CONCORE TŪHURA

Civil construction: a requirement for a robust and reliable training pipeline

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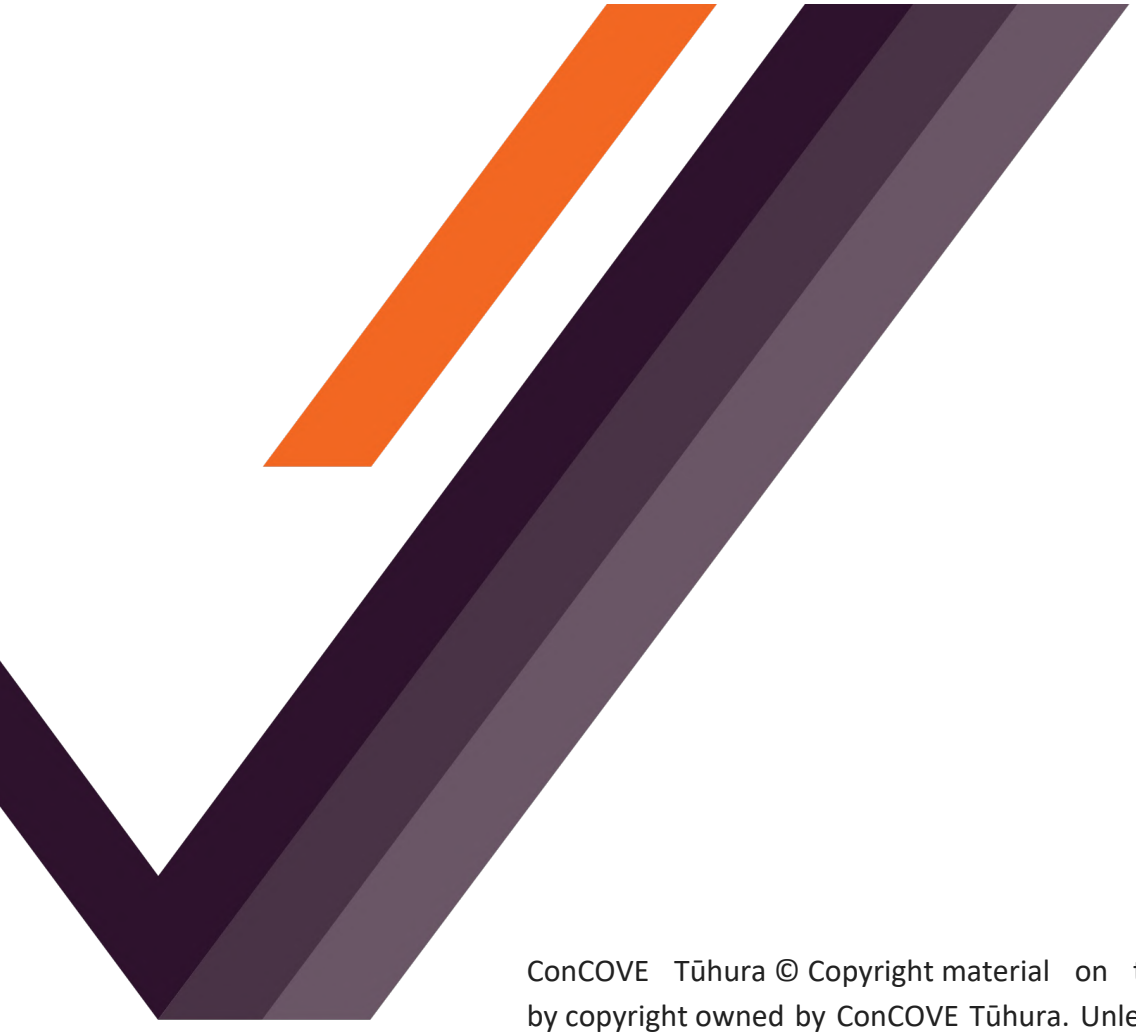

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The problem: a shortage of skilled workers in civil construction

Shortages of skilled labour are a persistent and recurring problem in the New Zealand civil construction industry, posing constraints in periods of growth for decades. This is of pressing concern given the current infrastructure deficit and a growing pipeline of work initiated to address the shortfall. Construction accounts for around 80% of the costs to build and maintain infrastructure. When the civil and heavy construction sector struggles to expand to meet demand, projects face cost overruns, or are deferred and delayed.

This report focuses on the issues driving a shortage of skilled civil construction trades workers and heavy machine operators and provides conceptual solutions and recommendations to address the problems identified. Civil infrastructure is of vital strategic importance for New Zealand's future. There is likely to be a substantial crossover of skills between horizontal (civil construction) and vertical (building and residential) construction, so improving training provision for horizontal construction will benefit the construction sector as a whole.

While the education pathway for civil engineers is generally well serviced by the tertiary education sector, the training pipeline for civil construction workers and tradespeople is less established. This pipeline has failed to keep pace with growth in the sector, resulting in labour shortages at their highest levels in decades. This shortage will be compounded as the current workforce continues to age. Skills are concentrated in older workers and retirements are removing skills and experience faster than the next generation is being trained. Furthermore, labour productivity in horizontal construction is lagging behind vertical construction, exacerbating the infrastructure deficit. A poor training pipeline for civil construction, chronic skill shortages, and a lack of adoption of new technology may be suppressing productivity growth in the sector.

Shortages can lead to reliance on temporary, untrained, or unskilled workers to fill gaps, reducing productivity, impacting quality, and posing safety concerns. Productivity in infrastructure construction hinges on skilled personnel; it requires teams with expertise who can handle costly and sophisticated equipment. However, low worker productivity creates a negative feedback loop. It necessitates significant labour allocation to projects and justifies low wages, which incentivises long hours and significant amounts of overtime. However, these factors have been shown to further reduce worker productivity, reinforcing

the cycle.

The pressing skills shortage shows that the current training provision in horizontal construction is inadequate. A number of training initiatives have taken place to address this, operated by a diverse array of government agencies, local authorities, NGOs, and industry trainers. However, these are small-scale trials, generally happening in isolation over a limited time period and heavily dependent on the motivation and energy of the individuals and organisations that initiated them. Without a comprehensive and organised system for education at scale, the majority of training for civil construction occurs on-the-job in small numbers, as most projects do not support a large proportion of trainees. Capital equipment and material costs are generally substantial and worksites are subject to a high degree of health and safety risks that are particularly exacerbated for novice employees.

The access point for new entrants to the industry is unclear, which compounds the already tight labour pool. Potential civil recruits acquire few relevant skills or experience during their schooling and there is a general lack of awareness of civil construction as a career path. Employers frequently rely on informal networks, or through trialling individuals from labour hire companies, as their most reliable methods of finding suitable new entrants. These methods can be inefficient at the industry level, and the reliance on informal networks in particular can reinforce ethnicity and gender imbalances in the construction workforce.

Low gender diversity also implies that the industry is missing out on potential employees. Although improving, the proportion of women in trades and civil construction is still extremely low. Cited reasons include inflexible and long work hours, a lack of awareness of civil construction as a career for women, and a potentially hostile or discriminatory work environment.

Migration may not alleviate the skill shortage. New Zealand companies are in an international competition to attract skilled migrants and retain domestic talent, with net outflows of construction personnel for the majority of the last 50 years. Recognition of skills obtained overseas can be difficult and current New Zealand immigration settings pose challenges for the upskilling of migrants. Construction firms tend to turn to migrants when the domestic labour supply is constrained, and in specialised civil infrastructure roles that may not exist locally. Migrants can facilitate expansion by reliving pressure on internal trainers and site supervisors during period of growth. However, COVID-19 demonstrated the vulnerability of relying on international migration to fill domestic skill shortages.

Fundamentals behind the problem: an underinvestment in training

High costs: The process of training a skilled civil construction worker is especially capital and time intensive. Equipment is generally large, specialised and expensive, and work often has high material requirements. Evidence from apprenticeship programs shows that firms are less willing to train when the payback period on their training investment is long, which is particularly the case for firms with high skill requirements. This could explain the lower uptake of apprenticeships in horizontal civil construction as compared to vertical building construction in New Zealand.

High costs also pose barriers to training for small firms, and this is exacerbated by layers of sub-contracting. Small firms are less able to spare the time or capital equipment to train recruits, while the further down the chain of sub-contracting, the lower profit margins generally become, reducing the capacity and the appetite for training. Small firms may lack the diversity of work required for apprentices and trainees to fulfil specific qualifications. These factors naturally create a shortage, as larger firms will not train an excess of workers for the small firms to draw on.

Signalling problems: Interacting with an individual through on-the-job training is one of the few methods available to horizontal construction firms to determine if a new trainee will be 'good' or 'bad'. With high training costs, high operating costs, and a high degree of hazards, civil construction firms face significant losses if a new employee turns out to be unreliable, unmotivated, or unsafe. An employee's attributes are generally not observable by the firm prior to the decision to hire and train. Firms must rely on 'signals' of an employee's quality, with the current focus being informal signals such as word-of-mouth referrals and trial employment through labour-hire companies to find new recruits.

