – ***MUTCD*** regulations – ***TRUM*** (Transport Management Regulations) updates – ***outside firms*** contracted to deliver new training to operators – legal and privacy laws
Knowledge acquisition from internal sources	– Other QTMR R&D projects – ***program-wide*** view and accountability of projects – extension from ***previous research*** to increase use of technology

Table 26 – Number of interviewees who discussed issues related to dimensions of absorptive capacity

Dimensions of absorptive capacity	Observed Yes/No
Transfer of knowledge	10 of 10
Assimilation of knowledge into organisation	10 of 10
Exploitation of knowledge	9 of 10
Knowledge acquisition from external sources	5 of 10
Knowledge acquisition from internal sources	5 of 10

6.3.2.3. Measures of absorptive capacity

Table 27 – Details cited from interviews of measures of absorptive capacity

Measures of Absorptive Capacity	Examples
Effort put into development of new products	– New ***federal laws*** and guidelines supersede state-based workplace safety laws – risk mitigation approaches – ***changes*** to and streamlined work practices – project management ***processes*** for the trials and deployment – ***deployment*** guidelines; – ***MUTCD*** (system requirements, updates, processes, guidelines, and technical notes – ***site specific*** alignment with regulations, policies, Acts, and codes – ***TRUM*** (Transport Management Regulations) updates – PHS ***procurement*** processes
Awareness of customer needs	– Vehicle speed measurement – ***warning signs*** at and around road work sites – ***technology*** interacts with the environment and its setting – ***reduction*** in - road worker fatalities, risks at road work sites – better ***traffic management*** with new traffic management plans and guidelines – ***reconfiguration, design, and manufacture*** for Australian right hand driving conditions – placement and deployment of ***signage*** at road work sites – ***supply and demand*** requirements for PHS – outcomes from ***Ombudsman*** report – ***QPS*** requirements for infringement notices – communication and feedback with ***travelling public*** – ***impact and benefits*** analysis of new technologies
Staff skills and investment in training	– ***Training support and notes*** for workplace risks and needs for safety – ***communicate*** advantages and strategies through communication packs, one-on-one conversations, toolbox talks and group discussions – ***education and training*** for QTMR staff on new technologies, and safety cultural change – promote ***industry discussions*** on data collected, trial findings and technology

Measures of Absorptive Capacity	Examples
	benefits – communications with the ***travelling public*** – ***Technology training*** delivered by external training organisations
Capacity for technological development	– Implementation focused on ***outcomes and success*** – ***field people*** have access to new technology and PPE – ***implementation and deployment*** of new technology takes time – lack of resources requires ***prioritisation*** of field work and trials – extension from ***previous research*** to increase the use of technology – new ***system and processes*** development within PHS – project management, trial coordination, implementation, deployment, and site selection ***guidelines*** – ***R&D funding*** and budget allocation – due diligence for procurement of new technology – increased ***funding needed in industry*** to further develop new technologies
Noteworthy economies of scale	– ***Risk mitigation*** implications for workforce and unions – units are not mass produced – endorsement within industry of trial outcomes – interest from ***other industries*** such as mining, security companies – ***procurement*** implications – interest from ***other organisations*** on R&D initiatives and new technologies
Awareness of competitors' technologies	– ***Private R&D*** organisations such as Opti Works (Fatigue Glasses trial) – high visibility BioMotion strips initiative and other ***CARRS-Q*** research projects – ***proximity Sensor trial*** and other QTMR R&D initiatives – ***R&D on LED*** display for speed control – ***new innovation*** for safety cameras – research projects investigate ***technological and organisational improvements*** for better safety
Capacity to adapt technologies from other sources	– Alignment with QTMR's 5-year ***cultural change process*** for Workplace Health & safety(WHS) – technology issues: unknown or unconsidered risks to road workers; informal and non-documented construction practices; unreliability; road worker's expertise; and safety practices.
Range of staff training	– ***Communication*** to disseminate trial results and keep people informed – trials conducted with ***bigger picture*** in mind instead of technical testing – ***education and training*** of all QTMR staff, in particular road workers
High level of technological specialisation	– ***External training organisations*** contracted to deliver training to unit operators

