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# Staged competition as a driver of construction innovation

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**Abstract**

Globally building operation contributes 30-40% of the primary energy demand in most developed economies. At the same time the construction industry is repeatedly found to have lower rates of adoption of innovation than other industries, despite being described as "a lively source of new ideas". A general conclusion is that the rate of innovation lags behind most other sectors. A new mechanism for innovation generation, diffusion and adoption is required. The automotive industry provides a benchmark for innovation, and has a distinct advantage with regards to development and implementation of innovation. Automotive 'staged competitions' (e.g. motorsport), occur within the industry between manufacturers, and rely heavily on the involvement of suppliers within the industry. Such competition provides an excellent platform for marketing, testing, and development of innovation within and beyond the parent industry. Although rare and fleeting, construction competitions already exist in the construction industry. However they are not as advanced as motorsport is for the purposes of generating, diffusing or adopting innovations. This case study research considers three unique existing construction competitions, and shows how each example can contribute to the increase in innovation in the construction industry. Further discussion of how these competitions can be optimized to drive innovation within the construction industry is provided with the ultimate aim to reduce resource use and reduce greenhouse gas emissions.

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*Keywords:* Construction innovation; staged competition; innovation; sustainability; emissions.

## 1. Introduction

'Innovation' as defined by the OECD in 1991 is an iterative process initiated by the perception of a new market and/or service opportunity for a technology-based invention which leads to development, production, and marketing tasks striving for the commercial success of the invention [1]. Despite being hard to measure and highly variable between industries, innovation is critical to the advancement of an industry and this is most evident by the focus put

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on the topic by Government, industry and researchers. Radical innovation is the most likely source of dramatic change within an industry [2] and this can apply to environmental and emissions related outcomes. Research covered here shows that the processes of technological innovation are well understood and opportunities exist to transfer knowledge from high innovation intensity industries to less innovative industries. The innovation efforts of companies are currently addressed using the patent system, which allows the inventor or innovator to create a monopoly on the technology [3]. Due to the exclusive rights of the patent system, the company benefits economically from obtaining a patent. The reciprocal outcome of this is that others are unable to utilize the technology, which restricts its advancement. In contrast, 'Staged Competitions' (where teams compete for a prize) offer an alternate method to reward innovation, usually by the awarding of a cash prize. In such situations, the organizers of the competition require public availability of the innovation details. Under this scheme innovators are rewarded financially and innovations are made available publically for a wider application. This type of approach has significant benefits with regards to the widespread adoption of a new technology, and are therefore promising as a new innovation mechanism. Historically, competitions for R&D have led to important innovations, with aviation featuring heavily [4], and more recently automotive staged competitions (motorsport) has demonstrated significant benefits to the automotive industry globally[5].

Staged competitions are always governed by rules agreed on by the participants or a governing body, usually specific to one particular sport (e.g. motorsport), and always specific to the event (i.e. as specific regulation). Staged competitions are comparable with sporting events but with the focus being on industry related technical, innovation, ideas or design contests. Such competitions are often primarily intellectual pursuits and require creativity, imagination and innovation. Despite the many applications and clear benefits, development of practical technical innovation solutions from this type of competition within an industry is not well understood with the exception of the numerous examples from motorsport. The focus of this research is to identify current successful uses of staged competition in construction, with the intention of understanding how to best driving innovation in the Australian construction industry, using motorsport as a theoretical lighthouse as to the potential benefits to the industry.

## 2. Background and Literature Review

As defined by Rogers [6] theory 'diffusion of innovations', a series of steps occur in order for an innovation to be successful; broadly, an innovation requires generation, diffusion and adoption. Due to the independence from traditional market forces, staged competition has a unique effect on this process. Staged competition can drive innovation where market forces are unsuccessful, likely due to lack of or incorrect capital expenditure [7]. Of equal importance, specific innovation issues in the market (e.g., failure in adoption of innovations) can be addressed by the design of the competition. For example an innovation contest is ideal for the generation phase of innovation. In contrast, a physical prototyping competition emphasises the adoption or implementation phase of the competition. In the case of motorsport, generation, diffusion and adoption are all achieved, which is why motorsport results in high rates of innovation transfer into the automotive industry. This knowledge allows the targeted use of staged competitions to drive innovation generation, diffusion and adoption in the Australian construction industry in order to reduce resource use and greenhouse gas emissions.