While there are pathways for civil engineering recruits through tertiary education, civil trade pathways are minimal. It is notable that the 'signal' of a tertiary education qualification is generally not utilised by industry to assess the suitability of a potential recruit. There is relatively limited engagement between polytechnics and the horizontal construction industry and employers generally do not trust the tertiary education system to deliver on their needs. Tertiary education courses are mostly used for compliance purposes and to demonstrate current competencies, rather than as a source of new labour.

Matching frictions between employers and potential employees: Significant matching frictions exist in the labour market for civil construction trainees. Industry reports that potential recruits are often not 'work-ready', and that there is a substantial disconnect between the expectations of new

entrants and the expectations of employers in regards to working conditions. This could be driven by labour-intensive models of construction, relying on long and inflexible shifts, unsociable hours and six-day work weeks. This precludes a match with individuals who desire part-time work or who have other responsibilities such as caregiving.

Gender disparities also persist, with frictions on both sides of the workplace pairing. On the employee side, a lack of awareness of construction and civil infrastructure as a career for women reduces the number of women recruits who enter the search. For employers, job-sites, roles, and workplace cultures have historically coalesced around masculine stereotypes which reduces the likelihood of finding a 'match' with individuals from outside of this group.

An uncertain project pipeline: An uncertain pipeline of work is commonly cited as a reason for underinvestment in training by civil construction firms. In response to this, estimates of future building activity and workforce requirements have been developed by several government ministries and departments. However, individual firms do not know if they will be awarded these future projects, reducing their willingness to train additional employees. A multi-skilled trade professional can take more than five years to train. By the time a contract has been awarded, it may be too late to commence large-scale workforce training. Due to high costs and long training schedules, individual firms considering recruitment focus on their own project pipeline, not the pipeline of the industry as a whole.

Lowest cost procurement exacerbates this issue. On-the-job training to meet future requirements increases the costs to deliver current projects. Clients are often unwilling to bear this cost. Competitive tenders, that do not specify training requirements, result in the cutting of skill development to reduce expenses.

Poor incentives in the current education system: There is a trust gap between industry and the education system, with employers not believing that the system meets their needs. Closing the gap requires the education process to both transform unskilled individuals into skilled workers, and to filter out those individuals who are unsuitable for roles in the industry. The current system is overly focused on the former, where 'Industry needs' are translated into assessment criteria with an associated qualification awarded to any individual who passes these assessments. However, the bureaucratic nature of the education system, a focus on course completion rates, and a binding of funding to enrolment numbers and retention, has produced incentive structures that prioritise getting large numbers of students through

education programs, with failure and drop-outs being minimised as much as possible, rather than been seen as part of the process of screening for suitable recruits. The education system is in a tricky position. Low failure and drop-out rates could signify that the provider is excelling in learning support and pastoral care, which are vital parts of the education process. However, it is also essential to recognise that not everyone will be suited for, or capable of excelling in, every course. Upholding the integrity of assessments is crucial to ensure that qualifications remain reliable markers of an individual's capabilities and job suitability.

There are few entry requirements for civil trades education programs, meaning that no pre-screening is taking place. However, learners are also provided potentially extreme numbers of chances to repeat assessments, meaning that minimal screening takes place as part of the education process. This can exacerbate the trust gap, as the qualification no longer becomes a useful signal of an individual's quality. Without a trustworthy external qualification, many civil construction firms rely on internal competency assessments. These can become highly firm-specific, resulting in repeated assessments every time an individual changes employer, despite significant overlap of skill requirements. This negatively impacts productivity, recruitment time, and worker job mobility.

Furthermore, the philosophy of many employers is that qualifications are to recognise skills gained through on-the-job work and training, rather than a prerequisite to employment acquired at a tertiary institution. While this perspective acknowledges qualifications as evidence of competency and suitability for employment, it also suggests a singular valid approach to skill acquisition: on-the-job training. This can exacerbate the trust gap between the industry and tertiary education, because tertiary institutions are definitionally incapable of delivering training that these employers value.

Conceptual training solutions

This report outlines some conceptual approaches to civil construction training. These cover formal and informal learning with both theoretical and practical skill development. This training can take place on-the-job, in campus settings, and through experience in simulators and virtual reality. The training can be part of a commercial construction operation or can be undertaken solely for the purpose of education. Each method has its advantages and disadvantages and a training schedule may encompass multiple modes of learning.

Of particular note is a large off-site campus for hands-on training in civil construction equipment and heavy machinery. The aim is to provide a controlled environment for trainees to learn and practice using techniques and machinery in a safe and repeatable manner. Students can undertake intensive courses with the freedom to make mistakes and learn from experience, facilitating greater skill acquisition in a shorter time. Significant agglomeration benefits exist, with scale allowing advanced facilities and support that would not be economically feasible in smaller or more dispersed operations. Such a site can also provide the base and resources for portable teaching options that provide pop-up training close to where services are desired.

However, a campus requires a high degree of capital investment and ongoing operational funding. The lack of an existing large-scale commercial operation in New Zealand suggests that it is unviable to meet these costs from course fees alone. Civil construction firms in New Zealand, unacquainted with this method, may need reassurance about the capability of educational campuses to replicate an actual worksite accurately. Investigation of the significant employment of such facilities overseas can help provide a suitable template for New Zealand.

Recommendations

There is unlikely to be a one-size-fits-all approach to solving the current skills shortage and skill development of a civil worker is a long-term, ongoing process. However, this report has identified four key areas to target:

1. **Significant and ongoing engagement with industry.** Industry voices need to be amplified and integrated with any proposed solution to the skills shortage. Effective and ongoing communication and collaboration between industry stakeholders, training institutions, and policymakers is crucial to address the industry's needs, especially considering the changing expectations of the workforce regarding working hours and work-life balance.

2. **Substantial and sustained funding at scale** to develop multiple training options. The significant public benefit justifies public funding, either through a transfer from taxation, or an industry-wide levy. Industry involvement in directing these funds towards effective uses is vital. Educational performance should be assessed based on post-study outcomes and employability, to align education outcomes with

industry requirements.

3. **A large campus for training at scale on civil construction equipment and heavy machinery.** High capital costs have been a barrier to investment in education in the industry, and one or more dedicated campuses can help address this issue. They are considered a standard component of training structures in other countries. Industry needs better options for civil training and there is a clear gap in the programs offered by the tertiary sector that misses education on large and complex equipment.

4. **An integrated training pathway**. The large campus would sit inside of an integrated training pathway. Education should move away from isolated projects and disjointed training and focus on civil construction education as a cohesive whole. A pathway is needed which can onboard recruits to civil construction from a variety of sources, backgrounds, and skill levels, and progress these recruits through to the competencies and skills that are in high demand in industry. This could involve several stages:

- **Initial Exposure:** Showcasing high-engagement drivers like simulators and heavy equipment at schools, career events, and community gatherings. Expanding recruitment programs for marginalised communities and emphasising the nature of construction work and potential career trajectories.
- **Work Readiness:** Providing basic skills, experience, and induction courses for individuals with limited skills or those transitioning to employment. This includes site awareness, health and safety, and support for acquiring driver's licenses if necessary.
- **Entry-Level Training:** Offering entry-level training for work-ready individuals either through education providers or on-the-job training. This training would focus on basic skills, teamwork, and health and safety.
- **Skill Development:** Providing ongoing skill growth and development for skilled and semi-skilled individuals. This can involve intensive off-site programs, simulators, on-site education, and apprenticeships.

Engagement and buy-in from industry is necessary at each step of the pathway. Part of this will require screening to take place for individuals not suited to the roles in industry. While this must be sufficient for industry to value and engage with the qualification process, it must not be overly strict or subjective. It should accommodate various learning environments, individual circumstances, and life challenges. Developing multiple pathways for success can help in this regard.

Gender diversity and support for individuals with caring responsibilities should be addressed, along with cultural and social barriers to progression within the industry. Structural remedies should be

developed to ensure workplace training progresses efficiently for all individuals, regardless of their background or circumstances.

Conclusion

This report emphasises the pressing need to address the skills shortage in New Zealand's civil construction industry, which poses significant challenges to growth and infrastructure development. Despite industry concerns about skills shortages persisting for years, little progress has been made. To tackle this issue, effective communication and collaboration between industry, policymakers, and training institutions are essential.

Key recommendations of this report include an integrated training pathway and the establishment of large training campuses dedicated to civil construction equipment. These campuses should align intake capacities with industry pipeline needs. Sustained funding from sources such as taxation or industry-wide levies, should be directed toward effective training programs using significant industry input. By implementing these measures and fostering strong industry partnerships, the civil construction sector can overcome its challenges and ensure a skilled workforce for the future.