Table 28 – Number of interviewees who discussed issues related to measures of absorptive capacity

Measures of absorptive capacity	Observed Yes/No
Effort put into development of new products	9 of 10
Awareness of customer needs	9 of 10
Staff skills - Investment in training	9 of 10
Capacity for technological development	8 of 10
Noteworthy economies of scale	5 of 10
Awareness of competitors' technologies	5 of 10
Capacity to adapt technologies from other sources	4 of 10
Range of staff training	4 of 10
High level of technological specialisation	1 of 10
Effort put into cost reduction	0 of 10

6.3.2.4. Features of open innovation

Table 29 – Summary of comments from interview considered relevant to significant features of open innovation

Significant features of 'open innovation'	Examples
Purposive outbound flows of knowledge and technology	– Better **awareness and risk** identification – **training and notes** for workplace risks and needs for safety – **communication packs**, one-on-one conversation, and toolbox talks, and group discussions – **information sought** by BCC, TMAQ, TCA, and other alliance contractors' and partners – **education, communication**, and consultation with key stakeholders across the industry; Liaise with areas such as signage – **reconfiguration, redesign, and manufacture** for Australian right-hand driving conditions; – mechanical Traffic Aid unit is currently **sourced from Asia** – education and communication across the **industry** and other states (such as NSW and Victoria) – project **implementation processes** to support the workflow – extension of **previous research** to increase use of technology in road construction safety – due diligence for new **procurement** processes – **MUTCD** technical notes updates – **education and training** for QTMR operational staff – relevance for **other industries** such as mining, security companies, and metal management
Abundant underlying knowledge landscape	– Safety **culture change** within QTMR – **standard R&D** initiative process – **urgency and awareness** for benefits of new safety technology – **consultation** with key stakeholders – due diligence and **procurement** requirements for PHS – use of **communication** packs, one-on-one conversations, toolbox talks, and group discussions – trial coordination, implementation, and work pattern changes within **RoadTek** – support from QTMR traffic management steering committee – need identified for **R&D** in safety area; – connection to **strategic objectives**, program governance, and program-wide view of projects – **internally driven** projects to support technological improvements for traffic management and safety
Business model focus on converting R&D into commercial value	– **Technology deployment** in line with environment and setting – liaise with **QPS** for traffic management requirements – new processes for **video data release** – **software and IT** requirements for viewing Trailer camera video feeds – **endorsement** of new technology within the industry
Equal importance given to external knowledge, in comparison to internal knowledge	– **MUTCD**, and **TRUM** (Transport Management Regulations) updates, and exemptions, – alignment to other regulations Acts, and policies – **education and communication** across the industry and other states – implications and application for **other industries** (i.e. – security management, mining, rail) – **site specific implementation** in line with industry regulations, policies, Acts, and codes – liaise with **QPS** for traffic management requirements – support from QTMR traffic management steering committee

Table 30 – Number of interviewees who discussed issues related to significant features of open innovation

Features of open innovation	**Observed Yes/No**
Purposive outbound flows of knowledge & technology	10 of 10
Abundant underlying knowledge landscape	9 of 10
Business model focus on converting R&D into commercial value	6 of 10
Equal importance given to external knowledge, in comparison to internal knowledge	6 of 10
New metrics for assessing innovation capability and performance	0 of 10
Rise of innovation intermediaries	0 of 10
Proactive and nuanced role of IP management	0 of 10

