Supporting Innovative Design and Construction

S. R. Taylor[1], CPEng, FIEAust.

[1]Major Road Projects Victoria, Level 25, 180 Lonsdale Street, Melbourne; email scott.taylor@roadprojects.vic.gov.au

ABSTRACT

Innovation is at the core of the engineering profession. Innovation is driven largely by the need to increase efficiency, reduce costs, or respond to increasing complexity. In today's context, these drivers appear to be converging, with efficiency, cost and increased complexity almost a baseline for all projects, and the impacts of climate change, sustainability and the circular economy a significant influence on the future of transport infrastructure. To seek the benefits of innovation on transport infrastructure projects, Major Road Projects Victoria's (MRPV) aims to facilitate the minimisation and removal of barriers and obstacles to innovation. The barriers to innovation include a risk-adverse culture, limited capacity and capability of resources (both within industry and government), leadership, regulatory requirements and a bureaucratic culture, and rewards and incentives for the implementation of innovation. Through a series of new initiatives, this presentation will outline how MRPV is supporting innovation in design and construction of major road projects in Victoria. To address barriers associated with risk-aversion and capacity, MRPV have implemented a new delivery model that focuses on a program of projects with incentives for innovative solutions. For barriers associated with leadership, regulatory requirements and bureaucratic culture, MRPV is leading a program of modernising and updating standards and specifications including trialling intelligent compaction, and creating of a new technical specific for recycled organics.

Keywords: innovation, transport infrastructure, standards, specifications

1 INTRODUCTION

Innovation is a corner stone of engineering. Clear technological and engineering advancements can be associated with human development. Similarly, in the transport infrastructure sector, often, innovative design and construction facilitates significant step changes industry wide. Without innovation, many of the currently projects being delivered would not be possible or even conceivable. Therefore, innovation must be fostered and encouraged by all participants (whether from government or industry) in the delivery of projects.

Innovation in the context of projects, organisations and industry can be viewed differently, and has differing lasting impacts. The transport infrastructure sector is comprised of a number of organisations (including government, contractors, suppliers, consultants etc), which in turn form smaller teams to deliver projects. Diagrammatically the relationship between projects, organisations and industry can be represented in Figure 1. When considering the impact of innovation, targeting the broader industry will obviously result in the greatest outcome as the benefits are realised over the greatest number of projects.

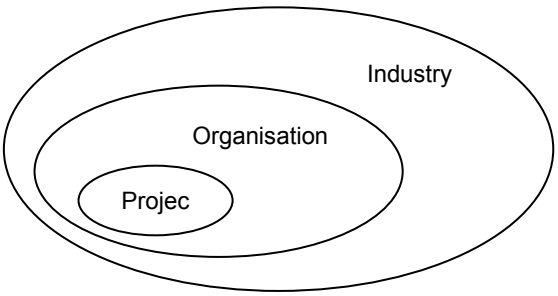

Figure 1. Relationship between projects, organisations and industry.

This paper begins by exploring the drivers and barriers to innovation in the transport sector, with a focus on identifying the barriers to implementation of innovation at the industry level. The paper then explores two key initiatives being undertaken at Major Roads Projects Victoria (MRPV) that aim to reduce and remove barriers to innovation and enable innovation to be realised across the entire industry. The specific initiatives being undertaken by MRPV include the Program Delivery Approach (PDA) used to deliver projects, and a program of modernising and updating standards and specifications.

2 DRIVERS FOR INNOVATION

Scholarly articles relating to "drivers for innovation" in engineering number in the multiple hundreds of thousands. It is clearly a well-researched and commented topic. Common themes in the transport infrastructure sector have been identified by a range of authors including Wipulanusat et al. (2019), Ozorhon and Oral (2017), and Salter and Torbett (2003). The drivers of innovation include;

- Innovations developed to increase efficiency and effectiveness.
- Innovations to reduce costs.
- Innovations in response to increasing complexity which can be derived from both internal or external sources. The rise of the 'mega' project is also a large source for innovations driven by a complex environment,
- Innovations in response to an external crisis which is becoming more commonly related to climate change, sustainable practices and the circulate economy.