1 Introduction

1.1 The problem

Shortages of skilled labour are a persistent and recurring problem in the New Zealand construction industry, posing constraints in periods of growth for decades. Lobo and Wilkinson (2008) document constraints arising from skill shortages in 2004 and 2005, while Chang-Richards *et al.* (2017) state that the 2010/11 Christchurch earthquakes exacerbated existing skill shortages in construction from 2010. Furthermore, every annual Civil Contractors New Zealand (CCNZ) industry survey since its inception in 2017 has cited a shortage of skilled workers as a major concern for industry[1]. This report will: outline the extent of the problem, delve into the structural factors which may be underlying these issues, explore some conceptual solutions for these problems, and conclude with recommendations to improve the situation in New Zealand.

Skill shortages in civil construction are of pressing concern given the current infrastructure deficit and the growing pipeline of work initiated to address the shortfall. A significant increase in the construction workforce is required to sustain growth in the sector. On behalf of the Infrastructure Commission, Sense Partners (2021) estimated a current infrastructure deficit of $104b, with projected underinvestment leading this to double by 2050. Subsequent extreme weather events have highlighted further deficiencies and vulnerabilities in New Zealand's infrastructure, suggesting that these figures are likely an underestimate. Government and councils have begun to address this shortfall, with a large and growing pipeline of infrastructure work[2]. MBIE (2022b) projects steady year-on-year growth in infrastructure investment until at least 2027.

Construction accounts for around 80% of the costs to build and maintain infrastructure (New Zealand Infrastructure Commission, 2022a). When the civil and heavy construction workforce struggles to expand to meet demand, projects face cost overruns, or are deferred and delayed[3]. New Zealand can ill afford constraints on the industry due to skill shortages. Infrastructure projects in New Zealand generally take twice as long to complete than comparable projects in Australia, resulting in significant losses from forgone economic benefits. Torshizian and Maralani (2022) find that the average completion time for infrastructure projects in New Zealand is 15 years, while comparable projects in Australia are completed within 8. Using the Waikato Expressway as an example, the authors show that the delay resulted in

[1] See https://civilcontractors.co.nz/Publications/10901/, accessed 11/05/2023.
[2] See https://www.tewaihanga.govt.nz/projects/search-the-pipeline/, accessed 11/05/2023.
[3] See Lessing *et al.* (2017), Karimi *et al.* (2018), Viles *et al.* (2020) and references therein.

forgone economic benefits of at least $2.3b, which is 1.2 times the capital cost of the project. Torshizian and Maralani (2022) suggest that the key causes of infrastructure delays in New Zealand are uncertainty and delays in decision-making.[4] Delays arising from constraints on the inputs to construction, such as a shortage of labour, are not addressed in Torshizian and Maralani (2022). However, globally, skilled labour shortages are identified as a key cause of construction project delays (Durdyev and Hosseini, 2020). Further delays to major works in NZ due to skill shortages would be costly.

The training pipeline for horizontal construction (civil construction) has failed to keep pace with the growth in the sector. Over the past 10 years, the civil workforce has increased by 23% (MBIE, 2022a), however unaddressed skill and worker shortages have compounded, and this has been cited as the leading challenge for the industry in the last three years of CCNZ industry surveys (CCNZ, 2021, 2022, 2023).

Several small-scale training initiatives have taken place, operated by a diverse array of government agencies, local authorities, NGOs, and industry trainers. However, these initiatives are generally working in isolation, and few have achieved longevity (May and Bryant, 2022). Recognising the issue, a core goal of the Construction Sector Accord is to bring together the industry to develop an Action Plan from the Construction Skills Strategy to ensure that the workforce is developing the skills that the industry needs now and in the future[5]. Part of this action plan is to consolidate approaches and knowledge, reduce duplication across different initiatives, and ensure that a comprehensive training solution is developed that meets the scale required by the industry. However, the action plan does not specifically address civil construction, which may have more complex and intense workforce requirements than the wider construction industry.

To address these training and workforce needs, this report focuses on vocational education and the training of skilled tradespeople and heavy machine operators, in particular for horizontal construction. Civil infrastructure is of vital strategic importance for New Zealand's future. There is likely to be a substantial crossover of skills between horizontal and vertical construction, so improving training provision for horizontal construction will benefit the sector as a whole. The remainder of section 1 explores the problem in more detail. Section 2 explains the fundamentals underlying the problem, while section 3 investigates some conceptual solutions. Section 4 makes recommendations for New Zealand and section 5 concludes.

[4] The authors suggest that these stem from poor coordination among decision-makers, consenting delays, ineffective financing arraignments and the RMA planning process.

[5] See https://www.constructionaccord.nz/transformation-plan/people/, accessed 11/05/2023.

1.2 Construction labour shortages are at record highs

Construction labour shortages are at their highest level since 1975 (New Zealand Infrastructure Commission, 2022b). Over 80% of civil construction firms say skill shortages are a challenge to growth and ~84% would hire today if the right skills were available (CCNZ, 2023). While these numbers have decreased modestly from 2022, (where they were 84% and 87% respectively[6]), they are still at some of the highest levels since industry surveys began in 2017. Modelling from the Workforce Information Platform (WIP) estimates that the construction workforce will need to grow by 35% to meet the workforce demands of the current pipeline of consented work planned for 2025[7]. Expansion on this scale in the short term is infeasible. In reality, consented projects will be deferred. Over the medium term, workforce growth of 30% is estimated to be required for civil construction specifically (May and Bryant, 2022). In the long run, it is suggested that the sector will need to double its workforce to close the infrastructure deficit (Sense Partners, 2021). Without a robust pipeline to deliver skilled construction recruits at scale, such expansion will be exceptionally challenging.

The labour shortage will be exacerbated as the workforce continues to age. Skills are concentrated in older workers, with evidence that retirements are removing skills and experience faster than the next generation is being trained. Although this is an issue worldwide[8], the problem may be particularly acute in New Zealand[9]. For example, historical evidence suggests that New Zealand has been less effective than Australia in attracting, training and retaining young people in trades. This resulted in the New Zealand trade workforce ageing faster than the Australian trade workforce in the 1990s (Haig, 2004). The causes behind this trend are unclear. However, there has historically been a net migration outflow of young trade professionals from New Zealand. Coleman and Karagedikli (2018) suggest that one factor is the change to a points-based immigration system in 1991 which favoured white-collar workers with tertiary qualifications over trades professionals. This change depressed the levels of inward migration for the skilled trades for several decades until 2011 when, following the Canterbury earthquakes, migration settings were adjusted to target construction workers for the rebuild. Combined with strong demand for labour, a significant net inflow was then observed for the first time since the 1960s.

Demographic changes driven by declining birthrates and increased life expectancy are also behind a

[6] See CCNZ (2022).
[7] The estimated workforce in March 2023 is 220k, while the projected workforce requirements in March 2025 is 297k. See the WIP Workforce Supply and Demand Model, https://wip.org.nz/supply-and-demand/, accessed 11/05/2023.
[8] See Albattah *et al.* (2015), Sivam *et al.* (2017), Ojelade and Paige (2020), and Torku *et al.* (2021).
[9] For discussions of workforce ageing driving skill shortages in construction in New Zealand see: Ayodele *et al.* (2022), May and Bryant (2022), and Schiff (2022).

sustained increase in the average age of the New Zealand workforce and the proportion of older workers (Tipper, 2012). Construction is no exception to these trends. In 1999, workers aged less than 30 years old made up 34% of the construction workforce, while in 2022 this proportion dropped to 31%. The proportion of workers aged 55 or older increased from 8% in 1999 to 16% in 2022[10]. Furthermore, early retirement is common due to the physical nature of construction work (Ayodele *et al.*, 2022). Skill shortages will be amplified as the current cohort of skilled older workers ages out of the labour market.

A correlated issue with an ageing workforce is the relatively slow adoption of new technologies in some construction professions, which can hinder productivity growth. 'Construction 4.0' is a catch-all term which has been applied to recent advances in construction processes and techniques, with a particular focus on computer and cyber-physical systems[11]. The New Zealand construction Industry may be lagging behind the Construction 4.0 revolution, with high-level examples including slow uptake of tools such as Lean Principals and Building Information Modelling, despite these becoming increasingly commonplace overseas (Doan *et al.*, 2021; Likita *et al.*, 2022)[12]. Low-level examples include anecdotal evidence from heavy machinery suppliers that automation and driver's aids designed to improve productivity are often disabled in New Zealand equipment because the operators believe they can 'do it better' than the machine.