6.3.2.5. Nature of open innovation

Table 31 – Summary of comments from interviews of nature of open innovation

Nature of open innovation	**Examples**
Inbound innovation (internal use of external knowledge)	
Exploitation	– ***New federal laws*** and guidelines superseding state-based workplace safety laws – ***technology*** interaction with the environment and its setting – ***balance*** between road worker safety and ***travelling public*** inconvenience around road work sites; ***Better communication*** and feedback with travelling public – new ways to ***measure speed*** at road work sites – ***greater academic involvement*** in R&D to provide better engineering solutions – systematic signage allocation plan – ***supply and demand*** requirements for PHS – engagement required with private traffic management centres and QPS – new traffic management plans and guidelines required to incorporate the technology – software and IT requirements for video surveillance – better ***impact analysis*** of new technologies
Retention	– Project management processes, and guidelines for trials, deployment, implementation, and decommissioning – ***defined conditions*** for technology application at road work sites – internal process changes – new traffic management plans and guidelines
Outbound innovation (external exploitation of internal knowledge	– Workforce and union implications – other ***QTMR*** and ***CARRS-Q R&D projects***; Extension from previous research to increase the use of technology in road construction safety; Researcher initiated research projects to investigate ***technological and organisational*** improvements – liaise with QPS with regards to ***traffic management*** requirements – ***interest*** from other ***states*** (NSW and VIC) and ***other organisations*** on R&D initiatives and new technologies – ***new signage*** to take into account new technology – ***better communication*** and feedback with travelling drivers on road work sites by new technology use – new traffic management plans and guidelines – relevance for ***other industries*** such as mining, security companies, and metal management – better ***impact analysis*** of new technologies

Nature of open innovation	**Examples**
Knowledge acquisition	– Ombudsman's report – MUTCD, TRUM, and other regulations, policies, Acts, and codes – extension from ***previous CARRS-Q research*** to increase the use of technology; Researcher initiated research projects to investigate ***technological and organisational*** improvements – ***outside firms*** contracted to deliver new technology training to operators
Non-pecuniary	– MUTCD, TRUM, and other regulations, policies, Acts, and codes – internal approvals – ***education*** and communication across the industry – legislation
Pecuniary re acquiring, sourcing, selling, and revealing.	– Cost and funding: allocations within the business areas**;** new funding for trials and equipment; sufficient funding needed for pilots and trials; and funding identified in budgets for safety initiatives – ***increased*** funding needed in ***industry*** for further development – more ***R&D*** required if ***funding*** allows it
Effectiveness	
Decreasing risks	– Better identification of ***high risk*** activities – changed and improved ***driver behaviour*** – reduced speeds – ***protection*** of road workers and travelling public; ***Reduction*** in road worker ***fatalities; Reduced*** likelihood of collisions – vehicle safety – **improved** awareness for motorists and road workers – better ***visibility*** and early vehicle detection for road workers – more effective road works; Better traffic management – ***R&D*** keeps saves lives, protects road workers and the travelling public – promote ***industry discussions*** on data collected, trial findings and technology benefits
Non-financial benefits	– Better identification of ***high risk*** activities – road work site benefits included: changed and improved driver behaviour; reduced speeds; protection of road workers and travelling public; vehicle safety; reduction in road worker fatalities; improved awareness for motorists of road workers; increased visibility and early detection of oncoming vehicles; more effective road works; better traffic management; better productivity at construction sites; and reduced likelihood of collisions. – more ***R&D*** saves lives – promote ***industry discussions*** on data collected, trial findings and technology benefits
Access to new markets	– Workforce and union implications – limited ***manufacturing*** in Australia; *Mechanical Traffic Aid* is sourced from ***Asia***; ***Reconfiguration*** required for Australia roads – ***interest*** from other ***states*** (NSW and VIC) and ***organisations*** on R&D initiatives and new technologies – endorsement from the ***industry*** – relevance and implications for ***other industries*** – ***procurement*** of new equipment
Enhancing technological effectiveness	– Process ***updates and revisions*** for implementation at work sites (i.e. pictures and words) – ***signs*** at road work sites: systematic signage allocation plan; and proper placement and deployment of signage – technology needs to interact with the ***environment*** and its setting – ***reconfiguration, redesign, and manufacture*** for Australian right-hand driving conditions – ***design changes*** for appearance (of the *Mechanical Traffic Aid*) and ease of transport from site-to-site – ***software and IT requirements*** within QTMR for viewing of video feeds from *Trailer Camera* units

Table 32 – Number of interviewees who discussed issues related to nature of open innovation