When returning to the levels of projects, organisations and industry, there is no known documented evidence of the amount of innovation done at the different levels – possibly due to the fact it would be difficult to categorically assign innovations solely to a project, organisation or industry. Yet at the project level, drivers for innovation would occur more regularly, but the likelihood of the innovations carrying through to the organisation or even the industry would be less common. That is, an individual project may develop an innovation, no matter how small, but fail to pass that innovation onto other projects within their organisation, or onto other

projects within different organisations. This means the risk of losing innovation done by a project is significant, as once the project finishes and the team is disbanded, there is little incentive or desire for the project learns to pass their innovations onto the next project. In the transport infrastructure sector this is largely driven by the competitive nature of projects, where organisations will tend to protect innovations from the broader market.

For the full benefits of any innovation to be realised by the broader industry, it requires an industry wide agency to oversee innovation for the industry. This is a role State Governments in Australia have significant part to play. Governments set the regulatory and policy environment within which industry operates. They are also the major purchaser of civil infrastructure within Australia. Therefore, it is within government's interest to ensure innovations succeed at the industry level so that their benefits can be fully realised.

3 BARRIERS TO INNOVATION

Likewise for drivers, barriers to innovation can equally have a significant impact on the success of innovations and the development of an innovative culture.

Wipulanusat et al. (2019) provided a framework for defining barriers and obstacles to innovation. The context they have defined barriers are those in the public sector which impede and delay government agencies from adopting and implementing innovations successfully. They propose barriers to innovation in the public sector include a risk adverse culture, limited resources, failure of leadership, regulatory requirements, few rewards and incentives, and a bureaucratic culture. Each of these barriers is discussed future in the following sections.

3.1 Risk Adverse Culture

Wipulanusat et al. (2019) proposed that due to the negative ramifications of risk-taking in the public sector, such as political damage to the government or public criticism, the public sector tends to have a risk adverse culture. In the context of innovation, this results in diminishing likelihood by government agencies of taking risks through the adoption of new technology. In the transport infrastructure sector, this is further compounded by the increasingly complex legal and commercial environments, where uncertainty in new technology, systems or processes leads to the suppressing of innovation at project, organisation and industry level.

A symptom of a risk adverse government culture is the creation of an overly conservative and prescriptive regulatory and legal environment. This then means innovations are constrained by the limitations and boundaries imposed by technical standards and specifications.

3.2 Limited Resources

Capacity can be considered in both the context of people and funding. Often innovation will require development and funding without knowing the outcome of the research being undertaken. Government's, however, operate on clear funding cycles and productive use of resources, leaving little space for the ability to innovate.

While this may be a reality of government entities, this is not such a barrier for private industry who are more willing to invest in innovation without the certainty of success. Therefore, to effectively remove this barrier, government and industry need to partner in a manner that makes best use of the limited resources, while still allowing individuals the freedom to explore new ideas or concepts.

3.3 Failure of Leadership

Wipulanusat et al. (2019) comment that leadership plays an important role in fostering a culture of innovation. "Leaders must find mechanisms to encourage the generation, adoption and implementation of innovations," (Wipulanusat et al. 2019). While the leaders don't need to be the creative force behind innovations, they are critical in supporting and championing innovation to ensure its success.

In a highly technical area such as transport infrastructure, this also requires leaders to have a level of technical literacy that they are able to identify innovation and encourage its growth. At MRPV this has been achieved by establishing a strong leadership team that consists of all the necessary skills required for successful project delivery in the transport infrastructure sector.

3.4 Regulatory Requirements

Change and approval processes within government are heavily controlled and regulated (Wipulanusat et al. 2019). Further, in the engineering context, standards and specifications play a significant role in defining acceptable minimum requirements. Many of these standards and specification are prescriptive in nature, which inherently limit the ability of innovators to use products, systems and processes that lie outside these defined boundaries.