Finally, a lack of skilled workers may also be constraining the existing workforce. At the same time that the industry is reporting staff shortages, an estimated 25,000 construction workers desire more hours (MBIE, 2021). One hypothesis that reconciles this contradiction is that a shortage of skilled workers may hamper the quantity of work available for low-skilled employees[13]. Evidence for this is given by the fact that, across the economy, underemployed individuals are more likely to be younger, have lower levels of schooling, and are more likely to be labourers, than individuals who report that they do not desire more hours (Meehan *et al.*, 2022). Addressing the shortage of skilled workers may enable the existing low-skilled workforce to be used more productively. Furthermore, providing opportunities for individuals

[10] Note that, due to an expansion in the construction workforce, the absolute numbers of workers in all age bands increased between 1999 and 2022, it is the relative proportions that have changed. Source: author's calculations using data from Stats NZ: LEED 2-way measures, by age and industry (based on ANZSIC06), using 'Total filled jobs' in 'Construction', available from https://nzdotstat.stats.govt.nz/, accessed 29/05/2023.

[11] See Forcael *et al.* (2020) for an overview.

[12] Likita *et al.* (2022) identifies that 'cultural resistance' to new technology implementation and a lack of knowledge and training about the new systems are key barriers to their adoption in New Zealand. These can be exacerbated among older workers. International evidence suggests that an older workforce is correlated with lower uptake of new technologies in small and medium enterprises (Meyer, 2011), which make up the majority of firms in construction.

[13] Additional reasons for underemployment could be a lack of capital equipment or a lack of supplies reducing the amount of available work.

who desire more hours to upskill enables them to fulfil the in-demand roles, satisfying both their desire for more work and improving the skills shortages in the industry.

1.3 Skill shortages and a poor training pipeline may hamper productivity growth

Labour force productivity is a measure of how much output is produced per unit of labour input, i.e. per hour of work. Fundamentally, it can be improved by: i) increasing capital e.g. giving workers better equipment or supplies so that they produce more output for each hour of labour; or by ii) increasing labour ability, e.g. through upskilling workers so they are more effective and produce more output with the same level of tools or material. Factors specific to construction that reduce labour force productivity are: the non-availability of materials; a lack of proper tools and equipment; incomplete or changing drawings and specifications; inadequate or ineffective supervision; and labour skill shortages (Hasan *et al.*, 2018).

Productivity is lagging in civil construction in New Zealand, which is exacerbating the infrastructure deficit (New Zealand Infrastructure Commission, 2021, 2022a). Both horizontal and vertical construction suffered from three decades of stagnation in labour force productivity from 1970 to 2000. However, since 2000, labour productivity has increased by 23% in vertical building construction, while horizontal civil construction has only seen a 5% increase over the same period. If labour productivity in horizontal construction had grown at a comparable rate to vertical construction, civil construction prices would be 10% lower, output would be 5% higher, and labour requirements for the industry would be 11% smaller (New Zealand Infrastructure Commission, 2022a).

While it is unclear what is suppressing the growth in productivity in horizontal constitution compared to vertical construction, a poorer training pipeline for civil construction may be a contributing factor. Evidence for this is shown in the relative underutilisation of formal training programs in horizontal construction. The residential construction workforce is approximately three times the size of the civil construction workforce (MBIE, 2022a). However, there are approximately ten times more apprentices enrolled in schemes geared predominately towards vertical construction as compared to programs

focussing on horizontal construction[14]. This suggests that the vertical construction industry may be more successful at upskilling its workforce, ensuring a continuing pipeline of skilled recruits, and hence increasing labour force productivity in that sector. Factors which may be driving the underutilisation of apprenticeships in civil construction are discussed in section 2.2.

Skilled worker shortages may force companies to depend on temporary, untrained, or unskilled workers, sometimes resulting in them undertaking tasks beyond their capability (Fernando *et al.*, 2016). This can lower productivity, raise the risk of errors, compromise project quality, and increase safety hazards. In contrast, a highly skilled worker and supervisor are significantly more productive, produce better quality work, and operate more safely than a novice (Hasan *et al.*, 2018; Yusoff *et al.*, 2021). Productivity in infrastructure construction hinges on skilled personnel; it requires teams with expertise who can handle costly and sophisticated equipment.

Low worker productivity, low wages, and long hours are part of a negative feedback loop. Low productivity necessitates significant labour allocation to complete projects, with a drive towards long hours and increased overtime to meet deadlines. Low productivity also justifies low wages, which incentivises workers to take on more hours to compensate. However, construction trades productivity significantly decreases as the number of hours worked increases. This is particularly exacerbated above 40 hours per week (Hanna *et al.*, 2005). Overworked tradespeople with low productivity produce less output per hour, reinforcing the need for long hours to complete projects, and this perpetuates the negative cycle. In contrast, more productive workers may be able to produce the same construction output in a shorter time, with a better work life balance, while justifying and enjoying higher wages.

1.4 Lack of diversity: leaving skilled people on the shelf

Low workforce diversity implies that the industry is missing out on possible employees. For example, the proportion of women in the construction industry has increased slightly over the last decade, yet it remains low, at only 15% in 2022 (MBIE, 2022a). However, this includes administrative jobs - only

[14] Although there will be considerable overlap between horizontal and vertical construction, the majority of apprentices enrolled in the following courses will likely enter residential construction: Carpentry and Joinery (19,455); Electrical Engineering (7,260); and Plumbing, Gasfitting and Drainlaying (4,750). These give a combined total of 31,465. This compares to the following apprenticeships that are predominately geared towards horizontal construction: Civil Engineering nec, mixed or nfd (1,905); Power Line Installation and Maintenance (935); and Road Construction (560). For a total of 3,400. Note that, for simplicity, only the top three apprenticeships by enrolment are considered in each sector. Considering a wider array of apprenticeships would further bias these numbers in favour of vertical construction. Numbers are based on 'participants in industry training' for 2021 available from https://www.educationcounts.govt.nz/statistics/new-zealands-workplace-based-learners, accessed 11/05/20213.

2.6% of tradespeople are women[15]. Assuming a relatively even distribution of baseline ability in men and women, this suggests that there are tens of thousands of potential skilled employees not being reached by industry recruitment.

This is a complex issue, likely driven in part by social inertia, where women do not see construction as a viable career path, and in part by industry not making space for women in the workplace. In 2022, only 37% of civil construction businesses said that they have initiatives to 'support female, older, disabled or otherwise diverse staff in on-site roles (not including office staff)' (CCNZ, 2022), with this dropping to 32% in 2023 (CCNZ, 2023).

Long and inflexible hours are frequently cited as barriers to women in construction[16], with the implicit assumption that women have additional caring or household duties not shared by their male counterparts. It is not beholden to construction companies to address the societal biases that generally push a disproportional amount of unpaid 'home production' onto women[17]. However, firms can access a larger pool of potential employees by making their workplaces amenable to individuals of any gender who have additional duties and responsibilities. For example, through more flexible working arrangements and support for childcare. Despite some notable efforts of individual companies and programs geared at recruiting women[18], adoption of such policies in civil construction is low in New Zealand, with only 25% of firms stating that they have flexible working or family-friendly policies (CCNZ, 2023).

Furthermore, while studies are lacking in New Zealand, evidence of a hostile and discriminatory work environment for women and minorities in construction has been observed in the US, UK and Australia[19]. In these regions, ethnic minorities are also typically under-represented, except in low-skilled, low-regulated, and insecure positions, where they are over-represented (see Bridges *et al.* 2020, and references therein). There is evidence of this pattern repeating for Māori and Pasifika in construction in New Zealand[20].

Explicit and implicit discrimination may be further exacerbating skill shortages in construction. A high degree of attrition of women and minorities post-study has been observed in civil construction apprentices in the US (Kelly *et al.*, 2015). The poor retention rate has been attributed to negative

[15] See https://bcito.org.nz/resources/women-in-construction/, accessed 11/05/23.
[16] See Bridges *et al.* (2020), May and Bryant (2022), Oo *et al.* (2022) and references therein.
[17] See Hyman (2017) for a discussion of such biases in New Zealand.
[18] See Women in Trades, Girls with Hi Vis, and Women in Infrastructure, at www.womenintradesnz.com, https://www.connexis.org.nz/girls-with-hi-vis/ and www.infrastructure.org.nz/win/, respectively, accessed 11/05/2023.
[19] See George and Loosemore (2019), Bridges *et al.* (2020), Loosemore *et al.* (2020), Turner *et al.* (2021), Loosemore *et al.* (2022) and references therein.
[20] https://diversityworksnz.org.nz/news-resources/news/diversity-roadmap-for-the-construction-sector, accessed: 11/05/23.

experiences in a masculine, hostile work environment and to exclusion from informal hiring and mentorship practices, which disadvantages career progression and employment opportunities – despite the existence of ostensibly gender and race neutral formal practices (Kelly *et al.*, 2015; Bridges *et al.*, 2020). There is currently no detailed information on post-study outcomes by gender or ethnicity for construction apprentices in New Zealand.

Finally, a significant amount of recruitment in the civil construction industry in New Zealand occurs through informal networks and word-of-mouth (May and Bryant, 2022). These practices can reinforce existing ethnicity and gender imbalances in the industry (Byrne *et al.*, 2005; Kelly *et al.*, 2015). Barriers to workplace diversity decrease the available talent pool and likely exacerbate recruitment challenges and skill shortages.