### *2.1. Construction innovation*

The literature on construction innovation refers repeatedly to the same historical examples of innovation, such as the introduction of structural framing (as opposed to load bearing walls) in the UK at the turn of the 20$^{th}$ Century [8-10]. This lack of innovation affected the productivity, quality and ultimately value for money from an efficiency perspective – simply, it did not innovate [11]. The low innovation rates of the construction industry are determined in comparison to other industries, with the benchmark industry to beat being the automotive industry [12]. In Australia, research has found that the construction industry is lagging in innovation as a whole and has only approximately 30% of businesses in the industry innovating, which is the lowest in any sector [13]. Considerable research has attempted to identify the recipe for innovation within the construction industry. Tatum [14] best summarized this large collection of previous research into strengths and weaknesses. With regards to strengths

Tatum highlights project organization, necessity and challenge, engineering and construction integration, low capital investment, capability and experience of personnel, process emphasis, and variation in methods. Highlighted weaknesses include investment reluctance, competitive conditions, institutional framework, seasonal and economic cycles, and role of suppliers. Tatum's summary clearly shows the static nature of the construction industry, which is a result of reluctance to innovate due to lack of incentive, institutional barriers, competitive conditions and reliance on small suppliers.

### *2.2. Automotive Innovation*

By contrast, the automotive industry has consistently innovated [15], with a strong research focus on radical innovations, acknowledging that incremental innovations actually form the majority of innovations in the industry [16]. Alongside performance and safety requirements, there is growing evidence of pressure from environmental requirements in driving innovation [17]. The automotive industry is consistently driving innovation (including radical) through regulation, perceived to be the most likely path towards low $CO_2$ from transport, when compared to behavioral modification [18], with electrification the widely accepted radical technological innovation to impact emissions in the automotive industry [19].

The automotive market also considers electric propulsion of cars as a luxury item and this represents an alignment of the innovation 'need' with market perception. Motorsport further enhances this perception, as is displayed in the most prestigious of motorsport events, formula 1, where hybrid propulsion can deliver fuel savings or power boost depending on how it is utilized [20]. This example demonstrates the different attitudes found in the automotive industry towards innovation advancements, many of which are extensively tested in motorsport prior to full scale introduction to the mass market, and it is clear therefore, that competitive motorsport has innovation related benefits to offer. Where the automotive industry is characterized by efficiency of production, motorsport drives agility, innovation and rapid technology development. Innovation that is tested in this competitive arena diffuses first to the low volume, high profit luxury automobile and eventually into the modern day mass produced road car, representing final adoption [21].

The significance of this relationship between the automotive industry and motorsport is evident in the statement of Toyota's founder Kiichiro Toyoda about the relevance of automotive racing, entitled 'Auto-racing and the Japanese Automobile Industry':

> *"Japan's auto industry must succeed in building passenger vehicles. To this end, manufacturers must participate in auto-racing to test their vehicles' durability and performance. With competition comes progress, as well as excitement among motoring fans. The aim of racing is not just to satisfy our curiosity, but rather to enable the development of the Japanese passenger vehicle industry."* [22]

This view is echoed throughout the industry, consequently motorsport is used by manufacturers as a test platform for development of new technologies, representing a 'live' form of R&D [23]. Radical innovations that have progressed from motorsport into the everyday road car are numerous and include the turbocharger, ground-effect chassis, and traction control [24].

The contrast between automotive and construction clearly shows the potential benefits for a staged competition in the construction industry to address innovation from generation to adoption.

The aim of this research is to determine how three well established successful competitions in the construction industry are driving innovation. More specifically, it seeks to understand how the competitions are driving the innovation processes; generation, diffusion and adoption; with the ultimate goal to address resource use and greenhouse gas emissions from the Australian construction industry.

## 3. Method

This research uses content analysis [25] of three case studies to determine how existing construction competition formats encourage generation, diffusion and adoption of innovations. Case studies are appropriate to be used to test or generate theory, and are particularly appropriate for areas where the research is still in its infancy, formative stages or there are no solid theoretical foundations. It is preferred when "how" or "why" questions are being posed [26]. It can include data from direct observation and systematic interviewing as well as from public and private archives. The case study competitions are:

- The Solar Decathlon,
- Australian architectural design competitions, and
- The LafargeHolcim Sustainable Construction Awards.

Each has been chosen as a representation of the different major types of competition already present within the construction industry, and with a focus on reductions in resource use and greenhouse gas emissions. The architectural design competition is studied in its generic format (due to the large number of variations, each of which is disconnected with previous competition, making no single competition the appropriate case to study).

## 4. Case Studies

### *4.1. Solar Decathlon*

The Solar Decathlon, of the U.S. Department of Energy, is an international competition that challenges 20 collegiate teams to design, build, and operate the most attractive, effective, and energy- efficient solar-powered house. The winner of the competition is the team that best blends affordability, consumer appeal, and design excellence with optimal energy production and efficiency. The first Solar Decathlon was held in 2002, and has since occurred biennially from 2005 - 2015. There is also a Solar Decathlon Europe, which was established under a 2007 agreement between the United States and Spain. The Solar Decathlon China was established with the signing of a memorandum of understanding between the United States and China's National Energy Administration in 2011. The first Solar Decathlon China was held in 2013, making the competition truly global.

