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NINE INNOVATION BARRIERS IN AUSTRALIAN CONSTRUCTION CONTRACTING

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ABSTRACT

The Australian construction industry ranks below average in intellectual property and software creation value compared to other sectors. The innovation performance of the built environment contractors is well chronicled. Importantly, these organisations have the most time and cost risk of all stakeholders. Therefore, improvements should have significant benefits to them and their customers. However, their innovation efforts face significant economic, regulatory and market barriers that are stubborn. This paper asserts that these sector characteristics slow the creation of novel products, services, and information technology more than most major industries. Overcoming these invention barriers should enable faster innovation and more significant improvement.

This paper outlines the nine most significant innovation barriers researched by the author in Australian construction contracting and suggests potential solutions. Addressing the seminal reasons for the lack of invention should decrease the impact of these obstacles leading to a better system and culture of innovation, thereby producing better industry performance. The relationship between construction organisation characteristics and industry innovation is relatively unexplored.

KEYWORDS

Construction invention, constructor innovation, breakthroughs, system barriers, novel products

INTRODUCTION.

Construction contracting businesses deliver most of the value while accepting risks such as cost, schedule and safety responsibility for their projects. However, mitigating this with innovation is difficult since the industry suffers from significant underlying economic, regulatory and market barriers. One indication of construction's anaemic invention activity is the value of intellectual property products, including software. In 2020, it was assessed at AUD 1,028,000,000, which was ¼ of manufacturing's output and ranked 13th out of 18 major market sectors (ABS 2021). Although, invention adoption provides better value for money for improved services or products and can help construction firms gain a competitive advantage (Kamal et al. 2016). This paper suggests that these sector

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characteristics seem to slow the creation of new products, services, and technology more than many industries.

We theorise that the unique combination of factors present in the construction industry is a significant barrier to improving safety, quality, cost and schedule. Innovation can improve these four outcomes, creating a sustainable and resilient built environment for businesses. Kamal et al. (2016) found no evidence of more innovation in larger firms. The largest companies have the most resources and incentives to develop breakthroughs but have been unable to in the modern era. Due to these observations, significant and stubborn reasons seem to exist; the researcher searched for them from experience in the literature review. This research outlines the nine substantial barriers in the researcher's experience and asserts potential solutions to overcome them. Querying SCOPUS, the Australian Bureau of Statistics, and other databases with key search words reflecting the nine factors yielded research findings.

LITERATURE REVIEW

According to Lim et al. (2010), innovation assists construction firms in lowering their costs, meeting deadlines and deepening their positive brand. Hillebrandt (1984) noted that many individual factors present in construction are not unique; however, the combination of factors is not found in other sectors. Critically, the relationship between industry characteristics and company innovation orientation is relatively unexplored. (Kamal et al. 2016)

The Built Environment is a crucial component to improving the quality of life (QOL) (Gregory 2009). With improved QOL comes higher levels of prosperity and increased chances of sustainability adoption (UN Habitat 2012). Innovating more of the material, processes and equipment used in construction will improve outcomes

Pheng and Teo (2004) observed resistance to change by construction organisations. They cite three factors: 1) organisational instability, 2) product diversity, and 3) misperceptions about the cost. First, predictability of construction company revenue is difficult due to the industries' highly competitive nature and sensitivity to the Australian economy. Additionally, the range of projects that a firm may pursue and build is unpredictable and determined by invidual customer procurement processes.

Research literature supports the assertion that there are multiple barriers to innovation in the Australian construction industry. Contractors in the Australia Pacific region were surveyed in 2022, cited "cost, effort and changes needed" 51% and "no clear demand from clients of stakeholders" 43% (RICS) As a result of these perceptions and impediments, this sector ranks below many others in intellectual property and software creation. Recent research by Leviakangas et al. (2017) shows that the Australian Construction Industry's investment in ICT is the bottom third of the nine major industries studied but is ranked third in multifactor productivity.

This literature review attempts to specify nine substantial barriers.

AUSTRALIAN CONSTRUCTION INNOVATION BARRIERS

1. Low percentage of net profit before tax

The construction industry invests in research and development much less than other parts of the economy. This sector invests less than 0.5% of sales in research and development (R&D), while the Australian national average is approximately 4% (Hassell et al., 2009). Large construction firms' net profit before tax is less than 10%, , e.g. Simonds, Lendlease,

and Global Construction, whereas technology companies range between 20-30%. Refer to Table 1.