An innovation within or for a government project will never be successful if it does not meet the wide range of regulation, guidelines, policies, standards and specifications. Further, where innovations use new technologies that lie outside current regulatory requirements there is the risk they will not be accepted as they cannot be measured against a set of requirements to determine if they are suitable of use.

A significant factor in much of the regulatory requirements that exists are they are prescriptive in nature, and as a result the product, process or system needs to fit within the framework and boundaries of the requirements very neatly. An alternate approach is to develop performance-based requirements, where the performance requirements are defined and testing procedures described, however the parts that constitute the final output are not defined. This enables individuals to innovate knowing their product, system or process only needs to achieve the output performance requirements.

3.5 Few Rewards or Incentives

Wipulanusat et al. (2019) comment that in government innovators rarely received feedback or a reward for their success, however "if the innovation fails or does not prove to be efficient, the innovators are responsible for all the costs." When translated into the transport sector,

particularly for traditional D&C delivery models, there is little incentive for contractors and designers to share innovations beyond their projects, meaning they can be short lived and not widely adopted.

Therefore, a key feature of delivery models that foster a culture of innovation are those that contain some element of reward and recognition for new technology, processes, or systems.

3.6 Bureaucratic Culture

The barrier related to a bureaucratic culture relates strongly to leadership and the risk adverse culture within government. Governments tend to be hierarchical in decision-making, as well as restrained in their promotion of innovation due to their inherent tendency towards regulation and certainty (Wipulanusat et al. 2019).

To overcome the barrier of a bureaucratic culture, MRPV has partnered with industry to delivery projects through the Program Delivery Approach (PDA) which has enabled projects to offer innovative solutions that address performance-based regulations, standards, and specifications. This ensures industry suppliers with new technology, process or systems can successfully implement their innovative solutions within the constraints of government requirements.

4 INITIATIVES TO ENCOURAGE INNOVATION

To increase and encourage new technology, systems, and processes within road projects, MRPV has been working on a number of initiatives that aim to remove and reduce the barriers to innovation. The next sections outline two key initiatives, namely the Program Delivery Approach (PDA) used to deliver projects, and a program of modernising and updating standards and specifications.

5 PROGRAM DELIVERY APPROACH

In mid-2020, MRPV implemented a new project delivery model called the Program Delivery Approach (PDA). The PDA offers the ability for a portfolio approach to the delivery of projects. The objectives of the PDA are to;

- Create a more sustainable contractor market, by engaging with the appropriate industry partner based on their capacity and capability.
- Improve the efficiency of project procurement resulting in saving time and minimising State and contractor costs.
- Improve project outcomes, contractor performance and optimise value through a more collaborative approach to procurement and delivery, by incentivising contactor performance, both financially and via future opportunities.

The PDA model awards projects to pre-qualified contractors and designers based on their capability, capacity, past performance, and ability to deliver value-for-money solutions. These pre-qualified companies have been assigned to MRPV's Construction and Design Panels. The panels divide industry partners into broad groups based on their capability.

Once selected, a contractor will follow a two-staged delivery model under the PDA, entering into a Project Development Phase to determine the scope and value of the project, and then the Project Delivery Phase once contracts are executed. A designer is engaged by the contractor in a sub-contract agreement similar to a traditional D&C model. The appointment is made after the award of the project to a contractor and before the start of the Project Development Phase, such that MRPV, the contractor and design all work collaboratively through both phases of the delivery model.

At its core, the PDA approach features elements of both the Alliance, and Design and Construct (D&C) project delivery models. The initial Project Development Phase is similar to Alliancing, whereby scope, risks and opportunities are shared and resolved with input from MRPV, contactors and designers. Once the contract is executed, the model converts to more of a traditional D&C, however payment is through an Incentivised Target Cost (ITC) payment mechanism, which reimburses direct costs and includes cost and non-cost incentives through a performance regime. However, a significant difference of the PDA model from current forms of delivery models is the projects are managed as a program of works enabling a more sustainable contractor and designer market.

