



PROJECT #93: INTERNATIONAL RESEARCH TOUR OF SAN FRANCISCO AND THE GREATER BAY AREA 2024

FINAL REPORT



ABOUT US

Building 4.0 CRC is an industry led research initiative co-funded by the Australian Government. It is tasked with revolutionising how buildings are designed, constructed and operated to build faster, safer, more sustainably and at a lower cost. With the housing crisis and cost of living pressures escalating, the work of the CRC has never been more important.

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CONFIDENTIAL: Yes No

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Disclaimer

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OUR DELEGATES



NAME	POSITION	ORGANISATION
INDUSTRY		
Jamie Buxton	Director of Acquisitions	MAB Corporation
Brett Donovan	Director & CRO	Utecture
Kyle Donovan	Director & CEO	Utecture
Murray Ellen	Founder	PT Blink
Daniel Fink	Founder / Associate	Republica / MIT
Tara Goldsworthy	Executive General Manager	Fleetwood
Ross Harding	Principal	Finding Infinity
Jay Humble	Co-Founder & Tech Lead	Sightdata
George Konstandakos	General Manager	Sumitomo Forestry Australia
Jeremy McLeod	Founder and Design Director	Breathe
Daryl Patterson	Advisor	
Alastair Porter	Co-Managing Director	Porter Group Limited
Julie Saunders	Director	URBIS
Timothy Spencer	Executive General Manager	Mulpha
Jan Van Der Berg	Senior Development Manager	Mulpha
UNIVERSITY		
Prof. Robery Amor	School of Computer Science	University of Auckland
Dr Duncan Maxwell	Program Lead, Building 4.0 CRC	Monash University
Prof. Tuan Ngo	Program Lead, Building 4.0 CRC	University of Melbourne
Dr Sara Omrani	Program Lead, Building 4.0 CRC	QUT
Dilshi Dharmarathna	Researcher	Monash University
Karen Tanfield	Researcher	University of Melbourne
Prof. Jennifer Whyte	Head, School of Project Management	University of Sydney
GOVERNMENT AND NOT-FOR-PROFIT		
Philip Alviano	Sustainable Building Advisor	Master Builders Association of Victoria
Jennifer Cunich	Chairperson	AHURI
David Harding	Executive Director	Business NSW
Scott Smith	CEO	Council of Mayors South East Queensland
Alex Waldren	National Director - Industry Policy	Master Builders Australia
Mike Zorbas	Chief Executive	Property Council of Australia
BUILDING 4.0 CRC		
Prof. Mathew Aitchison	CEO	Building 4.0 CRC
Clare Blizzard	EA to the CEO	Building 4.0 CRC
Smaro Exelby	Engagement Lead	Building 4.0 CRC
Kathy Mac Dermott	Engagement Advisor	Building 4.0 CRC

EXECUTIVE SUMMARY

a. The delegates had the opportunity to **view and understand the innovative approaches for industrialised building**. This included: large-scale industry implementation; international academic research; solutions to the housing crisis; and decarbonisation efforts in building.

b. The tour highlighted that **the challenges within Australia's building industry are global**. The US construction industry faces remarkably similar issues including: a lack of productivity; resistance to change; building value chain fragmentation; high carbon emissions and construction waste; long-term leadership, regulatory and capacity issues; housing affordability and shortages; and, labour and material issues.

c. Importantly, **Australia's size, institutional structures and system of government are not barriers**. Australia has an advantage with a consistent building code and fewer jurisdictions and variations in building codes. In the US, the large number of bodies with authority and widely disjointed zoning and construction codes are a significant barrier to innovation, growth and the mainstreaming of industrialised construction.

d. **Investment plays a key role in researching and developing innovative solutions**, and compared with Australia, US organisations have access to more funds. Recent spectacular failures have served to deter investment in building innovation.

e. Compared with US counterparts, **the Australian building industry and research ecosystem are on par or even ahead in terms of innovation and sophistication**. US companies' access to capital and the sheer size of the market supports rapid growth, which is rare in the Australian context.

f. **Decarbonisation of the building sector has not attracted the same level of interest and action in the US as it has in Europe and Australia**. This is changing and presents an opportunity for research and development of innovative technologies for embodied and operation emission reduction. It also presents an opportunity for new entrants in the US building sector to differentiate themselves.

g. **Successful innovation requires everyone working together**. Australia's CRC program is a model for other countries to bring together industry, government and research capability. Opportunities for international collaboration requires greater investigation.

DAY 1: SAN FRANCISCO



Welcome Dinner at The Workshop – State Bird Provisions

Speaker: Prof. Mathew Aitchison (CEO, Building 4.0 CRC)

Special guests:

Adj. Prof. Jerker Lessing (Civil and Environmental Engineering, Stanford University)

Tyler Pullen (Senior Technical Advisor, Turner Housing Innovation Labs)

Sunil Joshi (US Expansion Director - SF Landing Pad, Austrade)

Prof. Mathew Aitchison opened the welcome dinner with an introduction to Building 4.0 CRC, highlighting the status and challenges of the Australian building industry within the global context. There is an urgent need for investment in research innovation and construction to address the industry's 70-year decline in productivity, and to seek solutions for escalating housing and climate issues. Delegates presented their personal objectives for the research tour and identified opportunities and challenges within the Australian building industry.

Key delegate objectives for the research tour included:

- **Seek solutions for building industry challenges** including affordability, productivity, sustainability, lack of willingness to change, slow industry adoption and adaptation of industrialised construction, fragmentation, cost and labour issues.
- **Observe, understand, learn and be inspired** through experiencing first hand and learning how others in the world recognise and attempt to resolve building industry challenges.
- **Develop and strengthen meaningful partnerships and collaborations** within the global research and industry communities.
- **Inspire connections, networks, engagement and conversations** about innovation and change within the diverse mix of industry and research delegates.
- **Apply knowledge and lessons learnt** to the Australian building industry.
- **Bring a growth mindset**, a focus on change and a sense of optimism to inspire ideas around sustainability and productivity within the research community and building industry.
- **Enable change** within the traditional on-site construction industry and energise their engagement.

Delegates identified opportunities and challenges within the Australian market, including to:

- **Advocate for reform in government policy, industry processes and practices.**
- **Reduce and overcome perceived risks and associated costs** of the building industry, from design through construction stages.
- **Inspire change and actions that identify housing as a basic human right.**
- **Improve the quality of Australian building** by better enabling and equipping professionals.
- **Increase the impact of research and development in building, aligning outputs with applicability within the industry.**

DAY 2: SAN FRANCISCO

Visit 1 – Guided tour of University of California, Berkeley

Location: 1330 Broadway, Suite 430, Oakland, CA 94612

Host: Tyler Pullen (Senior Technical Advisor, Terner Housing Innovation Labs)

This guided tour highlighted significant landmarks of the university campus, including the California Hall, Sather Tower (Campanile) and Esplanade.



Visit 2 – Turner Center and Turner Labs, University of California, Berkeley

Hosts / presenters:

Ben Metcalf (Managing Director, Turner Center for Housing Innovation)
Ben White (Director, Builders Labs, Turner Housing Innovation Labs)
Michelle Boyd (Chief Strategy Officer, Turner Housing Innovation Labs)
Prof. Iris Tommelein (Civil Engineering Department, University of California, Berkeley)
Tyler Pullen (Senior Technical Advisor, Turner Housing Innovation Labs)

Resources:

- <https://turnercenter.berkeley.edu/wp-content/uploads/2021/02/833-Bryant-February-2021.pdf>
- <https://turnercenter.berkeley.edu/>

Operating within the University of California, Berkeley, the Turner Center for Housing Innovation's mission is to develop bold strategies to house families. It focuses on data-driven and action-oriented research to drive innovation and change across policy, practices and culture throughout the private and public housing sectors.