Table 1. Australian Publicly Held Firms by Selected Industry & Net Profit Before Tax Percentage
Source: Australian Stock Exchange–2021

Construction	Technology	Medical
Global Construction 8.1%	OFX 21.0%	Ansell 35.1%
Lendlease 6.4%	Technology One 21.2%	Sonic Healthcare 11.2%
Simonds Group 0.5%	Telstra 13.7%	Zenitas 13.6%

However, our industry's financial ability to invest in R&D can be viewed in other ways. If turnover is analysed per employee basis, construction's ratio is less than manufacturing: AUD 190,814 versus 487,000. On a per firm view, AUD 533,008 as compared to 4,698,014 (ABS 2021)

2. Lumpy asset problem

The investment needed to enable research and development of a product or service is a "lumpy asset". This is a financial term defining a type of investment expenditure that must be paid with a liquid asset. A firm cannot lease or pay for using a lumpy asset incrementally (Alvarez & Lippi 2013). Therefore, an innovation's value or utility cannot be realised unless purchased entirely in application. A recent study indicated that a significant investment in time and resources was required to introduce innovative systems and products (London and Pablo 2017).

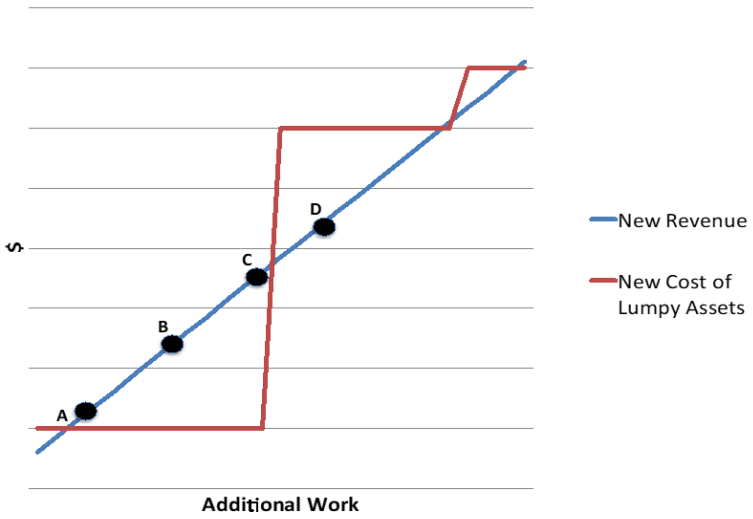

Figure 1. The stepped nature or "lumpy asset" dynamic of innovation

From Table 1, it is assumed that the net profit before tax is approximately 4%. This means that 25 times the cost in revenue recoups the additional expense of innovation. Therefore, as shown in Figure 1, an AUD 100,000 investment must be recouped by AUD in 2,500,000 turnover.

3. Low market share for industry leaders

The largest construction companies in Australia do not dominate the market. For example, CIMIC's market share of 2.0%, whereas BBPHA 1 Pty Ltd has approximately 1.0%, and Lendlease is less than 1.0% (IBISWorld 2022). Furthermore, market dominance has never occurred for any one firm. However, in other industries, for example, Google controls a majority of internet search activity, and Telstra has earned a plurality market share of cell phone services in Australia.

4. Extreme and nimble competition

Construction continues to be the industry with the largest number of businesses in Australia in FYE 2021 and accounts for approximately 16% or 410,839 of all businesses. Additionally, new entrants, which appear to be more aggressive in pricing and promises to customers, numbered most (6.1%) of the nine major industries (ABS 2021).

Construction is sometimes referred to as a "cottage" industry; 98.5% of construction firms employ less than 20 people, and only 0.1% of firms have workforces of 200 or more (ABS 2022). These small competitors are far more flexible in meeting customer needs and addressing their wants.

5. The "intersectionality" problem of construction

Classifying construction businesses as homogenous is problematic. Each business' operation is significantly affected by its characteristics. A simple categorising may include: a) trade focus, b) project type, c) region(s) operating in, d) client types, e) contract type(s) working under, f) publicly or privately owned, g) amount and type of technology used, h) number of employees, i) accounting basis and j) management culture. Since there are multiple choices for each of these nine areas, it is clear that over 3.6 million (10 factorial) combinations are possible. However, there are 410,839 built environment firms in Australia (ABS 2021); therefore, few organisations are similar (see Table 2).