The benefits of the PDA model for industry include;

- a more sustainable supply of projects for industry partners and their supply chain;
- creation of long-term competition based on performance rather than short term, cost driven competition;
- improved cost certainty through the reimbursement of all direct costs;
- better sharing and allocation of risk to the party best able to manage the risk;
- streamlined procurement processes leading to reduce procurement time and costs;
- streamline procurement processes and, in so doing, maximise efficient engagement of contractors and consultants of all tiers to perform works;
- enable more Front End Engineering and Design (FEED), investigations and assessment of project specific risks; and,
- better integrated project planning and project delivery through collaboration between government and industry.

When considering barriers to innovation, the PDA model has a number of key features that foster and enable creativity and allow new technology to be more easily adopted by projects, as well as shared with the broader industry. The key features of the PDA model to enable innovation are explored further in the following sections and include increased collaboration, risk mitigation and sharing, and incentivisation for innovation.

5.1 Collaboration

A significant feature of the PDA model is the closer collaboration between industry (both contractors and designers) and government, as well as the supply chain partners critical to the projects delivery.

By engaging a single team through the project development phase, risk and opportunities can be rigorously assessed and mitigated, which would not normally be achieved in a more traditional D&C projects. Further, the collaboration between government and

industry means that risks can be assigned to the party best able to mitigate those risks. It also enables a greater adoption of innovation, with industry and key suppliers able to bring forward ideas, with MRPV facilitating and enabling the adoption of the innovation.

5.2 Risk Mitigation and Sharing

Risk and risk management is dealt with very differently in the PDA model when compared with traditional D&C contracting. Considering only a single contractor and designer is taken through the project development phase with MRVP to develop a target outturn cost (TOC), it enables a shared understanding and contribution to risk mitigation. The eventual aim of the TOC development is to understand and eliminate risk by utilising resources, knowledge and relationships across both government and industry. Traditionally, in a D&C environment a contractor would assign a cost to items or scope they could not effectively mitigate or eliminate the risk. Whereas, in the PDA model, with input from MRPV, project teams work to identify and mitigate or eliminate all risk during the TOC development.

When considering the barriers to innovation, this model enables novel problem solving and innovative solutions to reduce or remove risk during the development phase of the project. Further, MRPV is able to draw on innovative solutions from across the industry to facilitate solutions for individual projects.

5.3 Incentives for Innovation

The final feature of the PDA model that encourages innovation is the use of financial and non-financial incentives for those projects that develop and adopt innovative solutions. Specifically, there is a KPI (key performance indicator), for both contractors and designer who develop innovative initiatives for not only the project, but that can be adopted more broadly in the industry. The assessment of the innovation KPI is based on the type of innovation(s) adopted, and defined as;

- **Continuous improvement** is defined as an initiative which is a continuous improvement initiative within the project. This is the lowest level of innovation that will trigger the KPI.
- **Innovation adoption** is an initiative which is adopted from another project. This is the starting point for more broader industry wide innovation and encourages teams to look at the practices of other projects to implement a new technology, process or system.
- **Industry application** is the highest level achievable within the KPI and is defined as an initiative which has industry wide application.

Contractors and designers are judged on the number and type of innovations adopted by the project, and given short term financial incentives, as well as longer non-financial incentives related to their ongoing performance.

6 MODERNISING STANDARDS AND SPECIFICATIONS

The second key initiative MRPV are undertaking to drive innovation at the industry level is through a program of modernising and updating standards and specifications. It is acknowledged that much of the work associated with this initiative is done in conjunction with the Department of Transport (DoT), who are the owner and operator of the assets delivered by MRPV.

A significant barrier to new products and new technologies is that standards and specifications don't allow or even consider the application of these emerging materials or concepts. This is a result of standards and specification being largely prescriptive in nature, where the minimum requirements define the inputs and describe what must be done to achieve the requirements. Prescriptive standards and specifications are best suited to situations where a high level of control is required and appetite for risk is low. However, under this framework, changes in technology or methodologies can not be easily adopted as it is unlikely the prescriptive standards or specification would have accounted for future innovations.