The Turner Labs is an independent, not-for-profit organisation founded to complement the research efforts and work of the Turner Center. It has a streamlined focus on innovation, data, best practice and new business ventures implementing new tools and programs. Turner Labs runs three initiatives: The Housing Venture Lab, Data Solutions Lab and Builders Lab.

The presenters focused on the role and ongoing work of the Turner Center and Turner Labs to address critical challenges of the Californian construction and housing industry including:

- The inability of the market and government to meet rising housing demand, escalating community resistance to the building of new homes/estates, the significantly increased cost of construction and labour shortages (due to the ageing workforce, impending 'retirement cliff' and unsupportive federal policies for immigrants).
- The rental and sale prices of housing in California have risen much faster than the rest of the United States. The increased cost per square foot of construction exceeds general inflation. The state's coastal cities are the hardest and most expensive to build in. California enacted state legislation in 2016 allowing homeowners to build Accessory Dwelling Units (ADUs) easier. Many ADUs are naturally affordable to households at or below 80% of area median income and often in areas with few other affordable options. The legislation spurred rapid growth in the permitting and building of ADUs in California, with permitting growing from 2,100 units in 2016 to 21,000 in 2021.
- Zoning reform is not enough. Long-term leadership from elected officials is needed and policymakers need access to evidence-based stimulation tools.
- The Housing Venture Lab is an accelerator program that partners with early-stage entrepreneurs, both from non-profit and for-profit business models, and focuses on affordability, equity and sustainability. Participating entrepreneurs receive six months of catalytic support, including seed grants, extensive advice on the business model being employed and partnership strategies, along with access to the Turner Center's national network and community of innovation. The current cohort of innovators includes Housing Connector, Kit Switch, Revalue.IO, Credevolv and A New Way Of Life. <https://www.turnerlabs.org/housing-venture-lab>
- Data Solutions Lab focuses on developing data-centric tools to support policymakers, advocates and researchers to make informed decisions about community housing. Its Housing Supply Simulator tool allows users to understand the types of housing that gets built within a neighbourhood by simulating policy effects, testing financial feasibility, and tailoring to geographic priorities. This initiative focuses on Los Angeles, San Francisco, San Jose, Arcata, San Diego, County of Sonoma, County of Los Angeles and

San Mateo. <https://www.ternerlabs.org/data-solutions-lab>.

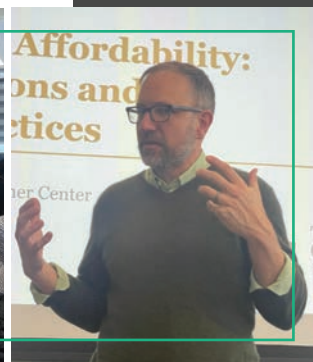
- The Builders Lab focuses on accelerating innovation within Architecture, Engineering and Construction (AEC) along with hardware manufacturing to scale effective and sustainable methods to deliver more homes faster, more affordably and more sustainably. The Lab provides early-to middle stage companies with strategic guidance on complex issues, including management issues, advice on market strategies, and access to an interdisciplinary network including mentors, advisors and partners. It seeks to bridge the gap between academia, industry and government while acting as an education hub for housing by facilitating knowledge sharing and disseminating information. The lab also provides space for 'mock ups'. <https://www.ternerlabs.org/builders-lab>.

Key insights

- California and Australia share common housing and building challenges including a lack of data and long term leadership, capacity issues, escalating costs, labour shortages, planning blockages, housing affordability and rental stress.
- Presenters generally referred to 'industrialised construction', rather than terms such as 'prefab' and 'modular'. Industrialised construction includes all processes that change and manage construction to achieve sustainability, cost effectiveness and affordability outcomes. This broader term accommodates the distinction between invention and innovation.
- There is momentum towards changing the definition of manufactured housing and removing the permanent chassis requirement which will have a 4–5% direct cost impact. The main challenges for manufacturing mobile homes in coastal California include unfavourable zoning codes that dramatically restrict where those structures are permitted.
- There are cultural and regulatory differences between Australia and the US in using institutional funding to overcome financing gaps.
- A key barrier for innovation in California is the incompatibilities and variations in building codes between local government jurisdictions.
- There is increased research on vehicle use and the carbon impact of scattered housing, including understanding and exploring the benefits of medium-density and high-density communities with better public transport.
- The lack of data has led to calls for industry mandates and policy changes, to better understand and forecast construction costs of housing. Public construction sector data is significantly lagging the private sector.

Key statistics

- Over 40% of the construction workforce is expected to retire over the next decade.
- There is an estimated shortage of 430,000 construction workers nationally and it is expected to increase.
- In 2021, Californian home prices were recorded to be 220% above the general home prices.
- 53.1% of renters across California are cost burdened.
- California showed a strong take up of accessory dwelling units (ADUs), with their numbers increasing tenfold over the past five years. This result is attributable to legislation and permits allowing homeowners to build up to two ADUs, given they comply with building codes and standards.



“Lack of data, capacity issues, long-term leadership issues and cost issues remain the biggest housing challenges in California...”

- Ben Metcalf -

Visit 3 – Factory OS

Location: Building 680 1245 Nimitz Avenue, Vallejo, CA 94592
Presenter: Matt Smith (Vice President, Factory OS)

Resources:

- <https://factoryos.com/>

Factory OS's primary goal is to combine innovative technology with tested manufacturing methods to efficiently produce and build affordable multi-family modular homes. It is committed to overcome the prevailing affordable housing issues and construction labour shortages through vertical integration across the value chain. Building 4.0 CRC delegates toured the factory floor and observed the production and assembling process of the modular housing units.



- Factory OS focuses on continuous improvement to maximise factory efficiency. Over time, workflow changed from accepting client proposals of conventionally designed products, followed by inefficient iterations of redesigning, and production, to modular construction. Currently, clients can choose from 25 different unit types that are already designed and built.
- Factory OS uses a patented operating system on an Autodesk platform, to improve factory work and production flow, in terms of efficiency and cost reduction through transportation. They incorporate technologies such as BIM digital prototyping, precision manufacturing and consumer focused smart home services.
- The factory floor allows year-round offsite construction, 12 hours a day. The factory uses smart material procurement practices that are enabled through short construction schedules and controlled storage.
- Factoring in carbon emissions during material selection and transportation requirements adds to the sustainability value of the units. Production technologies such as precision cutting and indoor material storage can reduce site waste by 40%.
- To overcome construction labour shortages, Factory OS maintains a partnership with the Northern California Carpenters Union, from which they recruit their workforce.
- 26 out of the 31 projects related to affordable housing construction.
- The company anticipates expanding their market outside California.

Key statistics

- The Factory OS construction solution has been proven to be 20–40% cheaper and 40–50% faster than conventional construction methods.
- 50% of their workforce had no prior construction experience; these workers undergo a 12-month training program. 35% of Factory OS employees are 'second chance' workers (formerly homeless, incarcerated, battling substance abuse etc.), recruited through Californian prisons.

Visit 4 – Urban Machine

Location: Building 680 1245 Nimitz Avenue, Vallejo, CA 94592

Host: Eric Law (CEO and Founder, Urban Machine)

Resources:

- <https://urbanmachine.build/>

Urban Machine is a timber recycling facility that uses robotics and artificial intelligence (AI) to reclaim lumber for reuse in premium wood products. Its primary goal is to reduce wood waste and promote circular construction practices. Delegates were given a guided tour of the site, including 'The Machine' – an innovative, small-scale prototype robot at early stages of testing.