Nature of open innovation	**Observed Yes/No**
Inbound innovation (internal use of external knowledge)	
Exploitation	9 of 10
Retention	7 of 10
Outbound innovation (external exploitation of internal knowledge	7 of 10
Knowledge Acquisition	6 of 10
Non-pecuniary	5 of 10
Pecuniary re acquiring, sourcing, selling, and revealing.	4 of 10
Coupled activities	0 of 10
Effectiveness	
Decreasing risks	10 of 10
Nonfinancial benefits	10 of 13
Access to new markets	6 of 13
Enhancing technological effectiveness	6 of 13
Less waste	0 of 13
Financial benefits	0 of 10
Stimulating growth	0 of 10
Lower costs	0 of 10
Other measures	0 of 10
Number of innovations	0 of 10
Shorter time to market	0 of 10

6.3.2.6. Benefits of open innovation approach

Table 33 – Summary of comments from interviews of open innovation approach

Category of factors	**Examples**
Level of interest of project team members	– **Responsibility** starts with DG, through WHS Governance group and is ultimately everyone's responsibility; Strong responsibility in operational areas – ***executive***, and ***Champion*** (the COO) are provided information of the initiatives – ***awareness*** within the organisation of research initiatives – ***Allied Agency*** (RoadTek) involvement – ***implementer*** is engaged with researchers – ***industry*** representation and involvement – ***suppliers*** engaged with ***researchers*** in the design and develop technical safety solutions – ***CARRS-Q*** has close links with QTMR on other research projects
Working environment	– ***Urgency and awareness*** for benefits of technology and implementation – ***consultation*** with key stakeholders – ***communication*** packs, one-on-one conversations, toolbox talks, and group discussions; Changes to work pattern communicated to road workers – support from ***traffic management*** steering committee – aligned with QTMR's 5-year ***cultural change*** process in WHS; Standard R&D initiative process within QTMR's cultural change program – ***governance*** and program-wide view and accountability for projects – ***procurement*** and due diligence requirements – more ***R&D*** required in road works safety
Formation of task groups	– WHS steering committee – traffic management steering committee – RoadTek – ***industry*** partners – ***project*** team/s – tate Government – WHS R&D Senior Advisor – liaise with ***QPS***
Capabilities of the people involved in	– ***Implementation and outcomes*** linked to success factors – field people require ***new technology and PPE***, but takes time

Category of factors	Examples
the innovation	– project management processes, and guidelines for trials, deployment, implementation, and decommissioning – ***supply and demand*** requirements for PHS – site determination, trial coordination, and implementation within ***RoadTek*** – ***safety steering group*** provides leadership role and development of implementation plans – *works and line managers* at RoadTek depots provide operational buy-in for implementation

Table 34 – Number of interviewees who discussed issues related to benefits of open innovation

Category of factors	***Observed*** **Yes/No**
Level of interest of project team members	10 of 10
Working environment	9 of 10
Formation of task groups	9 of 10
Capabilities of the people involved in the innovation	6 of 10

6.3.2.7. Drivers for construction innovation

Table 35 – Summary of comments from interview considered relevant to construction innovation drivers

Category of innovation drivers	Examples
Environmental pressures	
Market pull industry wide	– Better ***identification of high risk*** activities and increased risks to road workers – road works impacts: increased congestion; road rage and agitated drivers; vehicle safety; reduction in road worker fatalities; risk reduction to the travelling public; enhance safety for road workers and traffic controllers; and better traffic management around road work sites – safety needs identified from ***Ombudsman*** report – QLD ***Police*** Service (QPS) – ***technology*** support for road construction safety
Governmental clients with innovative demands	– ***State*** government driven – WHS steering committee – ***Minister*** for QTMR – interest shown from ***others states*** (NSW and VIC)
Innovation stimulating regulations	– Alignment with QTMR's 5-year ***cultural change process*** in WHS; – standard process for ***R&D initiatives***
Technological capabilities	
Technology push	– ***vehicle speed*** measurement and ***warning signs*** in road work sites – alignment with QTMR's 5-year ***cultural change*** process in WHS – extension from previous research to increase the use of ***technology;*** Researcher initiated research projects investigating ***technological and organisational improvements*** for safety – endorsement from the ***industry***; Interest from ***other organisations*** on R&D initiatives and new technologies – liaise with ***QPS*** – ***software and IT requirements*** within QTMR for the viewing of video feeds from *Trailer Camera* units
Programs promoting access to technology	– Aligned with QTMR's 5-year ***cultural change*** process in WHS – process for R&D initiatives – previous ***research*** to increase the use of technology to support road safety – research projects investigating ***technological and organisational improvements*** for safety