1.5 Migration is only part of the solution

Skill shortages in construction are a global problem[21]. New Zealand companies are in an international competition to attract skilled migrants and retain domestic talent. Available data from the past two decades shows significant net outflows of construction personnel from New Zealand to Australia (Schiff, 2022). This has been partially offset by inward migration from the rest of the world. However, recent positive flows are almost entirely driven by high migration over the decade following the 2010/11 Christchurch earthquakes. Taken over a longer time horizon, the net migration of construction personnel to New Zealand between 1962 to 2018 is negative (Coleman and Karagedikli, 2018).

Recognition of skills obtained overseas can be difficult. Each qualification in each country must be assessed and compared to its corresponding qualification in New Zealand, which can require significant work by the relevant accrediting bodies. This must be updated whenever regulations or curricula change in either country. These factors can limit the process to only the most similar, most numerous, or most in-demand qualifications. An alternative method is for the migrant to sit the appropriate assessment in New Zealand. While this may be suitable for micro-accreditations, where the individual may only need minimal training or preparation, it is not feasible for larger programs. In both cases, the individual or their employer may incur significant costs. Anecdotally, some accrediting bodies are reluctant to certify overseas qualifications in order to protect domestic training institutions and labour markets. Furthermore, some employers are reportedly hesitant to support their employees recognising overseas qualifications in

[21] For examples outlining construction skill shortages in the EU, the US, Canada, Hong Kong, and Australia see Brucker Juricic *et al.* (2021), Karimi *et al.* (2018), Albattah *et al.* (2015), Ho (2016) and Detsimas *et al.* (2016) respectively.

order to keep their wage costs artificially low. All these factors combine to result in skilled individuals being underutilised in lower-skill roles below their capabilities. This phenomenon is known as 'Brain Waste'. While there are currently no studies into brain waste for the construction workforce in New Zealand, there is evidence of brain waste for tertiary qualified migrants (Apatov and Sundaram, 2020).

Current New Zealand immigration settings pose challenges for the upskilling of migrants. The conditions of many temporary work visas require a minimum of 30 hours per week of work, and that formal training or study be less than three months in total. Otherwise, the work visa must be changed to a study visa, limiting the amount of work the individual can perform to 20 hours per week[22]. Most of the net increase in migrant workers in construction in New Zealand between 2012 and 2019 was accounted for by individuals on short-term and temporary work visas (Schiff, 2022). Officially training these individuals while remaining within their visa constraints may be challenging.

Furthermore, migrants have already demonstrated their willingness and ability to move countries for better opportunities, taking their acquired human capital with them. This may make companies less willing to invest in training for migrant workers. One study of return-migration and onwards-migration among foreign-born individuals in Sweden found that 73% of individuals who had migrated for work reasons had re-emigrated within 10 years (Monti, 2020). An investigation of the cohort of individuals who began on temporary visas in New Zealand in 2009, showed that over half live overseas after 10 years (Meehan *et al.*, 2023). The motivation behind this re-migration can be hard to determine. However, a lack of access to training to integrate into the labour market, underutilisation, under-employment, a lack of a pathway to permanent visa status, and barriers to family reunion could all be contributory factors.

A growing reliance on migrant labour also poses resilience problems. Inward migration accounted for only 3.4% of new entrants to the New Zealand infrastructure and construction workforce in 2001, however, this has steadily increased over time, rising to 14.1% prior to the pandemic in 2019[23]. This supply was extremely restricted during the pandemic, with difficulties and delays in bringing badly needed skilled workers through the MIQ system (ACE New Zealand, 2021), exacerbating existing skill shortages (MBIE, 2021). As Covid-19 showed, access to the overseas talent pipeline is far from guaranteed. In addition, the time taken to reach, recruit and onshore an overseas worker can be significant.

[22] More permanent visas permit a greater degree of study, particularly if required as part of an individual's employment. See specific visa conditions at https://www.immigration.govt.nz/new-zealand-visas, accessed 30/05/2023.

[23] New entrants refer to individuals who have not previously worked in the sector. In 2001 there were 1,100 migrants out of a total of 32,600 new entrants. In 2019 there were 7,200 migrants out of 54,100 new entrants. Data from https://sweetanalytics.co.nz/content/construction-workforce-demographics/, accessed 30/05/2023.

However, migration is a vital component of New Zealand's workforce. Due to the labour-intensive nature of construction, firms typically respond to volatile demand by varying the amount of labour inputs, often through changes in reliance on migrant labour (Schiff, 2022). Without this capacity to adjust, firms may need to charge more during good times to remain in business when demand drops, further increasing infrastructure and construction costs. Construction firms tend to turn to migrants when the domestic labour supply is constrained, and in specialised civil infrastructure roles that may not exist locally. Migrants can facilitate expansion by reliving pressure on internal trainers and site supervisors during period of growth. Furthermore, despite anecdotal preconceptions to the contrary, Schiff (2022) found that migrant construction workers do not appear to replace domestic workers, nor reduce wages. He showed that migrant workers are generally complementary to domestic labour and generally work longer hours than the industry average. Finally, it is notable that migrant workers are a relatively small proportion of the overall construction workforce, with recent estimates of around 7-10% (MBIE, 2021).

A strong domestic training pipeline will be complemented by migrant labour while providing workforce security.

1.6 Current training provision

> 'Civil construction training is an industry of pilot initiatives without a coherent strategy'
>
> - May and Bryant (2022)

The pressing skills shortage shows that the current training provision is inadequate. May and Bryant (2022) outline how a number of training programs have been discussed, with some pilot schemes taking place. However, these are small-scale trials, generally happening in isolation over a limited time period and heavily dependent on the motivation and energy of the individuals and organisations that initiated them. May and Bryant (2022) also note that, while a number of entry-to-work programs are operated successfully through funding from the Ministry of Social Development - Te Manatū Whakahiato Ora (MSD) and other agencies, pathways for new entrants other than disadvantaged social groups or long-term unemployed are not widely funded or delivered in volume. Furthermore, existing programs rely on the ongoing engagement of these agencies, which may be vulnerable to changes in the prevailing political climate or varying institutional priorities. If MSD exited this space, for example, it is unclear what education offering or funding provider would step in to fill the gap.

Without a comprehensive and organised system for education at scale, the majority of training for civil construction occurs on-the-job in small numbers, as most projects do not support a large proportion of trainees. Capital equipment and material costs are generally substantial and worksites are subject to a high degree of health and safety risks that are particularly exacerbated for novice employees (Tichon and Diver, 2010; Dzeng *et al.*, 2016). While some firms invest heavily in training, this is for their own requirements, rather than to meet the demands of the industry as a whole. For many small companies, large-scale training is infeasible, and they may not have enough variety of work to cover all the skills required for an employee's qualification.

In addition, the access point for new entrants is unclear. Potential civil recruits acquire few relevant skills or experience during their schooling and a lack of awareness of civil construction as a career path means it is often seen as a career of last resort for failed students. As May and Bryant (2022) discuss, employers state that they will recruit individuals of any skill level provided they are prepared to work hard. However, in reality, employers prefer people with skills and at least some job-site awareness and understanding. Most companies are unwilling to provide training to acquire those abilities, until they have built up a relationship with an individual and are sure that they are a good fit. Employers generally rely on informal networks, or through trialling individuals from labour hire companies, as their most reliable

methods of finding suitable new entrants (May and Bryant, 2022). These methods can be inefficient at the industry level, and the reliance on informal networks in particular can reinforce ethnicity and gender imbalances in the construction workforce (Byrne *et al.*, 2005; Kelly *et al.*, 2015).

2 Fundamentals of the problem

2.1 Suggested factors behind a lack of training

The failure of training to address skill shortages in civil construction in New Zealand is attributed to a myriad of causes. The most common being a hesitancy of firms to train in the face of an uncertain pipeline of work and the cyclical boom-bust nature of the construction industry (Chang-Richards *et al.*, 2017; May and Bryant, 2022). Other factors include: the length of time and high equipment requirements needed to train; difficulties in transferring skills between machines made by different manufacturers; the historic availability of skilled migrant workers; reluctance (or unawareness) of school leavers or career switchers to enter the industry; a lack of engagement with school leavers or career switches from industry who do not see these individuals as 'work ready'; a lack of ability for industry or education to deliver training at scale; a lack of ability for polytechnics to meet industry requirements; a miss-match between new entrants and industry's expectations of working conditions; and barriers of scale faced by smaller firms who lack the capacity to undertake training (Lobo and Wilkinson, 2008; Chang-Richards *et al.*, 2017; May and Bryant, 2022; Schiff, 2022).