In an innovative culture, regulations (including standards and specifications) should be flexible and adaptive to enable changes in technology and new practices. This is achieved using performance-based standards and specifications which focus on the requirement outcome. Under this framework, products much achieve a minimum performance using which ever means they wish. Typically, the performance-based standard or specification will require a series of tests to be undertaken to verify the product, process or system achieves the minimum requirement. The risk with this approach is that the suite of performance requirements may not account for a behaviour or outcome that was not intended to be achieved.

In practice, it is very difficult to write a standard or specification entirely using a performance-based framework. Therefore, what more commonly happens to enable an innovative culture, is that standards and specifications are written predominantly with performance-based requirements and use more prescriptive-based requirements for elements deemed high risk.

Looking back at the barriers to innovation, the move towards largely performance-based standards and specifications enables removal of barriers associated with risk-aversion, regulatory requirements and bureaucratic culture. The basic premise of defining the performance outcome rather than prescriptive requirements means the basic elements that have led to risk-aversion, regulatory requirements and bureaucratic culture are retained, in that risk and uncertainty are managed, however the performance-based approach enables suppliers to propose new technologies, techniques and processes.

6.1 Key Standards and Specifications

The range of standards and specifications MRPV is working on with DoT is diverse and covers the full range of technical disciplines within the road transport sector. It includes new and updated standards and specifications for plastic noise walls and slip form barriers, as well as guidelines for application of spray seal pavements. However, the focus of this paper is a couple of initiatives associated with geotechnical aspects of road infrastructure, including trialling the use of intelligent compaction for road pavement, and creating a new technical specification for recycled organics.

6.1.1 Intelligent Compaction

Compaction is the process whereby material is placed in layers and compressed to increase the density and uniformity of the pavement material. Compaction is achieved by a roller and applied to all layers within a road profile (e.g. subgrade through to asphalt).

Currently, the most widely used technique used to confirm the achievement of compaction is a combination of in-situ spot test with a nuclear gauge density device and proof rolling. These methods are limited in that they only evaluate a small portion of the entire road composition (e.g. approximately 1 %) and as a result may miss weak or unqualified compaction areas.

Intelligent Compaction (IC) is a compaction technology that uses "vibratory rollers equipped with the real-time kinematic (RTK) Global Positioning System (GPS), roller-integrated measurement system (normally accelerometer-based), feedback controls, and onboard real-time display of all IC measurements," (Chang et al., 2011). It is starting to be adopted in Europe, Japan and North America.

The benefits of IC include (Chang et al., 2011);

- IC allows mapping of each compaction layers to enable real-time identification of weak spots for corrective actions prior to the compaction of the upper layers.
- IC provides the means to maintain a consistent rolling pattern for 100% coverage of a construction area.
- IC enables consistent rolling patterns under lower visibility conditions such as night paving operations.
- IC technology enables digital record collection for future investigation.

In 2019, DoT developed guidelines for IC trials (Papacostas and Walker, 2019). The guidelines describe how to set-up production trial work lots for placement, compaction, testing and assessment for a single material type. Previously, the requirements within VicRoads Technical Specification 204 were prescriptive in their requirement to undertake some type of nuclear gauge testing and proof rolling.

Through support from DoT, MRPV engaged the Australian Road Research Board (ARRB) to develop a set of guidelines for project to successfully implement IC monitoring. The guidelines build on DoT's work and assist projects in the development of the testing procedure, including suggesting IC equipment, quality control processes, and supporting onsite construction methodologies.

Currently there are a few IC trials underway on MRPV projects resulting in the innovation being adopted across the industry. Further, the flexibility of the guidelines enables projects to utilise as little or as much of the IC technology as they wish.