Open to the public and free of charge, the Solar Decathlon allows visitors to tour ultra-efficient houses, gather ideas to use in their own homes, and learn how energy-saving features can help reduce power bills. The decathlon by name consists of ten contests governed by detailed rules which are directly measured or juried. Contest 3 is engineering based, and a jury of professional engineers evaluates each house for functionality, efficiency, innovation, and reliability. The other contests are generally not related to construction: Architecture, Market appeal, Communications, Affordability, Comfort zone, Appliances, Home life, Commuting, and Energy balance.

Although the competition is not focused on construction, energy and emissions are a main focus of the competition and this includes numerous construction specific criteria and requirements across the contests. For example, each team is required to comply with the competitions international building code, which covers structural performance, as well as other performance measures including fire safety and disassembly. In addition, each team is required to provide all drawings and project manual including construction specifications, and three iterations of the BIM model used for the project (design development, construction documentation, and just prior to completion).

From an innovation perspective, contest three includes an innovation category, with the following assessment criteria:

Innovation

- To what extent were unique approaches used to solve engineering design challenges?
- To what extent do the proposed innovations have true market potential?
- How well does the design demonstrate market-leading technologies and engineering integration?

The Solar Decathlon relies primarily on the use of existing innovations as well as novel design solutions. As an example, the third place entry in the 2011 Solar Decathlon from New Zealand included a novel drying cupboard solution above the hot water heater [27].

### *4.2. Architectural Design Competitions*

An architectural design competition is a generic term for individual building design competitions in which an organization that intends on constructing a new building invites design teams to submit design proposals with innovative and creative design solutions [28]. The winning design is usually chosen by an independent panel of design professionals and stakeholders (such as government and local representatives). This procedure is often used to generate new ideas for building design, to stimulate public debate, generate publicity for the project, and provide emerging designers with the opportunity to gain exposure. Architectural design competitions are often used to award commissions for public buildings due to the transparency provided; in some countries rules for tendering public building contracts stipulate some form of mandatory open architectural competition. Although this can be strictly considered to be a design competition only, in many cases competing teams include architects, head contractors, and consultants all providing their individual expertise towards the bid. Architectural design competitions are team-based and require a large investment of time with no guarantee of winning, which drives innovation generation at very low cost to the organizers.

Architectural design competitions have a long history of use for generating design ideas and selecting architects for projects, with early competitions dating back over 2000 years including the Acropolis in Athens as well as many roman church designs, more recently the White House, Guggenheim museums, World Trade Centre, Australian Parliament House and others. Organizers range from Governments to private developers, resulting in no transfer of knowledge following each competition, a problem consistent with the criticisms of the construction industry generally [14]. Typically, an architectural design competition results in the winner being awarded the contract to construct their submission based on a set of specific instructions- effectively the rules of the competition. In most cases architectural design competitions are considered to be one-off competitions, with no transfer of innovation between one and the next. Such competitions are very tightly regulated with regards to function scope, but allow flexibility in design. Architectural competitions are typically open to anyone and this drives greater design variation. In some cases they are open only to selected participants, for example those with the capacity to deal with a large project. Often competitions are international with a strong overseas contingent submitting. Acknowledging issues related to consistency and transferability, The Australian Institute of Architects (AIA) have developed design competition guidelines for such competitions, however these documents are not a requirement for a competition, as these competitions lack a central authority with regards to their governance. In any case there is no requirement for innovation as part of the guidelines.

### *4.3. LafargeHolcim Sustainable Construction Awards*

The LafargeHolcim Sustainable Construction Awards provide 2 million dollars U.S. as prize money for projects in the categories of buildings and civil engineering works; landscape, urban design and infrastructure; and materials, products and construction technologies. The competition requires entrants to be at the advanced stage of design with a high probability of execution. The awards were first conceived in 2003, and seek leading projects from professionals as well as ideas from the next generation that combine sustainable construction solutions with architectural evidence [29]. The awards also have a separate competition that targets young entrepreneurs to submit concepts, irrespective of actual implementation, and specifically asks for ‘blue-sky’ ideas in this category.