- The timber being reclaimed was used mainly for architectural purposes. Structural repurposing of reclaimed timber was possible only after a regrading process in accordance with the US structural classification system.
- 'The Machine' prototype robot comprises four robotic arms – top, bottom and both sides – with a manual feed into a 3-foot square glazed cube working environment used to evaluate process and problems. 'Beaks' on the robotic arms removed nails from the timbers fed into the caged workspace. If not removed the first time, the robotic arms try again until the nail is removed. The robotic system used lasers to locate the nails or metal and to determine which arm is best positioned to remove it, to avoid a clash between the arms.
- 'The Machine' was an innovative robotics solution at early stages of testing. It is anticipated to undergo improvements to increase its speed, make the feed bed larger, and to provide an automatic and more stable feed for optimal and effective performance.

DAY 3: SAN FRANCISCO AND PALO ALTO

Visit 1 – Autodesk Pier 9 Technology Centre

Location: Pier 9, San Francisco, CA 94111

Presenters:

Jared Coelho (Senior Manager, Strategic Partnerships – Construction, Autodesk)

Dr Fope Bademosi (Circular Economy and Construction Researcher, Autodesk)

Armelle Coutant (Co-Founder and CEO, Kit Switch)

Resources:

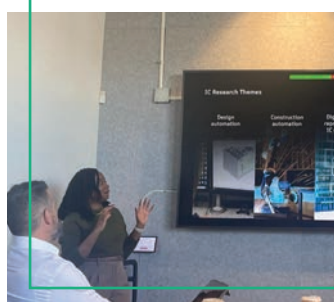
- <https://www.autodesk.com/technology-centers>

Autodesk is the world's leading software vendor for AEC industries. The company has established a range of thematic "Technology Centre" to develop and showcase its capability and R&D. The technology centre in San Francisco is focussed on the interaction between new digital design and production tools, with a focus on advanced manufacturing industries.

At the corporate level, Autodesk has divisions focussed on AEC, Media and Entertainment, and Industry. Our visit included a presentation by Dr Fope Bademosi from Autodesk's Industrialised Construction Research Group, with the title: "The Future of the Built Environment is Industrialised". Dr Bademosi's presentation gave an overview of Autodesk's current software for AEC, and the research into the opportunities and barriers presented by the move to an industrialised construction mindset.

Autodesk's Technology Centers also serve as a landing pad for innovative start-up companies. The delegation received a presentation from Armelle Coutant, CEO and Co-founder from 'Kit Switch', a modular kitchen start-up. Kit Switch reported 20–30% cost savings over traditional kitchen design and construction. The visit was concluded with walking tours of the company's research facilities and workshops located at Pier 9, which included advanced additive and subtractive manufacturing hardware and software.

Of interest was Autodesk's global partnerships, in particular their relationship with Australia's AMCA (Air Conditioning and Mechanical Contractors Association of Australia) that focuses on training union members on insurance and risk.



Visit 2 – Drive by the Tanahán Project

Resources:

- <https://chpc.net/wp-content/uploads/2022/12/Evaluation-of-the-Homes-for-the-Homeless-Fund.pdf>
- The Tanahán housing project is a 6-storey modular apartment development housing previously homeless people. Comprising 145 prefabricated studio apartments built over a concrete ground floor level, the prototype development structure brought together modular construction and philanthropic funding.
- The project faced numerous practical and social issues. Planning determinations meant the modular construction elements had to be installed at night due to concerns about the location and potential for construction to disrupt traffic. The overnight installation required additional considerations relating to lighting and safety of crane operators. A major challenge was resistance of the unions concerned about modular construction replacing manual labour.
- Despite these setbacks, reports stated the project (completed 2021) was constructed 30% faster than similar developments, and within the scheduled time frame (3 years) and costs goals (US\$400,000/unit).

Visit 3 – Stanford University

Location: 450 Jane Stanford Way, Stanford, CA 94305
Host: Prof. Martin Fischer (IC Chair, Professor, Civil and Environmental Engineering, Stanford University Director, CIFE, Stanford University)

Presenters:

Adj. Prof. Jerker Lessing (Civil and Environmental Engineering, Stanford University)
Dr Daniel Hall (Assistant Professor, TU Delft)

Resources:

- **BoKlok:** <https://www.boklok.com/global/>
- **ProjectFrog:** <https://www.projectfrog.com/>



Introduction and welcome to Industrialised Construction at Stanford University

Tour delegates received a comprehensive briefing on industrialised construction within a global context, including key case studies and a deep dive on new business models.

Key insights:

- While value added per work hour has increased by 250% in manufacturing in the last 50 years, it has remained flat in construction. An alternative to traditional building is needed if we are to improve productivity, reduce waste, shorten lead times, lift quality, decrease costs and achieve radical improvements in sustainability.
- Industrialised Construction is a global movement, with significant development in the past 15 years (Scandinavia, UK, Japan, USA, China, Singapore and Australia).
- Industrialised Construction is more than production and can't be solved on a project level. It requires strategic choices and a long-term perspective. An Industrialised Construction company's business model depends on its choice of platform strategy. Deep engagement with clients is required.
- Three new business models being used in Industrialised Construction comprise: a spinoff factory from a tier 1 contractor requiring little change to business apart from a structured learning a process; vertical integration offering full stack integration and speed to capture market, (eg BoKlok); and digital systems integration which provides a capital-light, agile development model. (eg Project Frog).

Business Case Studies

BoKlok – is a project development company with a product portfolio, factory production and site production. Operating in Sweden and the UK, BoKlok is jointly owned by Skanska and Ikea. The company started its work through customer identification investigating what their target customer could afford and most highly prize in their home. BoKlok wanted to ensure a single pre-school teacher with one child could always afford to buy one of their homes – setting the target cost and price level of their products. The company uses a product-platform with a high level of predefined solutions using standardised apartments and modules, described in detail to enable reliable manufacturing. BoKlok’s factory is at the heart of its production, with manufacturing and logistics integrated. Foundations and scaffolding are prepared before the modules arrive. The onsite assembly of the modules takes three to four days, including the roof structure. This work is followed by the onsite assembly of balconies, external stairs and the façade.

Project Frog - uses a digital systems integration business model, leveraging its proprietary kit-of-parts technology, platform development, optimised building components, material sourcing, and network of manufacturers to provide a holistic approach to productising buildings and offsite construction.

Key statistics

- The ‘value add hour of work’ has increased by 250% in past 50 years in nearly every industry except construction, which has remained flat or has reduced since 1964.
- Some approaches to Industrialised Construction can take 50% less time to construct with significant savings during project delivery due to concurrent scheduling enabling: 50% less time on site; 20% fewer trucks going to site and substantial site labour reductions (<https://www.projectfrog.com/industrialized-construction>). This reconfiguration of project schedules and labour make for safer and more equitable work sites.

Walking tour of Stanford University followed by Industrialized Construction Forum Reception

Resources:

- <https://cife.stanford.edu/events/industrialized-construction-forum-2024>

A tour of Stanford University campus, included the William R Hewlett Teaching Center, Stanford School of Design and Thinking commonly known as the “D-School”, the Chapel and the Doerr Sustainability School (previously the School of Earth Science) renamed by the University in recognition of sustainability as a priority issue. The University was established in 1885. The 3,310 hectare campus is organised around seven schools. The University is particularly noted for its entrepreneurship and is one of the most successful universities for attracting funding for start-ups.

The day ended with delegates attending the Industrialized Construction Forum (ICF) Reception for past and present speakers.