6.1.2 Recycled Organics

As waste becomes an ever-increasing problem for governments, the Victorian Government has developed the Recycled First Policy, whereby projects are encouraged to optimise the use of recycled and reused materials. The obvious weakness of this policy is that prescriptive standards and specifications can limit the type of materials used in civil infrastructure projects. To conform to a highly prescriptive-based standard or specification, recycled materials must achieve the same inputs as their virgin material counterparts which can be unrealistic.

In the landscaping discipline, this is particularly relevant for recycled organic materials. The Australian Standard AS 4454 (2012) Composts, Soil Conditioners and Mulches specifies the "requirements for organic products and mixtures of organic products that are to be used to amend the physical and chemical properties of natural or artificial soils and growing media." The standard is largely a prescriptive-based set of requirements, where physical and chemical requirements of nominated virgin materials are described.

Recycled organic materials don't easily conform with requirements of their virgin counterparts. Specifically, recycled organic materials can vary in quality largely due to the (i) the extent of impurities within the recycled material (e.g. plastics, paper etc), and (ii) the extent of processing time allowed to create the compost or soil conditioner. To enable recycled organic materials to be used on civil infrastructure projects, MRPV in collaboration with DoT and ARRB, are in the process of developing a technical specification for recycled organics. The intent is to define the performance requirements for a range of uses of recycled organic material, that link back to the classifications used within AS 4454 (2012). These include for landscaping (e.g. planting, hydro-mulch, turf topdressing, soil conditioning, fertiliser), erosion control (e.g. soil compaction mitigation, filter berms, and compost blankets), and biofiltration (e.g. filter media). By developing a technical specification, the innovative use of recycled organics is available for all projects within the industry.

7 CONCLUSION

Government has a significant role to play in ensuring innovations flourish and thrive across industry. The risk of innovations developed by industry and suppliers being stifled by barriers imposed by government are significant. The case of encouraging innovations is compelling with drivers for innovative solutions including increased efficiency and effectiveness, reduced costs, the ability to respond to increasingly complex environments, and the ability to respond to external crisis.

To facilitate innovation, several barriers must be overcome including the public sector risk adverse culture, limited resources, failure of leadership, regulatory requirements, few rewards and incentives, and a bureaucratic culture.

MRPV has initiated two key programs that aim to reduce and remove barriers to innovation. The specific initiatives being undertaken by MRPV include the Program Delivery Approach (PDA) used to deliver projects, and a program of modernising and updating standards and specifications.

8 ACKNOWLEDGEMENTS

The author wishes to acknowledge a number of people and organisations who have been instrumental in the development and implementation of both the PDA model

and modernising standards and specifications. These include Allen Garner (MRPV's CEO) and Steve Cornish (MRPV's COO) for their leadership of the MRPV PDA model, Leon Choo (MRPV's Quality Manager) for his leadership of the Intelligent Compaction trials at MRV, and ARRB and DoT support of both the Intelligent compaction trials and development of the recycled organics technical specification.

REFERENCES

Wipulanusat,W., Panuwatwanich, K., Stewart, R. A., and Sunkpho, J. (2019), "Drivers and barriers to innovation in the Australian public service: a qualitative thematic analysis." Engineering Management in Production and Services, Vol 11 (1), 7-22.

Ozorhon, B., and Oral, K. (2017) "Drivers of Innovation in Construction Projects." Journal of Construction Engineering and Management, 143 (4).

Chang, G., Xu, Q., Rutledge, J., Horan, B., Michael, L., White, D. and Vennapusa, P. (2011) "Accelerated Implementation of Intelligent Compaction Technology for Embankment Subgrade Soils, Aggregate Base, and Asphalt Pavement Materials." Federal Highway Administration, Report No. FHWA-IF-12-002.

Papacostas, A. and Walker, A. (2019), "Guidelines for Intelligent Compaction (IC) Construction Trials." Department of Transport, Victoria.

VicRoads, (2015) "Technical Specification 204: Earthworks." Department of Transport, Victoria.

Australian Standard, (2014) "AS 4454 (2012) Composts, Soil Conditioners and Mulches."