The judging criteria specifically target innovation and transferability (judging category number 1 - innovation and transferability – progress), with the latter representing the diffusion potential of the innovation developed for the project, thus specifically attempting to overcome the barriers found in the architectural design competition format that limits transfer of innovation between projects [30]. For the innovation and transferability category, the following criteria are made [31]:

- Projects must demonstrate innovative approaches to sustainable development, pushing the envelope of practice and exploring new disciplinary frontiers. Breakthroughs and trend-setting discoveries must be transferable to a range of other applications.
- Innovative concepts regarding design, integration of materials and methods, structure, enclosure and mechanical systems.
- Dissemination of knowledge, including project documentation, communication, education and training.

## 5. Discussion

The three case studies of staged competition in construction show a considerable variation in structure and format; organizer and entrant; and stage (generation, diffusion adoption) of innovation. Each of the competitions has its own merits with regards to innovation; however none is identifiable as being successful in all stages – success being defined by the progression of an innovation from generation – diffusion – adoption. The Solar Decathlon is a physical prototype competition resulting in trialing and In order to win team target designs and products that provide a relative advantage over other teams, and trialability of a constructed prototype occurs as a result; this being a strength of the competition. However, the narrow focus of the Solar Decathlon provides only a small solution space, due to the specificity of the rules, which limits the wider application of an innovation. The competition provides a platform for marketing exposure of the manufacturer's products which represents a form of diffusion for the innovation; however there is little evidence of adoption of innovation from this competition. In order to make the Solar Decathlon address adoption of innovations into the main industry, a stronger involvement of the industry, and requirements for prototyping to become production items would be required (such as the homologation requirement found in motorsport).

Architectural design competitions by contrast provide a design focused innovation generation platform, but are otherwise poor in driving diffusion and adoption of innovations generated. This is attributed to the fact that competitions are held independently from each other which results in minimal transfer of innovation between projects. Although individual competitions are very specific to site, scale, and client requirements, there is considerable opportunity for innovation transfer between projects. In order for the architectural design competition to be more successful at driving the final adoption of innovation, a central competition resource that collects the innovation for diffusion and adoption would be required, such as that provided by the Royal Institute of British Architects (RIBA) who actively run architectural design competitions on behalf of clients [32]. This would be analogous to the FIA who is responsible for all formula 1 races, providing consistency and continuity.

The LafargeHolcim Sustainable Construction Awards presents a different type of innovation competition due to its retrospective nature, which like the architectural design competition is primarily focused on the generation stage of innovation, despite clear direction in the judging criteria towards diffusion and adoption. Because the awards are decided during or towards the end of the design stage, the awards have limited impact on diffusion and adoption. For this reason the Awards do not drive innovation per se, but rather they award good innovation that has already occurred. However, unlike the previous mentioned competitions, the LafargeHolcim Sustainable Construction Awards are very broadly focused, thereby providing a large solution space; for example by including awards for materials innovation as well as building designs. For this reason, as well as the judging criteria of transferability, the awards competition is potentially effective in driving a wide range of innovative outcomes, but still requires improvements in diffusion and adoption to be valuable as an innovation tool.

## 6. Conclusion

The literature shows how the automotive and construction industries differ in their use of staged competitions for generation, diffusion and adoption of innovation. Specifically, the construction industry is low in innovation and lags behind most other industries. The automotive industry has the benefit of motorsport as a source of innovation, which is adopted by the main industry. In contrast to motorsport, the construction industry has examples of staged competitions that tend to be niche, sporadic and/or discontinuous. However, it is possible to model the motorsport

format and structure in order to correct the missing steps in the construction industry innovation process, resulting in the final adoption of innovations generated. The Solar Decathlon is the clearest example of a competition in construction with innovation criteria, but as yet remains a competition between universities with no evidence of transfer to the mainstream construction industry. The Solar Decathlon illustrates that construction-related competition can be successful. In contrast, the architectural design competition is an example of staged competition that exists within the industry already, and therefore also has a strong link relevance when looking at formats and industry acceptance. However, competitions of this type are almost always one-offs and this discontinuity does not foster innovation diffusion or adoption. In addition, although a design competition includes construction-related innovation it is not inclusive of the construction process, making adoption very difficult to deliver. Finally, the LafargeHolcim Sustainable Construction Awards target innovation in their criteria but are not responsible for the advancement of innovation generations as they are awarded after the innovation process has occurred. For this reason this type of competition can only be seen to be promoting existing innovation that has occurred to the industry. Although rewarding good design is a worthwhile outcome, it is not consistent with the intention of a staged competition to drive innovation from generation to adoption.

This research reviews how three well established successful competitions in the construction industry are driving innovation, focusing on the innovation processes; generation, diffusion and adoption; with the ultimate goal to address resource use and greenhouse gas emissions from the Australian construction industry. Further research is required into other competitions within construction and their impact on innovation, as well as what successful formats could be specifically adapted with the ultimate goal of driving innovation through staged competitions in construction.

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