DAY 4: PALO ALTO

10th Industrialized Construction Forum, Stanford University

Resources:

- <https://web.cvent.com/event/4ec8dd8c-024c-497d-a61d-44770979acc2/summary>

Introduction

IC Chair Prof. Martin Fischer opened the milestone 10th Industrialized Construction Forum. The theme of “Taking Care” defined the international forum and informed each session.

- Session 1 - the people who occupy the buildings being produced.
- Session 2 - the planet.
- Session 3 - respecting the construction workforce.

Keynote 1: Ten for 10, Adj. Prof. Jerker Lessing (Civil and Environmental Engineering, Stanford University), Dr. Daniel Hall (Assistant Professor, TU Delft)

To celebrate the ICF's 10th year, Adj. Prof. Jerker Lessing and Dr Daniel Hall presented ‘Ten for 10’ – 10 points of reflection that captured 10 years of the Forum. The first five points - the ‘Past’ - reflected on what the Forum has discovered over the past 10 years, while the second five points focused on - the ‘Future’ - exploring the challenges of research and industry innovation and the opportunities to be addressed. Key points were the urgent need for the construction industry to change, given the sector’s central role in nations’ economics, and its role in providing shelter and responding to climate change.



“Tackling the often-paradoxical challenges of climate and housing crises, circular industrialised construction and the needs of developing countries are huge challenges that provide us with huge opportunities. They all require research and development - that is not possible alone, we need to do this together. - Adj. Prof. Jerker Lessing -”

Key Insights

- Prefabrication alone will not change the industry. The use of prefabricated structural elements in Sweden increased from 62% to 88% between 1995 and 2018, but this rise was not accompanied by any notable productivity increases.
- The productivity of industrialised construction (IC) in Sweden increased by 20% between 2014 and 2020, with costs decreasing by 16% over the same period. IC currently has a three month shorter build time on average than conventional construction.
- Urbanisation is a global trend. Urban populations are estimated to grow from 50% to 68% in society between 2020 and 2050. 90% of this growth is expected to occur in Africa and Asia.

Session 1

Speakers: Daryl Patterson (Industry Advisor), Samuel Jordi (Deputy Head REP, Implenla), Basil Starr (Founder and Chairman, Palari) and Christoph Marquardt (Lean Manager, Haas Fertigung)

Daryl Patterson (Industry Advisor): A \$200m education – 15 years of industrialised construction endeavours

Tour delegate Daryl Patterson delivered a presentation drawing on his experiences at Lendlease as they explored new economies and materials. Daryl shared case studies from his work using cross laminated timber (CLT), and the creation of two factories, including one that produced bathroom pods.

Daryl also shared his experience in digital technologies in particular design automation, highlighting that digital is what you need to scale IC solutions, not what makes the solutions economical in the first instance. Success is achieved when parts are recognised as commodities and when common interfaces and smart connectors are defined, and significant efficiencies can be achieved.

Daryl cited Wright's Law which states that if an industry is challenged to double the production of a widget, it will become increasingly cost effective to manufacture increased batch sizes. But this can only be achieved with universal interfaces. Daryl challenged the conference delegates to consider how and when universal interfaces will be achieved, when so many people are currently pursuing their own systems of parts and will never achieve scale.

Key insights:

- Cost do not go down over time if projects are wholly unique.
- Manufacturing the structure enables manufacturing everything else.
- More value change equals more complexity and decreases margins.
- Agency over design is critical.
- Custom fabrication has no cost advantage.
- Standard products in small batches limits efficiency.
- Designers struggle against standardised products.
- Qualitative factors are great, but cost is what counts.
- Parts are commodities. Connectors are IP opportunities.

- Smart connectors offer massive labour reduction potential.
- Manufacturing the part: doubling a batch size yields cost reductions with every doubling – 20% saving per doubling.
- Assembling the building: smart connectors displace assembly labour – 10-90 x throughout.

Samuel Jordi (Implenia): Customer-focused real estate products

Working with Implenla, one of Switzerland's leading construction and real estate services provider, Samuel Jordi discussed customer-focused productisation. This was presented through examples from Implenla's qualitative research into prospective aged care development from the view point of the future end-user. The focus of this presentation was on simplicity, adaptability and circularity of the product, with an emphasis on starting with the customers.

Key insights

- There is a difference between project process (traditional construction) and product process (industrialised construction).
- There are benefits to engaging early with the end-users and stakeholders.
- A customer-centric mindset is critical and prototyping is a valuable tool for customer design engagement.

Key benefits of the product approach

- Fast and scalable.
- Reduced risks per project.
- Economies of scale.
- Consistent high product quality.
- Measurable sustainability.
- Variability achieved through configuration.

Basil Starr (Palari): Modular residential construction customer-centric approach

Palari is proposing the first 3D printed net-zero energy community in Palm Springs, using designs based on modular panels that allowed a construction period of four days per house. This concept was extended to the design of customised ADUs with solar panels and battery back-up and a focus on healthy, holistic living.

Key insights

The benefits of 3D printing and automated production processes include the following:

- Fewer materials.
- Use of recycled materials.
- A production process that produces only 1% of waste when compared with the traditional construction of a wall envelope on site (based on BuroHappold).
- Homes that can achieve a net-zero energy consumption by installing solar panels and battery storage (pre-construction analysis from testing by BuroHappold).
- Questions remain with regards to commercialisation and scalability of 3D printing for mass housing solutions.



Christoph Marquardt: Build better with Haas Fertigbau

Christoph Marquardt's 12+ year passion for construction processes, lean construction and digitalisation led to the 'Haas Haus Konfigurator', an online digital platform that allows customers to configure a buildable home with a fixed price from a kit of digital model parts.

In line with many Building 4.0 CRC partners' digital focus, the Haas 'Better bau' online configurator demonstrated the power of:

- A customer friendly interface focused on usability.
- Digital construction files that can integrate cost information.
- Data that can be extracted, related to users.
- The need to interface with proprietary BIM software (Autodesk Revit).
- The opportunity of proprietary BIM-to-manufacture software link to the point of production.
- Further potential lies in additional interconnection between production and (material/ product) suppliers (identified as ERP-System), opening ip potential platform business dynamics.
- Calculation tool linking the Haus Konfigurator to the production ERP-System to facilitate mass extraction for immediate costing of the client's preferred design.

Key insights

- 13% of Haus customers in Germany and 9% of their customers in Austria were reported to have used the Haus Konfigurator.
- Users of Konfigurator reported to have reached 72,000 world-wide.

Lessons learnt

Christoph identified the following lessons from developing the Konfigurator:

- A digital 'result' must begin with a completed vision or design.
- Not all colleagues have the same ability to imagine a digital solution.
- Not all details can be planned in advance.
- Agility is key.
- Assumptions are useful but may need to be revisited later.
- The digital process takes time.

Session 2

Speakers: John Fay (Founder and CEO, Lada Cube), Giulia Scagliotti (PhD Candidate, Stanford University), Emanuel Heisenberg (Founder and CEO, Ecoworks) and Prof. Jennifer Whyte (Professor Project Management, University of Sydney)

John Fay (Lada Cube): 2 x 4 of the future

John Fay introduced Lada Cube, a building product company looking to transform how building materials are used. The company's main product is a modular wall system (a wall cassette 'kit of parts') that can be used for short-term fit-outs or permanently, resulting in sustainable outcomes through longevity and reusability. The talk highlighted many benefits of productisation, especially cost and delivery certainty, and the potential for building products to be part of a circular economy.