A notable suggested factor behind low training rates is that employers are less willing to invest in training due to the risk of 'poaching' where newly skilled individuals are hired away by competing firms after their training is complete (Daniel *et al.*, 2019; May and Bryant, 2022). The poaching firm free-rides on the training firm's investment and in aggregate this is theorised to reduce the incentives to train across the industry. However, international evidence suggests that firms that have suffered from poaching of apprentices do not reduce their training activity in response (Stockinger and Zwick, 2017). Moreover, in a competitive labour environment (where poaching is potentially more common), the quality and availability of apprentices produced are higher than in an uncompetitive environment. This quality boost is observed for all apprentices, not just those who are poached (Stockinger and Zwick, 2017). Finally, evidence from small firms suggests that less than 10% consider poaching as a barrier to training provision (Kitching and Blackburn, 2002). There are limited studies on poaching in New Zealand construction,

although it is perceived to be an issue by some members of the industry (May and Bryant, 2022).

Related to the perceived problem of poaching is the relatively high turnover rate in construction and the high rate of 'job churn'. While employers suggest that high turnover rates diminish their appetite for training investment, Jaffe and Chappell (2018) find that job churn is important for driving productivity growth in the construction industry in New Zealand. Firms with new workers are more productive than those with no change in their workforce, which Jaffe and Chappell (2018) suggest is due to knowledge flows that move with the workers between construction firms. This suggests that 'job churn' may be optimal at the industry level, even if individual companies prefer a high degree of staff retention.

2.2 The root of the problem

The causes cited above are expressions of four root problems: high training costs, the difficulty for prospective trainees to signal their quality, matching problems between firms and workers, and an uncertain project pipeline for individual firms.

2.2.1 High costs

The process of training a skilled civil construction worker is especially capital and time intensive. Equipment is generally large, specialised and expensive, and work often has high material requirements[24]. Training is typically on-the-job, with high opportunity costs from slow or differed operation during training, high costs for re-doing poor work, and high hazards and risks that are particularly exacerbated for novice workers (Wang and Dunston, 2005; Tichon and Diver, 2010; Vahdatikhaki *et al.*, 2019; Dzeng *et al.*, 2016; May and Bryant, 2022).

Evidence from apprenticeship programs shows that firms are less willing to train when the payback period on their training investment is long, which is particularly the case for firms with high skill requirements (Caicedo *et al.*, 2022). The economic model of apprenticeships defines three phases[25]. The initial period is characterised by high employer costs in training expenses and apprentice wages, and low apprentice productivity, usually representing a net loss for the employer. Over time the ability and productivity of the apprentice improves, increasing their output. Employer costs may grow with the apprentice's wage (although at a slower rate than output growth), or costs may fall if training and equipment overheads

[24] Innovations such as virtual reality (VR) are reducing capital equipment requirements for training, however, adoption is slow, and some proportion of knowledge transfer must take place on real-world equipment.
[25] For an intuitive explanation, see figure 1 in Lerman (2019).

decrease. Consequently, the second phase is defined when the employer begins to receive a benefit from the output of the apprentice relative to their cost. These benefits may be substantial as the apprentice nears the ability of an experienced worker, yet remains on a lower apprentice salary. The third phase begins once the apprenticeship is complete, typically accompanied by an increase in wages. It is assumed that the output of a fully qualified worker exceeds their wage cost, (otherwise the employer would be making a loss). Other benefits to the employer in this stage come from the hiring of an in-house trained apprentice, namely: reduced turnover, lower recruitment costs, and greater confidence in the abilities of the former apprentice and their fit to the employer's workplace.

The payback period for an apprentice depends on the cost of stage 1, vs the benefits of stages 2 and 3. For many firms, apprenticeships are profitable within the apprenticeship period, however for high-skill roles, and for firms with high training costs, apprenticeships only become profitable after accounting for substantial benefits in stage 3 (Muehlemann and Wolter, 2014; Lerman, 2019; Caicedo *et al.*, 2022).

A relatively long payback period for investing in civil apprentices compared to apprentices in other trades could be responsible for the lower uptake of apprenticeships in horizontal civil construction as compared to vertical building construction. This also helps explain why firms are unwilling to train in the face of an uncertain project pipeline - by the time the apprentice is generating income for the firm, the firm's pipeline may have reduced, and the newly trained worker could be surplus to requirements. Projects may only last months, however an apprenticeship lasts for years, representing a significant commitment for firms (May and Bryant, 2022). Finally, high costs rationalise the reluctance to train in an environment of poaching or 'job churn', since firms risk losing their investment in human capital to competing companies before seeing a positive return.

High costs also pose barriers to training for small firms, and this is exacerbated by layers of sub-contracting. Small firms are less able to spare the time or capital equipment to train recruits, while the further down the chain of sub-contracting, the lower profit margins generally become (Tam *et al.*, 2011; MBIE, 2021). This reduces the capacity and the appetite for small sub-contractors to take on the costs and risks of training additional workers. These factors naturally create a shortage, as larger firms will not train an excess of workers for the small firms to draw on. Similarly, high costs incentivise firms to only train for their current requirements, and rely on migration or recruiting from other firms to meet future demand (May and Bryant, 2022; Schiff, 2022).

In addition, small firms may not have sufficient diversity of work to provide the necessary experience

for apprentices and trainees to fulfil specific qualifications. While this could be due to a lack of scale, it could also be a symptom that the qualifications are not fit for purpose and are unrepresentative of the roles in the industry. This fits with an alternative hypothesis behind the relatively low uptake of apprenticeships in horizontal construction, namely that the apprenticeships are not focussing on the skills and roles required by the industry.

Finally, even if apprenticeships are fit for purpose, they may be underutilised due to the relative infancy of the program in the civil construction industry (May and Bryant, 2022). This would suggest that expansion of funding and further development of programs that can help incentivise uptake and accelerate adoption is beneficial. Requirements for a number apprenticeships as part of a tender for large government projects can increase utilisation, however, this may not be sufficient in isolation. Strong partnerships need to be developed between industry, training providers, and funding institutions.

2.2.2 Signalling problems

Interacting with an individual through on-the-job training is one of the few methods available to horizontal construction firms to determine if a new trainee will be 'good' or 'bad'. With high training costs, high operating costs, and a high degree of hazards, civil construction firms face significant losses if a new employee turns out to be unreliable, unmotivated, or unsafe. An employee's attributes (capability, productivity, motivation, reliability etc.) are generally not observable by the firm prior to the decision to hire and train. Firms must rely on 'signals' of an employee's attributes[26], in much the same way car insurance companies rely on a customer's age and their number of prior accidents as signals about the likelihood of them making a future claim.

The typical signals used by firms to evaluate potential recruits are generally not available to horizontal construction firms. These signals are educational attainment and promotion history (Spence, 1973; Waldman, 2016), neither of which applies when the main entry requirement for a construction trainee is a full driver's licence. Instead, firms typically rely on informal signals such as word-of-mouth referrals and trial employment through labour-hire companies to find recruits. Companies will then develop a working relationship with an individual to assess attitude and aptitude before committing to an apprenticeship or further training (May and Bryant, 2022). While there are pathways for civil engineering recruits through tertiary education, civil trade pathways are minimal.

[26] See Spence (1973) for the seminal treatment of signalling in job markets.

The signalling problem also explains the relatively limited engagement between polytechnics and the horizontal construction industry. As noted by May and Bryant (2022), 'Employers do not trust the tertiary education system to deliver on their needs'. Through the process of on-the-job training, individuals who do not meet the firm's requirements, or who decide that the industry does not suit them, will cease their training. In this way, on-the-job training provides a system for employers to evaluate an employee's attributes, and screen out the individuals they do not think are suitable. Unless firms can be assured that the same process occurs through tertiary education, they will not value the 'signal' of a qualification obtained at a non-vocational institution as an indicator of the suitability of a potential recruit.

The signalling issue for tertiary education could be due to incorrect learning outcomes, e.g. training individuals in different techniques than those used on job-sites. However, the problem is most acute for a core role of tertiary education: providing a bridge to skilled positions in industry. For employers practising on-the-job training, observing an employee regularly turning up for low-skill work for six months is a good signal that the individual is reliable and suitable for training for a higher-skill position. However, some individuals may be suitable for the higher skill role, yet are unable or unwilling to spend the time in the low-level position on site. For example, they could be skilled career-switchers, who cannot afford to take a pay cut, but are able to take classes to retrain. While industry may prefer that workers 'do their time' in the low-level position, talented individuals have options, and many would rather upskill and step directly into a more challenging role. Tertiary education should act as a pathway to the skilled position, as well as providing additional pastoral support for learners that require it. However, if industry does not trust the tertiary education sector to sufficiently screen for unsuitable individuals, then it will be less inclined to engage with graduates of the tertiary program.

2.2.3 Matching difficulties

A related but separate problem to the signalling issue described above is labour market matching. This is an economic framework that uses search and matching frictions to reconcile the apparent contradictions of a labour market which simultaneously exhibits unemployment and job vacancies[27]. Individual workers must spend time and resources to locate and apply for job opportunities that suit their skills and pref-

[27]The canonical model of labour market search is known as the Diamond-Mortensen-Pissarides model, named after three economists who won the Nobel prize in 2010 for their work leading the development of the framework, see Diamond (1982), Mortensen (1982), and Pissarides (1985). This framework also explains other stylised facts that a competitive labour market model cannot explain, such as persistent unemployment, differences in wages between otherwise similar workers, and cyclical fluctuations in unemployment.

erences. Firms must spend effort advertising, screening and training to acquire potential new employees that suit their role requirements and workplace environment. These frictions impede a successful 'match' between employer and employee.