Category of innovation drivers	Examples
	– endorsement from the ***industry*** and ***other organisations***
Finance the pilot projects	– Cost and funding requirements within business areas – ***funding*** for ***trials*** and equipment – increased ***funding*** needed in ***industry*** – funding identified in the ***budget*** for ***safety initiatives*** – more ***R&D*** into ***safety*** if funding allows
Technology leadership strategy	– Stop-Think-Go approach – ***technology*** should interact with the ***environment*** and its setting; Interaction with GPS and speed limits – ***new standards*** within the industry – ***standard*** project and technology implementation ***processes*** across the organisation
Technology fusion	– ***Vehicle speed*** measurement and ***warning signs*** at road work sites – ***technology*** should interact with the ***environment*** and its setting; Interaction with GPS and speed limits – ***software, IT requirements and processes*** for the viewing video feeds from *Trailer Camera* units and data releases
Knowledge exchange	
Broad view of risk	– etter identification of high risk activities – changed and improved ***driver behaviour*** – reduced ***speeds*** – ***protection*** of road workers and travelling public – vehicle safety – reduction in road worker fatalities – improved: awareness for motorists of road workers; increased visibility of oncoming vehicles; and early vehicle detection for operators – more ***effective*** road works and better ***traffic management*** – reduced likelihood of collisions – R&D ***saves lives***, and protects road workers and the travelling public
Stimulation of research	– R&D projects within QTMR – researcher initiated research projects investigating ***technological and organisational improvements*** for safety – CARRSQ research projects – more ***R&D*** related to ***safety***
Training of workers on the site	– External firms contracted to deliver ***new technology training*** to unit operators – ***training and notes*** for stronger awareness of workplace risks and needs for safety – staff education and training: implementation and operation; and safety cultural change – ***new guidelines*** for site plans and implementation – defined conditions for ***application***, and ***implementation*** of technology – ***consultation*** with key stakeholders
Lateral communication structures	– Within QTMR: better awareness and risk identification; information packs, one-on-one conversations, toolbox talks, and group discussions; the travelling public; and work pattern changes for operators – industry wide: education and communication; liaise with areas such as signage and regulations; shared safety information; and interest shown from other organisations, associations, and contractors – ***dissemination*** of trial results and keeping people across the department informed – relevance and implications for ***other industries***
Creation of knowledge networks	– ***Endorsement*** from the industry – interest from other ***organisations*** (BCC, and TCA), ***other states*** (NSW and VIC), ***associations*** (TCA, TMAQ) and ***QTMR alliance contractors*** (CCF, QMCA) – ***shared*** safety information within the ***industry***
Programs promoting collaboration – industry wide	– Interest from ***other states*** (NSW and VIC) – education and communication across the industry – ***endorsement*** from the industry – interest from ***other organisations*** on R&D initiatives and new technologies – industry ***briefings*** – working with alliance partners
Effective information	– QTMR research initiatives