Table 2. Sample differences of construction firms

Characteristic	Number	Factor
Trade	10	General, Civil, Marine, Façade, Electrical, Plumbing HVAC, Structural, Roofing, Flooring
Home Office Location	6	NSW, QLD, VIC, NT, WA, SA
Market Location Focus	3	Rural, Urban or Suburban
Client Types	3	International, National or Local
Contract Types	6	Lump-Sum, Alliance, PPP, D-C, Time & Materials or Cost Plus
Company Ownership	2	Private or Public

Technology Adoption	3	Robust, Average or Weak Adoption
Employee Number	3	Small (1-19), Medium (20-100) or large (100+)
Accounting Basis	2	Accrual or Cash
Management Culture	4	Owner-Operator, Family, Team, or Bureaucratic

Most innovations cannot be economically feasible for the inventor if they appeal to only a few customers i.e. if there are few buyers of a construction-specific innovation-its high cost and time investment cannot be formally justified. Projects are also dissimilar, making possible targets less in number (see Table 3)

Table 3. Sample differences in construction projects

Characteristic	Number	Number and Type General Factors
Use Type	7	Residential. Commercial, Industrial, Institutional, Civil, Marine, and Infrastructure.
Location	3	Urban, Suburban, and Rural
Funding	3	Public, Public or PPP
Client Type	3	Government (Federal, State. And Local), Corporate (Local or International), or Individual.
Construction Process	4	New Construction, Remodeling, Rehabilitation, or Replacement

6. The industry is precarious

The construction industry has a high failure rate when compared to other sectors. Recent data from the ABS (2021) reported 14.0% of the companies that started 2021 exited by the end of the year. The Australian Tax Office (ATO) latest filings report that 78% of Business Owning Households hold some form of debt. Additionally, 54% of Australian companies declared a loss and thus paid no taxes. This appears to point to a financially meagre environment with little means to pay for innovation. It seems to justify an aversion to speculative investment, which characterises research and development. Further demonstrating risk, a bankruptcy study sponsored by Australia's Construction Forestry Maritime Mining Energy Union (CFMEU 2014) concluded that the construction industry outscored all other industries for each deficiency category above $500,000.

IBISWorld (2022) identified Key Success Factors (KSF) for a construction business that indicates nimbleness is critical. The top 3 most significant include 1. Ability to expand and curtail operations rapidly in line with market demand. 2. Operators must be able to quickly alter labour force numbers to match short-term cycles in market demand. 3. The ability to hire experienced, productive workers, especially during periods of low labour availability, is crucial to success.

7. The construction industry has problematic employment dynamics

The Australian Bureau of Statistics (ABS 2021) documents that 37% of worker services are secured by contract, whereas the next highest – administrative and support services - is slightly over 20%. This seems to indicate that there is little incentive to make employees more productive since they are on contract for a fixed hourly rate, lumpsum outcome or a fee per piece, and thus, there is less need to create or adopt innovation to make them more productive. Similarly, independent contractors have little incentive to invest in large-scale and risky innovation since these arrangements represent employment, not a business opportunity.

The Australian government labour statistics show that between 1991 and 2019, involuntary employment separation (Lost Last Job) ranged from 76% to 274% of the total employment population (ABS 2022). This means that the knowledge of a specific innovation may travel with a departing employee, thus disincentivising the creation of a unique task methodology and training to facilitate mastery.

8. A service such as construction is difficult to patent

Nagy (2013) notes the difficulty of patenting services and protecting the inventor's intellectual property rights. It is partially due to its intangible nature. In Australia, patents are strong protection for unique tangible products for a legally prescribed 20-year period. However, this can be a protracted and challenging process that is a high risk to the creator of patents. Research by London and Siva (2013) indicates the challenges for those in the construction industry to create and protect their patents. The Australian system affords few rights to the creator of patents and little protection with the onus solely with the creator. Coupled with this, it is not easy to patent a process, construction or otherwise, and protect it from duplication by competitors. In preserving a method as intellectual property, it is difficult to prove where the employee's expertise and experience (current or former) stops and the organisational, institutional knowledge rights start.

9. The Government is not keeping pace nor encouraging construction innovation

Western nations have robust laws governing construction activity and limiting risk to the construction service buyer and end-user. This risk governance is core to the role of industry regulators and appears to lag the rapid pace of invention (Soeteman-Hernández et al. 2019). Few proactive processes conditionally approve early phase creation of innovative ideas or development. Rose and Manley (2014) noted that regulatory agencies in Australia lack clear procedures for assessing new products. Suprun and Stewart (2015) found repeated "Regulations, public policy, and supporting mechanisms" barriers in many countries.

DISCUSSION

Expecting organic innovation in the construction industry has been minimally effective over decades. The barriers listed appear to be too great for contractors to tackle alone. Eight of the nine barriers cited cannot be significantly changed. They are a product of the industry's dynamics. . However, government inspired innovation support can be grown. Seeking ways to overcome these barriers may include partnerships with universities, government, and associations, using activities such as hackathons and business incubators.