Lessons learnt

John identified the following lessons over the past 10 years of production:

- Productisation is the translation of a one-off design into a scalable and repeatable system of standards and processes.
- The benefits of productisation include speed of delivery, higher precision, less risk, improved costs (65% reduction of costs predicted) and reduced variability.
- Affordability is considered the 'Holy Grail' of construction, productisation of buildings is part of the solution.
- A productised 'kit of parts' is a sustainable system that falls between traditional 'stick-built' construction and modular furniture systems. Kit of parts require minimal skilled labour for assembly and may include reusable components.
- Lada's business model includes direct sales, education (certification), installer networks (partnerships), licensing, resellers, financing (loan options) and a buy-back program.
- Digital processes include data in (building plan) – conversion to Lada script with breakdown into standardisation (analysis), panel and part, fabrication (automation) and workflow productisation – and data out – invoicing, costing, digital fabrication files, BOM Inventory Management, assembly instructions, construction documentation).

Giulia Scagliotti (Stanford University): Enabling circularity with industrialised construction: Lessons learned from case studies

Giulia Scagliotti's research focuses on the intersection between industrialised construction, circularity and sustainability.

A key insight gained from examining two case study IC companies – one in Europe and one in the Bay area – was the value of disassembly (essential to circularity). Giulia suggested this could be better facilitated by keeping technical systems such as services, structure and skin



separate and easily accessible, and planning and testing disassembly during the design stage. A novel aspect of this research was the proposed introduction of a material and system 'passport'.

Key statistics

- More than 540 million tons of demolition debris are generated in the US every year (EPA, 2018). This waste generates the same amount of embodied carbon as all the people of California over the same time period.
- Many buildings are being prematurely demolished. The main reasons for demolition included the area (site) being required for redevelopment (35%); the building is no longer suitable for the needs of owners (24%); and a lack of maintenance (24%).
- 80% of the products' environmental impact is influenced by decisions taken at the design stage.

Emanuel Heisenberg (Ecoworks): Social renovation for net zero

Emanuel Heisenberg presented his company: Ecoworks, a Berlin-based, climate-focused building contractor start-up. Responding to the need for the property sector to decarbonise, the Ecoworks approach is 'serial renovation' – to transform Germany's existing and often historic building stock to a 'net-zero' efficiency standard, while simultaneously reducing CO² emissions generated in the building construction sector.

Ecoworks scans existing buildings using digital laser scanning technology and then imports results into the Ecoworks BIM-based software. This process facilitates the digital planning of new skins. The new digital designed elements are provided to the factory via BIM, creating a modular building envelope made of components designed for assembly. The new building components – which to date have included facades, roofs, windows and MEP (mechanical, electrical, plumbing) elements – are constructed in the factory using bio-based materials. Complete building elements are installed on site using cranes.

Key statistics

- 46% of apartment buildings in Germany currently require renovation works that include energy efficiency upgrades.
- Ecoworks 'serial renovation' approach is reported to have moved up to 80% of work from the construction site to the factory.
- Renovations completed to date have achieved 'energy plus' efficiencies (Hameln, Kuckuck).

Resources:

- <https://ecoworks.tech/>

Keynote 2 – Prof. Jennifer Whyte (University of Sydney): Lessons from recent construction innovation and industry transformation

Prefabrication has a long history in Australia. It's not that we can't do it. We can do it – and we can do it better than we did 50 years ago.

- Prof. Jennifer Whyte -

Building 4.0 CRC tour delegate Prof. Jennifer Whyte presented the Second Keynote Address. Her presentation focused on her engagement in the UK Government's Digital Transformation of Construction programmes, which involved re-orienting a low-tech, low-cost, conflict-driven industry to a high-tech, high-value, collaborative working environment.

Key insights

- The digital transformation of the construction industry requires a different relationship with the research base and a rethink of the way government, industry, and academia challenge each other.
- The Transforming Construction Network Plus initiative – was one such example that focused on bringing together construction, manufacturing, energy, and digital industries. It was significant in connecting and transforming the research base, particularly the way academics engaged with industrialised construction.

Lessons learnt

Jennifer focused on three UK-based business models for Design for Manufacture and Assembly (DfMA) that highlighted the UK's digital transformation process:

- HTA Design (Architects) and their dedicated volumetric supplier who constructed the highest steel framed volumetric building in the UK at the time.
- Laing O'Rourke, one of the pioneers of DfMA in the UK that has worked systematically on improving their operations and production lines.
- Bryden Wood, an architectural firm that has supported government to develop product and digital platforms, publishing the results of their work in accessible open source publications and websites.
- Project ecologies, specifically human, technical, and material resources and competencies were identified as key challenges for the future of industrialised construction.

Resources:

- <https://www.ukri.org/publications/transforming-construction-challenge-brochure/>
- <https://www.hta.co.uk/>
- <https://www.laingorourke.com/>
- <https://www.brydenwood.com/>

Session 3

Speakers: Dr Duncan Maxwell (Director, Future Building Initiative, Monash University; Building 4.0 CRC Program Lead), Dr Fope Bademosi (Autodesk Research), Tyler Pullen (Senior Technical Advisor, Turner Housing Innovation Labs) and Lars Pettersen (Design Manager, Skanska Sverige AB Automated Construction)

Keynote 3 – Dr Duncan Maxwell (Monash University): Industrialised Building: the Standard of Architecture

Building 4.0 CRC tour delegate Dr Duncan Maxwell (Monash University) delivered the Third Keynote Address. His presentation considered the role of design in creating and defining new industry practices and 'standards'. The talk considered how standards (and by extension, Industrialised Building) are often approached from a technical viewpoint, and the opportunity for architecture and design to define new building products and working systems. However, as with Jennifer Whyte's talk, Maxwell conditioned that interest in Industrialised Building is by no means new, and therefore we must work collaboratively to establish a new industry.



There must ... be a fundamental change to construction practices ... only the industrialisation of all necessary building elements ... will lead to a comprehensive solution to our current housing problem...

- Walter Gropius, 1926 -



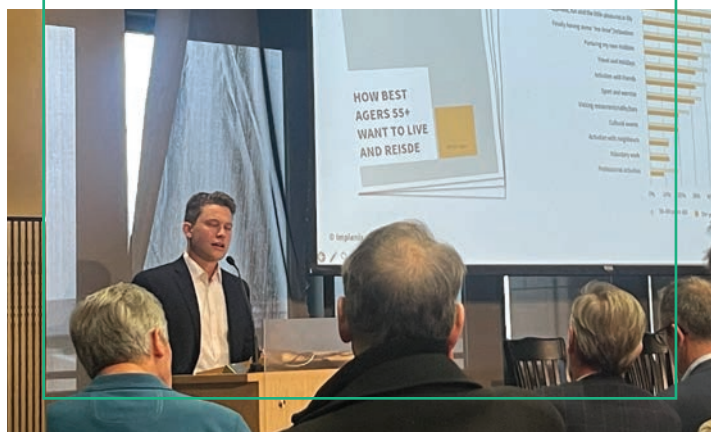
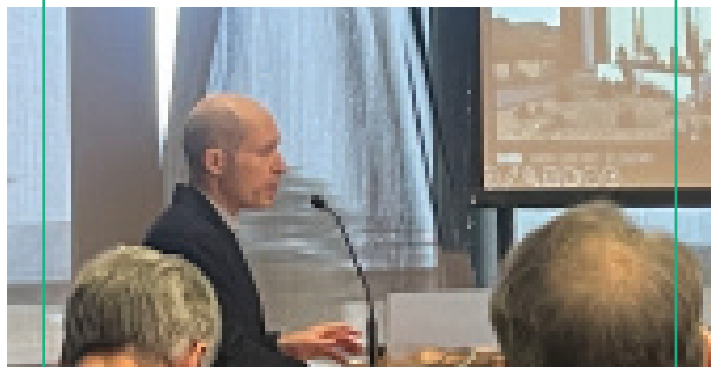
Key insights

- Change is difficult – some inspiring initiatives from the past are still waiting to be realised, whereas others that were produced set up a legacy of failure that can be hard to overcome.
- Design – and the power of 'front-end' decisions hold the potential for realising change and empowering the whole supply chain. This holistic perspective is considered central to creating new, improved solutions for successful industrialised construction.