Category of innovation drivers	Examples
gathering	– Ombudsman's report – liaise with ***QPS*** with regards ***to traffic management*** requirements – ***MUTCD*** and ***TRUM*** regulations, required exemptions, technical note updates, system checks, and any other any regulation, policies, Acts, and codes – alignment with QTMR's 5-year WHS ***cultural change process*** – extension from ***previous research*** to increase the use of technology
Boundary spanning	
Strategic alliances in long-term relationships	– Research partnerships with CARRSQ – workforce and union implications – ***shared information*** within the industry; Interest shown from ***other*** organisations (BCC, and TCA), ***other states*** (NSW and VIC), ***associations*** (TCA, TMAQ) and ***QTMR alliance contractors*** (CCF, QMCA) – external firms contracted to deliver ***new technology training*** to unit operators – ***contractors*** expertise and experiences in the field – relevance and implications for ***other industries*** – information and communication to road workers – implications for ***large and small contractors*** in using new equipment
Involvement of the client	– Changed and improved ***driver behaviour;*** Communication to the travelling public – ***reduced speeds*** around road work sites – ***protection*** of road workers and travelling public; ***Reduction*** in road worker fatalities – vehicle safety – improved: awareness for motorists of road workers; increased visibility of oncoming vehicles; and early vehicle detection for operators – better ***risk identification*** mechanisms – more ***effective*** road works and traffic management; – ***reduced*** likelihood of collisions – ***R&D*** saves lives, protects road workers, and the travelling public
Innovations from suppliers	– Workforce and union implications – ***procurement*** processes of new equipment form PHS – supplier's ***engaged with researchers*** design and develop technical solutions – new innovations for Trailer Camera operations
Explicit coordination of the innovation process	– ***Responsibility*** in operational areas – RoadTek: responsible for implementation; alignment to outcomes and success factors; and support from works and line managers for operational buy-in – ***procurement*** processes within PHS – responsibility starts with the ***Director-General*** – WHS Governance group – ***QTMR safety steering group*** provides leadership role and development of implementation plans
Mechanisms sharing financial risks and benefits	– ***Better*** risk identification – ***cost and funding*** requirements within business areas – funding for trials and equipment – ***increased*** funding needed in industry – ***Funding*** identified in budget for safety initiatives – more ***R&D*** into safety if funding allows
Integration of design and build	– ***Redesign and manufacturing*** for Australian driving conditions – mechanical Traffic Aid sourced from **Asia** – ***design changes*** for ease of transport from site-to-site, and better appearance (of the *Mechanical Traffic Aid*) – supplier's ***engaged with researchers*** to design and develop technical safety solutions meeting the customer's needs – ***design and testing*** prior to deployment – ***technology and engineering*** designs incorporated at road work sites
Coordination of participating groups	– ***Everyone*** is responsible for WHS – responsibility in ***operational areas*** – director-General – WHS Governance group
Empowerment	– WHS R&D Senior Advisor

Category of innovation drivers	Examples
and innovation leaders	– WHS Section lead – ***COO*** obtains updates and report on initiatives
Empowerment of innovation champions	– ***QTMR COO*** (Emma Thomas) seen within QTMR as the safety ***Champion***; obtains updates and report on initiatives – WHS R&D Senior Advisor – WHS Project lead

Table 36 – Number of interviewees who discussed issues related to drivers for construction innovation

Innovation drivers	Observed
Environmental pressure	
Market pull industry wide	10 of 10
Governmental clients with innovative demands	6 of 10
Innovation stimulating regulations	2 of 10
Subsidies for innovative applications and materials	0 of 10
Government guarantee for markets for innovative firms	0 of 10
Technological capacity	
Technology push	6 of 10
Programs promoting access to technology	5 of 10
Finance the pilot projects	4 of 10
Technology leadership strategy	4 of 10
Technology fusion	3 of 10
Product evaluating institutions	0 of 10
Knowledge exchange	
Broad view of risk	10 of 10
Stimulation of research	9 of 10
Training of workers on the site	8 of 10
Lateral communication structures	6 of 10
Creation of knowledge networks	4 of 10
Programs promoting collaboration	4 of 10
Effective information gathering	3 of 10
Integrated and informal R & D function	0 of 10
Boundary spanning	
Strategic alliances in long-term relationships	8 of 10
Involvement of the client	8 of 10
Innovations from suppliers	7 of 10
Explicit coordination of the innovation process	6 of 10
Mechanisms sharing financial risks and benefits	6 of 10
Integration of design and build	4 of 10
Coordination of participating groups	3 of 10
Empowerment of innovation champions	1 of 10
Empowerment and innovation leaders	1 of 10

7. Bibliography

ACT Road Safety Strategy and 2007–2008 ACT Road Safety Action Plan 2007–2010. Retrieved 18 April 2011 from http://www.tams.act.gov.au/move/roads/road_safety/act_road_safety_strategy

Australian Transport Council (2010). Draft National Road Safety Strategy 2011 – 2020. Retrieved 18 April 2011 from http://www.atcouncil.gov.au/documents/atcnrss.aspx

Austroads Inc. (2009). “Austroads research report - National Approach to Traffic Control at Work Sites. AP-R337/09.”