Longterm, creating an industry culture of innovation could be a strong leverage point for increasing value for all stakeholders. Isaacson (2014) suggests three main parties are crucial to involve: Peer Inventors, Market and Government. Unequal attention of one over the others is suboptimal. Critically, Australian Universities are an extension of the

government and should be equally engaged as part of the solution.. In Australia, the government has created programs for businesses and inventors, regardless of industry, to assist in accelerating the development and market deal-making process. The construction sector has sponsored innovation incubators and hackathons

Generally speaking, there is a strong commonality between macro-level motives and benefits for industry and university actors (Ankrah 2013). Private companies appear to want to engage and collaborate with the best researchers (Abramo et al. 2009). Universities have created innovation hubs. These have grown the size of peer inventor groups. They should be included as part of a transformative plan. Suprun and Stewart (2015) found that most contract relationships between industry and universities were strong and enduring. Universities are well-positioned since they perform the "triangle of knowledge" for novel creation composed of research, education, and innovation (Abramo et al. 2009). Universities are performing these functions better than other stakeholders as a group.

Industries can benefit from partnering with allied ones. This is known as a sister industry strategy. Examples include motor vehicles, the petroleum industry, or computer software and hardware manufacturers. It should help the construction industry if it utilises the same approach. Manufacturing is a viable candidate due to modular construction and prefabrication's value. Construction's custom non-mass production nature could improve this partner sector's fortunes.

People innovate via multiple approaches such as "learning by doing". Charles and Ray Eames were furniture design legends in the 1940s that took the "learning-by-doing" mentality to new heights and mastered collaboration throughout their careers. Another approach is "combined thinking of the creative arts and hard sciences". George W. Carver at the turn of the 20th century balanced his interests and talents in science and art. Carver's observation, experimentation, replication, and communication skills enabled novel combinations resulting in his inventions.

Innovation is a team endeavour. The lone inventor who carries the product from idea to market has a poor probability of succeeding. Importantly, investors do not bet on this model. Instead, team members should have "learned on someone else's nickel". The raw graduate is worth more after they have industry experience, i.e., their idealism is tempered by failure and confidence boosted by success. They understand the complexities and uneven pace of the innovation cycle. Importantly, if the young inventor has learned the foundations first and then advanced their thinking, they can bring the transcendent ideas to the present, creating more value and thus quicker adoption by the market.

According to Isaacson (2014) Each inventor group should possess three skills to create their product or service vision and bring it to reality:

1) Excellent ideation energy
2) Robust product or service development skills
3) Strong business savvy, including deal-making

This list suggests that more than one person must be involved. Rare is the person who can master all three. Investors know that a product's chances of success are what they are wagering on and a team of people with profound skills in the needed areas improves probabilities. The quality of the team perfecting the invention helps determine the amount of funding and its disbursement schedule. Another investor decision-making criteria the

innovation in fitting an uninhabited market. This means more value is perceived earlier in a product's lifecycle.

Some may assert that implementing information and communication technology (ICT) will significantly improve efficiency. However, recent research by Leviakangas et al. (2017) shows that the Australian Construction Industry's investment in ICT is in the bottom third of the nine major industries studied but is ranked third in value-added.

This inverse result of construction's significant value increase versus a low technology expense from a return on investment perspective seems to be supported by some of the other factors mentioned in this paper. Most construction contractors do not see evidence of a productivity increase from more ICT investment. So, productivity improvement seems to be a product of other focuses such as more intelligent project management, organisational leadership, process improvements and entrepreneurial thinking.

Contractors are not alone in investing modestly in ICT. The Toyota Production System's (TPS) thinking is the same. The company believes in purchasing, implementing and training proven software as stated in its principle 8, "Use only reliable, thoroughly tested technology that serves your people and processes". The reference to proven implies the previous version. They assert it is a hallmark of an efficient organisation. Lean does not teach leading-edge or next-generation software utilisation. Other experts, such as Collins and Hansen (2011), assert from their research that the highest performing publicly held corporations are careful about technology investment. They found that top-quartile firms in several industries utilise one or more software version(s) older than the current one. This appears to keep negative impacts manageable such as training expense, unknown software problems and small, unknowing user groups.