Lessons learnt

Research projects being explored at the Future Building Initiative through Building 4.0 CRC were presented, including:

- Long-span low carbon floor systems that looked at product selection complexity (in collab. with LL Digital & SFAU).
- An investigation of the bathroom pod as a way to understand the implications of introducing volumetric 'product' in project settings (in collab. with LL Digital).
- A review of project flow to determine how construction may be improved by introducing DfMA and lean construction (in collab. with LL Digital & AG Coombs).





Dr Fope Bademosi (Circular Economy and Construction Researcher, Autodesk): The future of the built environment is Industrialized; **Tyler Pullen (Turner Housing Innovation Labs):** Driving industrialized construction innovation at Turner(s); **Lars Pettersson (Skanska Sverige AB):** Reinforcement – On job-site automation

The last 3 speakers offered insights into:

- Technical innovation, product and software needs for Industrialised Construction (Autodesk).
- Research at the Turner Center for Housing Innovation (UC Berkeley) and its independent, not-for-profit complement, the Turner Labs, including a presentation of the Tanah Project.
- Realised experimentation in on-site automation in laying reinforcing for bridge construction.

The broad aim of the Turner Labs' Builders Lab is to .. provide some sense of truth and sanity to the world of IC, where I think there are a lot of overblown claims but also misunderstandings on all sides..”

- Tyler Pullen -

Lessons learnt

- Policymakers can take steps to support Industrialised Construction projects and move them closer to feasibility. Steps such as reducing impact fees (US), increasing permissible number of units/site by 25% and reducing parking requirements were identified as having the potential to reduce 'hard' costs by 10% (Tyler Pullen).
- Automated construction (identified as high volume, low mix, serial production with repetitive 'robotic movements' that have the potential to be carried out by programmed robots) can result in more efficient construction (Lars Pettersson).

Key challenges

- Crossing the knowledge silos between professions.
- Testing and prototyping (identified as capital and time intensive), but important to support innovation.
- Valuing innovation (not just invention).
- Earning (and keeping) trust as a key feasibility support.
- Careful calculation of robotic movement to achieve success in automated construction.



DAY 5: PALO ALTO

Visit 1 – GOOGLE R+D

Location: 641 Baltic Way, Sunnyvale, CA 94089

Hosts:

Phil Williams (Director, Design Build Construction)

Michael Tymoff (Director, Real Estate District Development)

No photography or recording was permitted during this event.

Visit 2 – Stanford University Knowledge Share

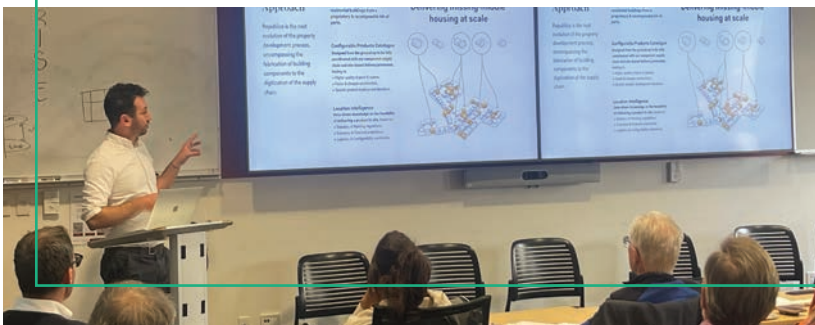
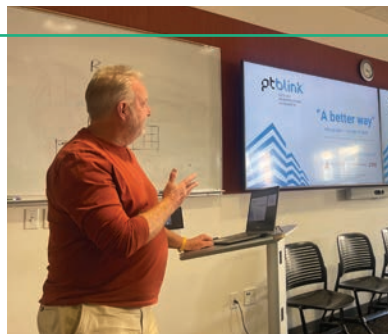
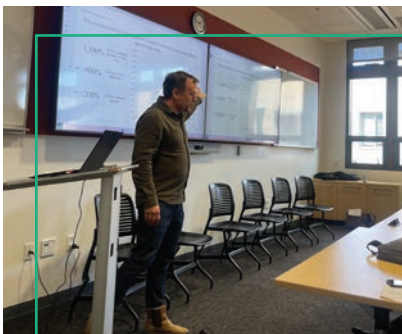
Hosts:

Prof. Mathew Aitchison (CEO, Building 4.0 CRC)

Adj. Prof. Jerker Lessing (Civil and Environmental Engineering, Stanford University)

Dr Daniel Hall (Assistant Professor, TU Delft)

The Knowledge Share session featured an array of presenters from the building and development industry and venture capitalists. Each presentation highlighted and disseminated experiences and insights across global projects and organisations.



Industry Presentations

New Avenue Inc (ADU), Kevin Casey (Founder and CEO) – New Avenue Homes follows a system-led and team-based approach to design and build new housing including ADU's. This process re-invents houses as complexes of two or more homes that encourage family, community and health.

- The company has successfully reinvented US\$350 million worth of housing. The organisation investigated establishing in-house creative control as well as full financial control to create an integrated ecosystem.
- Politics, zoning laws, building permits and regulations have a significant impact on ADU trends.
- **Resources:** <https://www.newavenuehomes.com/>

Sustainable Living Innovations (SLI), Arlan Collins (CEO and Co-Founder) – Sustainable Living Innovations provides a patented panelised building system for the multi-family residential market. It mainly focuses on delivering affordable housing solutions while meeting global sustainability standards.

- The company manufactures high performance building panels designed for rapid and efficient onsite installation. The building construction system can be highly repetitive and scalable.
- SLI is delivering the world's first Net Zero Energy (NZE) multi-family tower – 303 Battery. This project has already been audited and pre-certified by the International Living Future Institute under the Living Building Challenge.
- Initiatives to enhance this project's sustainability include reduced energy and water consumption reduced tower weight to lower embodied emissions, and use of factory-assembled panels to minimise material waste.
- **Resources:** <https://sli.co/sustainability>

“ Design something to be built in a factory
and nowhere else, not the other way around... ”
- Arlan Collins -

The Neutral Project, Nate Helbach (CEO and Founder) – This project aims to revolutionise sustainability-led real estate development.

- The project incorporates innovative construction technologies and practices such as eco-friendly materials, and adherence to Passive House standards to deliver low-carbon structures.
- It is an approach to redefine sustainability through structures that facilitate sustainable communities, sustainable development and sustainable investing.
- **Resources:** <https://www.theneutralproject.com/>

System Build, Santiago Ossa (Co-Founder) – System Build aims to revolutionise project estimation and requests for proposal (RFPs) for prefab and offsite construction manufacturers.

- System Build uses novel technology and artificial intelligence to create an efficient proposal process. It aims to overcome the difficulties in responding to clients' RFPs.
- Although the main requirement is to standardise the process of construction, every company is trying to build a niche market.
- **Resources:** <https://systembuild.io/#>

Industry Presentations

Whoosh, Alastair Porter (Co-Managing Director, Porter Group Ltd; tour delegate) and Jeral Poskey (CEO, Swyft Cities) – Whoosh is a transport solution that aims to deliver personalised point-to-point transportation using smart electric vehicles via a light, flexible elevated cable, and a rail network.