Biggs, S., Davey, J., & Freeman, J. (2011). “Safety leaders’ perceptions of safety culture in a large Australian construction organisation.” In 1st International Conference in Safety and Crisis Management, 24-28 June 2011, EUC Cultural Center, Nicosia, Cyprus.

Bossink, B. A. G. (2004). "Managing drivers of innovation in construction networks." Journal of Construction Engineering and Management-ASCE 130(3): 337-345.

Bovis Lend Lease. (2007). Environment, Health and Safety. Retrieved 26 July 2011 from http://www.lendlease.com/en/Group/Lend-Lease/Worldwide/Responsibility/environment-health-and-safety.aspx

Chesbrough, H. (2004). "Managing open innovation." Research Technology and Management 47(1): 23-26.

Chesbrough, H. (2005). Open Innovation: A new paradigm for understanding Industrial Innovation. In Open Innovation: Researching a New Paradigm. H. Chesbrough, S. Vanhaverbeke and J. West. Oxford, Oxford University Press.

Cohen, W. M., and D. A. Levinthal (1990). "Absorptive Capacity: A new perspective on learning and innovation." Administrative Science Quarterly 35(1): 128-152.

CRC Construction Innovation. (2007). A Practical Guide to Safety Leadership: Implementing A Construction Safety Competency Framework. Retrieved 26 July 2011 from http://eprints.qut.edu.au/27620/

Davis, P. R., and Walker, D. (2009). "Building capability in construction projects: a relationship-based approach." Engineering Construction and Architectural Management 16(5): 475-489.

Eisenhardt, K. M. and J. A. Martin (2000). "Dynamic Capabilities: What Are They?" Strategic Management Journal 21(10/11): 1105-1121.

Flatten, T. C., Greve, G.I. and Brettel, M. (2011). "Absorptive Capacity and Firm Performance in SMEs: The Mediating Influence of Strategic Alliances." European Management Review 8(3): 137-152.

Gibb, A., Haslam, R., Hide, S., and Gyi, D. (2004). “The role of design in accident causality.” In Designing for Safety and Health in Construction: Proceedings from a Research and Practice Symposium. Hecker, S., Gambatese, J., Weinstein, M. (Eds.), Portland, OR, USA, 11–21.

Huizingh, E. (2011). "Open innovation: State of the art and future perspectives." Technovation 31(1): 2-9.

John Holland Passport to Safety Excellence (PSE) program. (2010). Retrieved 5 July 2011 from www.johnholland.com.au

Joss Group. (2010). Occupational Health and Safety Policy Statement. Retrieved 8 August 2011 from http://www.jossgroup.com.au/systems/2008726391.htm

Lawson, B. and D. Samson (2001). "Developing innovation capability in organisations: A dynamic capabilities approach.” International Journal of Innovation Management 5(3): 377–400.

Ling, F. (2003). "Managing the implementation of construction innovations." Construction Management and Economics 21: 635-649.

Leighton Contractors. (2008). Safety Initiatives. Retrieved 26 July 2011 from http://www.leightoncontractors.com.au/sustainability/safety_and_health/safety_initiatives.html

National Harmonisation of Work Health and Safety Regulations COAG Consultation Regulation Impact Statement (2011). Retrieved from http://ris.finance.gov.au/2011/02/07/national-harmonisation-of-work-health-and-safety-regulations-coag-consultation-regulation-impact-statement-%E2%80%93-workplace-relations-ministers%E2%80%99-council/

Nieto, M. and P. Quevedo (2005). "Absorptive capacity, technological opportunity, knowledge spillovers, and innovative effort." Technovation 25(10): 1141-1157.