There are other disincentives for construction innovation. For the investor, the service nature and its openly viewable construction conditions challenge the protection of intellectual property. Contrastingly, manufacturers may close off factory sections for inspection or view. Additionally, today's innovation may be less valuable tomorrow. For instance, information technology has shown increasingly rapid change; Moore's law shows evidence of that. Therefore, another robust industry-centric software may be eclipsed quickly. These are not only applicable to programming but to the companies that create them. This is a risk. These organisations' status changes over time through decision-making, ownership transition or management succession. The construction organisation experiences a change in customer support, costs or software functionality which can ripple to projects and organisational performance.

Our observation is that construction companies seem to prefer late adoption for four reasons 1) employee mastery of software over time will improve its value, 2) it will become less expensive to purchase, and 3) a novel breakthrough may become available while the contractor is in the adoption or implementation stage. 4) Information technology company product or support negatively changes long-term. Contracts' conservative and risk-averse thinking may dictate that competitors accept the risk first, then suffer early adoption mistakes.

An industry-led research agenda should recognise and prioritise application over theoretical research. Given the limited amount of funds, prioritisation seems logical. This will produce more implementations of other industries' innovations. Companies in different sectors such as military, aerospace, computing, and engineering have budgets for robust and long-term R&D. Construction appears to benefit significantly from developing industry applications such as drones, information technology and materials. However, Leicht et al. (2014) analysed construction research activity as distinct from

development and application activities. They found these latter expenses are three to four times the research expenses depending on the year measured.

RECOMMENDATIONS

Encourage more industry-led research partnerships

Due to low margins and high-risk factors, it must be realised that a more innovative environment needs to be created for construction to improve more quickly. This can start with formal partnerships between industry practitioners and university researchers. Public resources and industry knowledge should be synergised. As part of this, it is imperative to have contractor-directed research partially or fully funded by the industry. When categorised separately, funds for development are invested more than pure research in the AEC industry. Innovation centres can be a hub for spawning the practical from the theoretical.

As an example, some universities have actively developed funding for industry-directed research in Australia. Advisory Groups leading the sector should assist in govern the apportionment of expenditures toward relevant research. Construction Contractors should be able to focus their financial advancements on one of several research areas in this scheme. The atmosphere of construction invention should intensify.

Reform the patent process

Encouragement for the construction industry toward higher patent activity should be a priority for Australia. This increases the culture of innovation. Besides the obvious boost to safety, quality, and efficiency, patents can be an income stream for innovators and give the industry and its members incentive to improve rapidly. In addition, a patent's 20-year protection facilitates financial rewards for those who can create solutions to industry problems.

Additionally, the patent process is a healthy exercise in determining unique inventions. A patent is given only if the creation is a breakthrough or significantly improves an existing patent value. However, a patent focus might be criticised as selfish and potentially harmful to society. Some want to emphasise an open source focus on intellectual property. They see it as a better ethic. However, it will not incentivise the innovators to invest their time, energy and capital.

Construction's private and public leaders should focus more on innovation

All stakeholders appear to benefit from early review processes and monetary incentives for innovations. The role of government is critical. For example, the government could create and engage in a primary approval process that will provide a general critique of an inventor's submission. Also, to address and encourage invention, governmental agencies could use more performance-based specifications to permit innovators to design and produce new products to deliver design intent and desired outputs.

More government, university and industry-sponsored hackathons and incubators focused on the construction industry would increase the current pace of ideation and product development. Deal-making should follow.

As a further improvement, review the language in areas such as contracts, procurement documents, and specifications to encourage more performance-based criteria and capture of advances in processes after projects are completed.

CONCLUSIONS

These nine barriers appear to slow Australian construction's innovation (intellectual property and software) pace, and thus, it ranks below average compared to other sectors. The obstacles outlined in this paper make the overall lack of innovation understandable. However, taking the strategic view and acting in a targeted fashion can only help industry leaders facilitate future innovation and improvement in constructing shelter, infrastructure and processing facilities.

The industry's practitioners are sensitive to many things including risk and low return on investment.. There are many constraints this paper points to, and so adapting other industries' proven innovations may be a better strategy than greenfield invention. Regardless, once any solution is confirmed as valuable, it must be tailored, marketed and implemented. Overall, the cost for the contractor and the opportunity for the innovator appear to be adverse.

A new outlook is needed by industry, government, universities, inventors, and construction firms with these barriers in mind. Contractors are incentivised to strive for safer, higher quality, and cost predictable projects. Innovative solutions help create this end goal and minimise the risks undertaken. However, construction organisations need other groups' engagement to help overcome the barriers outlined. Each project stakeholder and interested third party can assist. An enthused and supported construction industry can create an innovation culture that benefits everyone.

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