Significant matching frictions exist in the labour market for civil construction trainees and recruits. Industry reports that potential recruits are often not 'work ready', and that there is a substantial disconnect between the expectations of new entrants and the expectations of employers in regards to working conditions (May and Bryant, 2022). This could, in part, be due to the assumption that civil construction is the 'industry of last resort for failing students' which masks the often substantial analytical, practical, and awareness skills required to excel on job sites[28]. The mismatch in expectations could also be due to labour-intensive models of construction, which frequently requires long and inflexible shifts, often involving unsociable hours in early mornings or late nights, and with frequent six-day work-weeks (Morrison and Thurnell, 2012; Lingard *et al.*, 2021). This does not match the work patterns desired by many people, reducing the potential pool of recruits construction can draw from.

A structure of long and inflexible shifts also precludes matching with individuals who want part-time work, or who have caring duties or other responsibilities. Part-time employment is less common in construction compared to all industries (at 7%, compared to 26% for all industries), and the proportion of part-time work in construction has been falling since around 2017 (MBIE, 2021). Across the economy, only 19% of men and 17% of women who are employed part-time are underutilised and desiring more work[29]. This suggests that the majority of part-time workers choose to do so for lifestyle, caring, or study reasons. The data shows that women are also more likely to be employed part-time, with 11% of employed men and 28% of employed women working part-time. An inability or unwillingness to accommodate part-time work could be one structural barrier to women's participation in construction.

Long hours and six-day weeks may be unavoidable in some construction roles. In this case, the workforce match can be improved if employers signal this requirement in advance to potential recruits, along with the corresponding rewards for working those hours. However, employers will also benefit from a greater potential pool of recruits if they can adjust their work-models to accommodate part-time work. For example, if reliability and competency could be assured, two individuals working three days

[28] For many students, particularly those with undiagnosed learning difficulties or who exhibit neurodiversity, on-the-job learning may be more suitable than traditional education. Such students may excel in vocational education, exceeding what their academically 'successful' peers could achieve in similar circumstances. However, this can lead to an assumption in society that construction is less challenging than other sectors because 'failing' students are doing well in the industry.

[29] Figures are as of quarter two of 2022. Source: Household Labour Force Survey, 'Persons underemployed by sex', quarterly data, available from https://infoshare.stats.govt.nz/, accessed 1/06/2023.

each could fulfil a six-day work-week. Or two people working five or six hour shifts can replace one worker doing a ten or twelve hour day. Total fixed per-worker costs may be higher, however overtime costs should be lower, and there could be substantial gains from productivity and health and safety improvements from well-rested employees with less burnout (Hanna *et al.*, 2005; Brossoit *et al.*, 2019; Lee *et al.*, 2020; Lingard *et al.*, 2021).

Further research is needed to understand the extent that sub-contractors and self-employed workers utilise flexible or part-time work arrangements. Firms often fill roles that could be suitable for a part-time employee with a skilled sub-contractor instead. There has been limited investigation of whether self-employed trades personnel make greater use of flexible working or part-time opportunities, or if the pressure of being a small sub-contractor pushes individuals to take on more work than desired.[30] In any case, self-employment demands skills, experience, connections, and entrepreneurial spirit, usually obtained through traditional employment with full-time and rigid work schedules. While an investigation of the extent to which self-employment can meet the needs of some individuals in civil construction for part-time and flexible work would be valuable, this employment model is unlikely to provide a suitable avenue for all individuals with such requirements.

Outside of inflexible working hours, other matching problems may be drivers behind the low proportion of women in construction, with friction on both sides of the pairing. On the employee side, a lack of awareness of construction and civil infrastructure as a career for women reduces the number of women recruits who enter the search (May and Bryant, 2022). For employers, job-sites, roles, and workplace cultures have historically coalesced around stereotypes of construction workers being physically strong, heterosexual, white, young men (Smith, 2013; Bridges *et al.*, 2020). This reduces the likelihood of employers finding members from outside of this group who 'fit' their side of the match. These stereotypes further deter women from engaging with the industry, and those who do enter may struggle to excel unless they conform to, or subvert, these stereotypes (Oo *et al.*, 2022). These stereotypes can also reinforce the reliance on informal networks for recruitment. Clustering by gender, ethnicity, and social attitudes in informal networks means that employers who hire through such networks are limiting their search radius to individuals who are generally similar to themselves or their existing workforce. This, by default, finds individuals who are a better 'fit' to a male-biased match (Byrne *et al.*, 2005).

So-called 'positive stereotypes' can also be just as limiting as negative stereotypes in aligning a

[30] This situation may arise from concerns about future job security prompting self employed individuals to accept work whenever available, or from having little negotiating power with the large contractors who provide their main sources of income.

workforce match. Some women in trades industries have reported acceptance from male peers by focusing on 'low strength' fitting and finishing work (i.e. cleaner and lighter trades) or through demonstrating their advantage at working in confined spaces due to their (relatively) smaller size (Agapiou, 2002). Furthermore, it is not uncommon for well-meaning employers or clients to say that women tradespeople are valuable due to a 'greater attention to detail', because they 'keep the tools clean', or because they are 'better at cleaning the job-site' on completion[31]. Positive stereotypes can be just as prejudicial and constraining as negative stereotypes (Kay *et al.*, 2013; Czopp *et al.*, 2015), penalising individuals who do not conform. Women do not have a monopoly on fastidiousness or small frames, and men do not have exclusivity over strength or slovenliness. Both positive and negative stereotypes hinder a successful workplace match by excluding or deterring the majority of individuals who have traits outside of these preconceptions.

Finally, while both positive and negative stereotypes can be problematic, approaching a workplace from different viewpoints can be beneficial. Women in trade industries report developing 'smart' work practices to save their bodies from unnecessary strain (Smith, 2013). However, careful management of the human body is essential for all physical work. Approaching work from outside of a hegemonic masculine culture permits interrogation and critique of the masculine stereotypes that often encourage workers to use their bodies unsafely (Oo *et al.*, 2022). These insights are forgone if the workplace match is designed with one individual in mind.

2.2.4 Uncertain project pipeline for the individual firm

Due to high costs and long training schedules, individual firms considering recruitment focus on their own project pipeline, not the pipeline of the industry as a whole. Construction firms repeatedly report an uncertain project pipeline as a key concern (May and Bryant, 2022; CCNZ, 2022, 2023). Recognising this, estimates of future building activity and workforce requirements have been developed by: the Ministry of Business, Innovation and Employment (MBIE)[32]; the Construction and Infrastructure Workforce Development Council[33]; and the Infrastructure Commission[34]. These pipeline estimates generally use information on consented and planned projects to estimate future activity in the industry, with the goal of clarifying anticipated demand and helping businesses plan for future requirements. However, individual

[31] See discussion in Smith (2013) and Bridges *et al.* (2020) and quotes in May and Bryant (2022).
[32] MBIE (2022b).
[33] https://www.waihangaararau.nz/for-industry/research/workforce-information-platform/ accessed 11/05/2023.
[34] https://www.tewaihanga.govt.nz/projects/search-the-pipeline/ accessed 11/05/2023.

firms typically have no information on whether they are likely to win the tender for these future projects, reducing their willingness to train additional employees to meet speculative demand. Furthermore, given the boom-bust nature of construction, a firm that expanded to meet unconfirmed work may be left in the lurch during a downturn when consented or planned projects are differed or cancelled (Allan *et al.*, 2008).

A multi-skilled trade professional can take more than five years to train (May and Bryant, 2022). By the time a contract has been awarded, it may be too late to commence large-scale workforce training to meet the project requirements. In which case, firms requiring more labour may recruit migrants or employees from other companies, with only a small degree of workforce expansion through on-the-job training, since most projects cannot sustain a large proportion of unskilled trainees. Potentially, only firms with suitable existing workforce capacity to handle the project will tender, reducing the pool of potential applicants and lowering competitiveness and innovation in the industry.

Lowest cost procurement exacerbates the issue of underinvestment in skill development. On-the-job training to grow the workforce and meet future requirements increases the costs to deliver current construction projects. Clients are often unwilling to bear this cost, and may not include requirements for training as part of their tender. Competitive responses to these tenders result in skills development being cut to reduce expenses, with lowest-cost bids often being entered by firms that do not use the project to train future employees. Anecdotally, even for projects that do require training, this is one of the first expenses to be cut to rectify a budget overrun or to address funding pressures. On aggregate these factors results in lower levels of training than is needed to sustain and grow the workforce.