NSW Transport Roads and Traffic Authority (2010). Guides, Handbooks, and Reports. Retrieved 18 April 2011 from http://www.rta.nsw.gov.au/publicationsstatisticsforms/index.html

NT Worksafe, (2011). Retrieved 5 July 2011 from http://www.worksafe.nt.gov.au/documents/11_03_2011_ntws_media_release.pdf

Queensland Workplace Rights Ombudsman (2009). Report on Investigation: Contract Traffic Control Industry. Retrieved 6 February 2012 from http://www.workplacerights.qld.gov.au/resources/reports/trafficcontrol/index.htm

RoadTek. (2005). Practical Completion Report: Stop-Think-Go. Queensland Government.

South Australian Road Safety Strategy 2003 – 2010. Retrieved 18 April 2011 from http://www.dtei.sa.gov.au/__data/assets/pdf_file/0006/32955/strategyw.pdf

Subramaniam, S., Gannapathy, V., Subramonian, S., & Hamidon, A. (2010). *Automated traffic light system for road user's safety in two lane road construction sites*. WSEAS Transactions on Circuits and Systems, *2*(9), 71-80.

Teece, D. and Pisano, G. (1994). "The dynamic capabilities of firms: an introduction." Industrial and Corporate Change 3(3): 537-556.

Teece, D. J., Pisano, G., and Shuen, A.(1997). "Dynamic Capabilities and Strategic Management." Strategic Management Journal 18(7): 509-533.

Transport and Main Roads. (2008). Brief for Decision: Funding Strategy for Safety Leadership Project.Queensland Government.

Transport and Main Roads. (2009). Application of Imaging and Recording Technologies as a method of early collision detection, incident reduction and evidence recording onboard Main Roads Barrier Trucks: Final Report. Queensland Government.

Transport and Main Roads. (2010). Application of Reversing Camera Technology aboard Main Roads mobile plant: Final Report. Queensland Government.

Transport and Main Roads. (2010). Research and development of new proximity technologies: Project Proposal. Queensland Government.

Transport and Main Roads. (2010). Stop-Think-Go: Communication and Action Plan. Queensland Government.

Transport and Main Roads. (2010). Trial application of LED Speed Indicatign Device (SID) Signage at Road Works: Project Outline. Queensland Government.

Transport and Main Roads. (2010). Trial application of Trailer Based CCTV systems and associated road signage: Project Outline. Queensland Government.

Transport and Main Roads. (2010). Zero Harm: Communication and Action Plan. Queensland Government.

Transport and Main Roads. (2011). Fatigue Glasses Trial: Project Plan. Queensland Government.

Transport and Main Roads. (2011). Mechanical Traffic Aid: Trial Report. Queensland Government.

Transport and Main Roads. (2011). Review and Implementation of Harmonised WHS Legislation for QTMR: Project Plan (Lite). Queensland Government.

Transport and Main Roads. (2011). Workplace Health and Safety Management System: Project Plan (Lite). Queensland Government.

Victoria Road Strategy. 2008-2017 Arrive Alive. Retrieved 18 April 2011from http://www.arrivealive.vic.gov.au/about/victorias_road_safety_record/victorias_road_safety_record.html

WA Safety Strategy: Towards Zero 2008-2020. Retrieved 18 April 2011from http://www.ors.wa.gov.au/StrategiesRoadSafety/Pages/NewStrategy2008-2020.aspx

Wood, J., Marszalek, R., Lacherez, P., Tyrrell, R., & Chaparro, A. (2010). "Perceptions of Visibility and Conspicuity of Biomotion Clothing Configurations for Road Workers at Road Work Sites." In Proceedings of Transportation Research Board 89th Annual Meeting 2010. TRB Publications: Washington, DC.

Zahra, S. A. and George, G. (2002). "Absorptive capacity: A review, reconceptualisation and extension " Academy of Management Review 27(2): 185-203.