- It is an on demand, low impact, direct route and low-cost transportation solution. It aims to reduce embodied emissions by replacing concrete with steel and cables. It intends to use low embodied carbon materials for stations and stops.
- A fully operational prototype system has been developed, with a pilot project being progressed in Queenstown (New Zealand).
- Whoosh anticipates an 85% reduction in energy use compared with a typical bus or rail system.
- **Resources:** <https://whoosh.solutions/>

PT Blink, Murray Ellen (Founder; tour delegate) – PT Blink provides a construction software and marketplace to allow flexible, offsite manufacture and onsite integration of multi-storey buildings. It aims to deliver faster, safer, better, less waste construction solutions.

- The Fells Apartments was a project undertaken by PT Blink, where seven floors of the superstructure were built in 11 days. Its total project time was reduced from 16 to eight months.
- The Blink DMI platform uses a digital twin to serve as a single source of truth throughout the development and into the operational phase of the building.
- **Resources:** <https://ptblink.com/dmi-platform/>

Donovan Group, Kyle Donovan (Director and CEO; tour delegate) and Brett Donovan (Director and CRO; tour delegate) – The Donovan Group and Utexture provide the construction professional community with an easy-to-use tool that allows rapid alterations and personalised designs in real-time.

- Customers can instantly view the visual and cost impacts of design changes. The tool can provide accurate and precise take offs, and produce sales plans, specifications, quotes and material schedules.
- Utexture is looking into innovative methods of integrating carbon reduction methods at every step of pre-construction.
- **Resources:** <https://utecture.com/>

AR-MA/Republica, Daniel Fink (Founder / Associate; tour delegate) – AR-MA/Republica provides an advanced computational design and architecture solution through an integrated approach.

- AR-MA focuses on a design for manufacture and assembly approach, which includes the development of a kit-of-parts systems, to optimise material usage, followed by the planning of the assembly process.
- They design to deliver construction projects and processes that are streamlined, with minimised waste, and higher quality and affordability.
- **Resources:** <https://www.ar-ma.net/>

Sightdata, Jay Humble (Co-Founder & Tech Lead; tour delegate) – The Signa construction safety solution automatically identifies safety incidents and hazards on a construction site in real time.

- Its primary aim is to increase safety performance within construction sites, empower EHS professionals, and reduce construction project risks.
- This innovative solution is easy to use, provides real time risk alerts, produces site safety reports, safety control assessments, preservation of workers safety and secure data. It uses vision, machine learning, heatmaps and PPE detection to carry out its activities.
- **Resources:** <https://sightdata.ai/>



Brick and Mortar Ventures, Alice Leung (Vice President, Platform and Product Strategy) – Bricks and Mortar Ventures identify and invest in emerging companies developing innovative software and hardware solutions, focused on sustainability, regulatory changes and carbon accounting. They seek to grow entrepreneurial groups that are disrupting design, construction and maintenance of the built environment.

Blackhorn Ventures, Dr Raymond Levitt (Operating Partner) – Blackhorn is a group of entrepreneurs, investors and operators investing in start-ups whose solutions aim to support decarbonisation and increase resource efficiency throughout all phases of buildings and infrastructure. Funds focus on transport and mobility, supply chain logistics, energy and the built environment, and digital transformations. Raymond served on the Faculty of the Department of Civil and Environmental Engineering in Stanford from 1980 until 2017. He founded the Global Projects Center (GPC), which develops new financing, governance and organisational approaches to strengthen the long-term financial, environmental and social sustainability of projects.

Austrade Landing Pad, Sunil Joshi (US Expansion Director (SF Landing Pad)) – The San Francisco Landing Pad helps Australian tech scale-ups prepare to enter the US, providing guidance on marketing, fundraising, legal and accounting, HR and an access to a network of mentors. The initiative includes the US Export Acceleration bootcamp, designed to give founders an understanding of the foundations needed to build a US go-to-market strategy.

Plug n Play Ventures, Leonardo Rocchetti (Ventures Lead Built Environment and Deep Tech) and Elana Ruiz (Global Ventures Lead for Real Estate Tech) - Plug n Play Ventures is an international early stage venture capital firm. In its Real Estate and Construction vertical, the group has partners with 16 organisations and accelerated more than 250 start ups, 215 of which involved seed funding. AI, workforce and financing were identified as the three dominant trends in the industry.



DAY 6: TRACY, CUPERTINO, MENLO PARK



Visit 1 – Tour of Volumetric Building Companies

Location: 2302 E. Paradise Rd, Tracey, CA 95304

Host: Jennifer Dormiani (Director of Operations, VBC)

Resources:

- <https://www.vbc.co/>

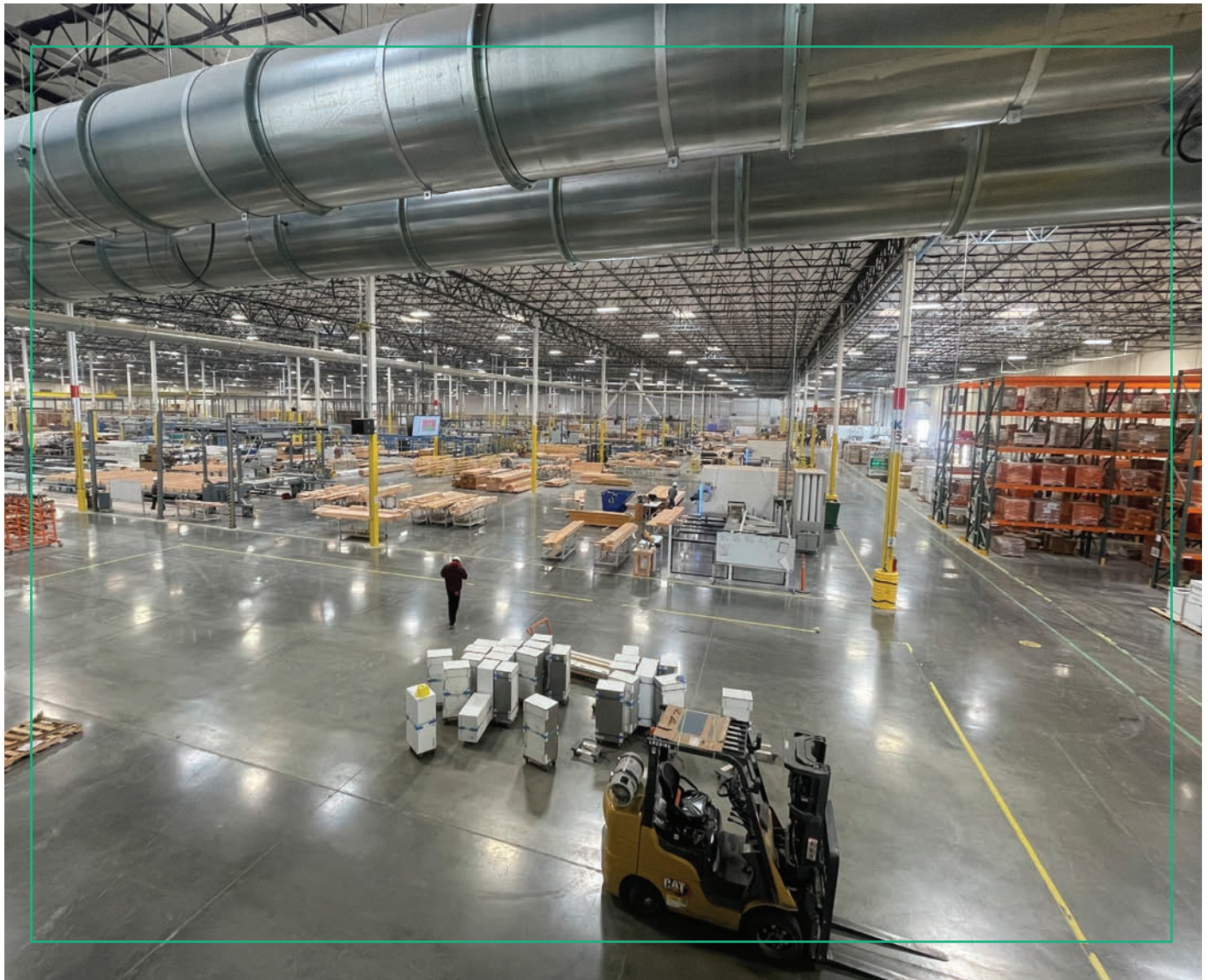
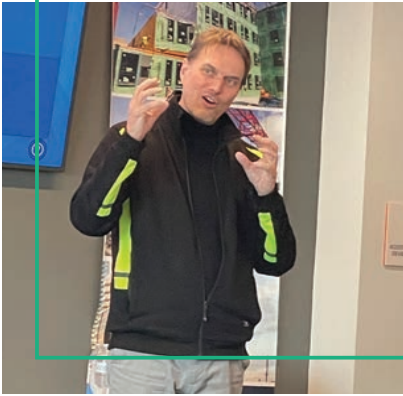
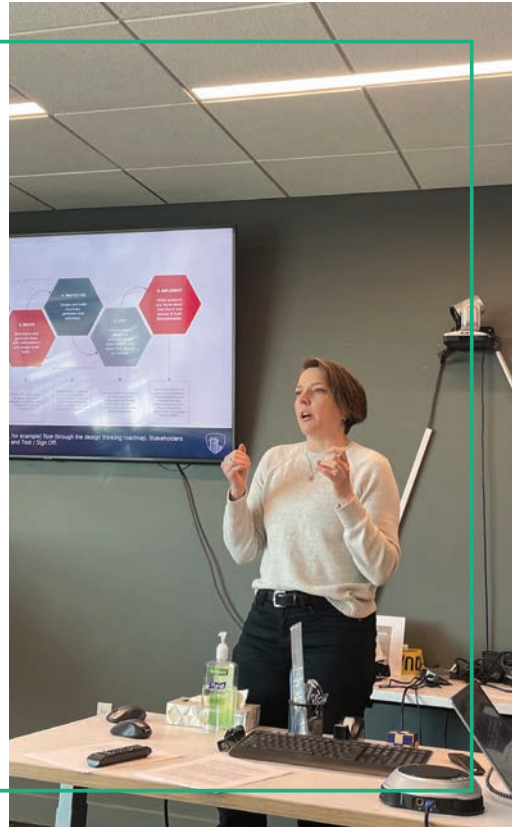
No photos were permitted while delegates were on the factory floor, however photos were permitted from the first floor balcony and inside the prototype dwelling located on the factory floor.

The visit to the Volumetric Building Companies' (VBC) Tracy factor was of particular interest to many delegates as it was previously the home of Kattera's most automated manufacturing plant. VBC purchased the Tracy factory in 2021, marking VBC's expansion into the West Coast market for volumetric modular manufacturing – a 600,000 sq ft (55,742 m²) factory with the capacity to manufacture 25,000 sq ft (2,323 m²) of housing per week on a single shift.

After a preliminary site briefing, delegates inspected the factory floor including a completed and fully fitted prototype dwelling that had been shown in multiple trade shows around the US.

Key insights

- Current order sizes vary: big orders are defined as 400 modules or more and small orders from 75 to 100 modules. The size of projects ranged from low rise to medium rise buildings.
- The location of projects is an important criteria in the evaluation of the viability and cost-effectiveness to VBC and the client.
- Production is running at four units a day, with a view to lift to eight a day by August.
- Developers are the end customers.
- Certification is achieved by tagging each completed unit and providing electronic access to the associated data certificate. This approach facilitates mandatory on-site inspections, specifically final inspections that impact issuing the final certificate of occupancy by QCs (building surveyors) working in a variety of jurisdictions.



Visit 2 – ADU in situ

Location: Pleasanton CA
Host: Kevin Casey, Founder and CEO, New Avenue Inc

The delegates viewed an ADU on site, which was being fitted out at the time of the visit. The ADU project involved the reinvention of an existing garage into a new residential dwelling.

Visit 3 – Apple Visitor Centre

Location: 10600 North Tantau Avenue, Cupertino, CA 95014

Resources:

- <https://www.apple.com/retail/appleparkvisitorcenter/>

The new Apple Visitor Centre allowed delegates to engage with the latest digital visualisation technology. A blank model of the surrounding Apple precinct could be viewed and explored in 3D (with animation) using tablets referencing the associated interactive digital building information.



Visit 4 – Goldbeck House

Location: Menlo Park
Hosts:
Tim Schoenheit (Senior Innovation Manager)
Andre Brueck (Innovation Manager)
Stefan Gehder (Senior Innovation Manager)
Resources: <https://www.goldbeck.de/en/>

Our visit to Goldbeck was a fitting end to the research tour, with our hosts bringing together the themes of supply chain, BIM, venture capital and innovation.

Key insights

- Goldbeck is a private company founded in Germany in 1969 and now operates in 111 locations worldwide.
- Goldbeck has grown from a steel manufacturer to the largest family company in the German construction industry.
- It currently operates out of 30 factories across Europe and the US and employs over 2,500 architects and engineers.
- Goals of sustainability, building excellence and future orientated construction technologies have been its core drivers since its inception. These goals influenced the early adoption and ongoing development of BIM and other digital technologies, as well as uptake of new and emerging digital technologies.

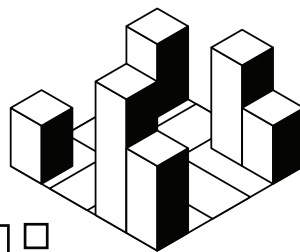
Key takeaways

- Contentment vs conflict of interest – Presenters spoke of their ongoing assessment of suppliers and how they approached conflict when there were health or environmental issues associated with suppliers or their products. The Goldbeck approach is to fix the problem rather than pass it on to others to solve.
- Research projects are a key focus, including research into energy.

Closing address by CEO, Building 4.0 CRC Prof. Mathew Aitchison

1. After several years of problems, 2024 is “the year for solutions”. There are solutions we can try to address the global issues plaguing housing supply and affordability, but they still need development. This is a long way from the defeatism, chauvinism and parochialism that often pervades debates all around the world. Importantly, we can learn from the costly mistakes of others.
2. The Australian building innovation scene is at, or above world standard. Our companies, our institutions, our thinking and our research infrastructure are what is required to change the industry.
3. As a country, our size, system of government and our societal structures are not a problem, they are an opportunity. Consider the 19,000 local jurisdictions in the USA and the difficulties in bringing new products and processes to market.
4. The time is right to push for a better way. What we saw on this tour shows if we can support each other (and not go it alone) we will be successful. We had all the ingredients on this tour that we need to make the critical difference.
5. Don't forget design! And don't forget the people! All our efforts will be for nil if people don't love, delight and embrace what we do. While we don't often hear it talked about, there is a shadow side to industrialisation, one that can lead to poor quality and an impoverished view of what design and good building can bring. We should be clear in stating that this is not our collective path.





building 4.0 crc



Australian Government
Department of Industry,
Science and Resources

Cooperative Research
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