An industry pipeline of predicted work is of most use to an independently financed training institution. For example, a government-funded education provider with both: a mandate to provide skilled workers for future industry requirements, and the capability to meet these needs. Such an institution can notice a predicted future spike in demand and expand its training provision, knowing that there will be jobs available in whichever firms ultimately end up winning the future contracts. This addresses the negative market externality whereby firms, unwilling to gamble on training for contracts they may not win, underinvest in aggregate in training for future requirements. A capable institution would have sufficient dedicated space for large equipment operations, along with the corresponding machinery and education personnel. The greatest bottleneck to surge capacity is likely to be space considerations, given the land-intensive nature of heavy equipment training, which emphasises the need for a dedicated facility for

this type of training provision.

2.3 Poor incentives in the current system

The vocational education system in New Zealand is made up of a number of key components. The Workforce Development Councils (WDCs) are responsible for setting standards and developing qualifications that meet industry requirements. These qualifications are administered by the New Zealand Qualifications Authority (NZQA). Programs designed to teach students to achieve these qualifications are developed and implemented by Te Pūkenga and private training establishments. Funding for these providers is generally achieved through a mixture of course fees paid by employers and learners, and through funding on a per-learner basis by the Tertiary Education Commission -Te Amorangi Mātauranga Matua (TEC) based on the recommendations from the WDCs.

This education system is full of hard-working individuals, who care about student outcomes and about developing and growing the skills of the New Zealand workforce. However, as currently structured, the system is not achieving its core objectives, with incentives running counter to the goal of meeting the industry's requirements. There is a trust gap between industry and the education system, with employers not believing that the system produces individuals suited to their needs (May and Bryant, 2022).

Closing the trust gap requires the education process to both transform unskilled individuals into skilled workers who meet industry needs, and to filter out those individuals who are not suitable for roles in the industry. The current system is overly focussed on the former, where 'industry needs' are translated into assessment criteria with an associated qualification awarded to any individual who completes a program that demonstrates that they meet these requirements. By necessity, this simplification of jobs to assessment criteria misses the complexities of a role in industry, resulting in an inexact method to identify workers who have been sufficiently well trained and who are suitable for the position. However, this problem is compounded by the bureaucratic nature of the education system. A focus on course completion rates, and a binding of funding to enrolment numbers and retention, has produced incentive structures that prioritise getting large numbers of students through education programs, with failure and drop-outs being minimised as much as possible, rather than been seen as part of the process of screening for suitable recruits.

It is worth noting that the education system is in a tricky position. Low drop-out and failure rates could also signify that the provider is excelling in learning support and pastoral care, which are vital

parts of the education process. While a poorly taught course is likely to have high failure rates, unless screening for suitable individuals takes place as part of program entry requirements, drop-outs during the program are to be expected and, arguably, encouraged for those individuals the program, or role, does not suit. It is essential to recognise that not everyone will be suited for, or capable of excelling in, every course or job role. Upholding the integrity of assessments is crucial to ensure that qualifications remain reliable markers of an individual's capabilities and job suitability. Support should be provided for learners to transition to alternative programs or more suitable employment if needed.

Provision of a service that entails a significant bureaucracy faces risks that service delivery is structured to favour the bureaucracy, rather than the recipients of the service (Nolan, 2005). The focus on completion rates is one such example, as it provides a method for education providers and accreditors to evaluate the 'performance' of a program, while not actually assessing the ability of the course to perform its primary function of providing skilled individuals for industry. There are minimal entry requirements for civil construction trades education programs, meaning that no pre-screening is taking place. However, in order to keep completion rates high, learners are also provided potentially extreme numbers of chances to repeat assessments, meaning that minimal screening may take place as part of the qualification process. This lack of screening means that suitability is only rigorously assessed once on the job. This suggest that the lack of trust in the industry of the tertiary education system to consistently deliver skilled workers is potentially justified.

Without a trustworthy external qualification, many civil construction firms rely on internal competency assessments. These can become highly firm-specific, resulting in repeated assessments every time an individual changes employer, despite significant overlap of skill requirements. This negatively impacts productivity, recruitment time, and worker job mobility.

Furthermore, the philosophy of many employers is that qualifications are to recognise skills gained through on-the-job work and training, rather than a prerequisite to employment acquired at a tertiary institution. While this perspective acknowledges qualifications as evidence of competency and suitability for employment, it also suggests a singular valid approach to skill acquisition: on-the-job training. This can exacerbate the trust gap between the industry and tertiary education as, definitionally, tertiary education is incapable of providing a type of learning environment that these employers value.

Finally, there is evidence that some industry training providers do not apply for TEC funding for some NZQA-accredited programs that they provide. Instead, these courses are solely funded by employers and

learners. A cited reason for the lack of engagement is a consideration that the process is too bureaucratic and time-consuming. At the margin, there are likely to be some firms and students who would engage in training if the costs were lower. The fact that TEC funding is available to fill this need shows that the role has been considered socially valuable and worthy of public funding. However, the system has broken down and this training is going unfunded and, in some cases, unfulfilled.

3 Conceptual solutions

3.1 Training methods

A number of methods exist to recruit and train construction and civil infrastructure personnel. These cover formal and informal learning with both theoretical and practical skill development. This training can take place on-the-job, in campus settings, and through experience in simulators and virtual reality. Training can be funded in a variety of ways: direct funding from employers paying course fees, indirect funding through industry levees or union fees, transfers from general taxation by central or regional government agencies, transfers from donations via payments from NGOs, or paid by the learner, either directly from fees up front, or through a tax on their future earnings, often in the form of student loans.

The following subsections provide an overview of each conceptual training method, along with summaries of the advantages and disadvantage of each approach. A few examples of New Zealand implementations of each method are also given. It is worth noting that a training schedule may encompass multiple modes of learning, and that, as demonstrated through recruiting skilled migrants, the learning does not need to take place in New Zealand. Conceptual sources of funding for such training is discussed in section 3.3.

As detailed extensively in this report, the current method of skill provision in New Zealand is failing to produce enough skilled workers at the industry level.

Method 1: On-the-job training in a commercial operation

On-the-job training emphasises learning through practical application on job-sites. Trainees work on commercial projects under the guidance of experienced workers or instructors using the tools and machinery of the commercial entity. The construction output produced by the trainee contributes to the deliverables for the company and must meet corresponding quality standards and deadlines. Generally, trainees start with simpler tasks and tools, and progress to more complex assignments and machinery as they gain proficiency. Competencies may be assessed by accredited instructors. At the conclusion of training, individuals will usually continue with the employer who trained them.

This is the most common training approach in use in New Zealand. While generally effective for individual firms, this method is evidently insufficient at the industry scale as demonstrated by the chronic and persistent skills shortages facing the sector.

Method 1: Pros

- It is the actual job, individuals learn hands-on skills directly relevant to the role they are recruited for.
- This can be efficient at the firm level as firms generally only train if they have the need and capacity to train.
- There may be less societal overhead as external agencies or entities are not necessarily required. (Unless needed to recognise qualifications).
- Once on the job, the labour force match can be quite good, with companies able to observe and screen for individuals who do not 'fit' the role, and individuals able to observe directly the workplace requirements and potential career trajectories.

Method 1: Cons

- Individuals need to have the job already to undertake training, they may not learn transferable skills to other workplaces, and there may not be enough diversity of work at one employer to produce a multiskilled and qualified trade professional.
- Training is expensive to the firm in material, time and equipment. Projects may take longer, may be of lower quality, and have increased health and safety risks. Poor quality work must be redone to meet the commercial deliverables.
- Training may have negative payback for the firm until after training is complete, reducing the incentive to train in the wake of uncertain project pipelines and high turnover rates.
- If not combined with a qualification, the trainee may be stuck at one firm. If skill competency is recognised by a qualification then there may be higher societal overhead with a need for an external accrediting agency.
- Low scalability as firms generally have limited capacity to train and most projects cannot support a large amount of unskilled trainees.
- Relatively slow to train a well-rounded professional. Projects are what is commercially needed, not what will meet learning objectives. Learning may need to take a back seat to commercial requirements, with less time for supervisors to instruct on higher-skill tasks.
- Smaller firms may not have resources to train, and larger firms will not train an excess.
- Can suffer from uncontrolled environments, such as different weather, projects, instructors, and companies, which may mean inconsistency in training standards. Instructors may be proficient at the job, but lack skills in education and teaching.
- Generally firms train for what is needed now, not for what is needed in in the future. Firms focus on their own project pipeline meaning that the industry as a whole is not efficiently considering future workforce needs.
- Can result in low propagation of new techniques and knowledge, as individuals typically learn how it is currently done.

Method 1: Examples

This method is used across a wide variety of firms and job-sites.

Method 2: On-the-job training in a non-commercial operation

This method is related to method 1, with a similar focus on learning through practical application on job-sites under the guidance of experienced workers or instructors. However, in this case, trainees work on non-commercial projects where one of the key deliverables of the training is the qualified individuals themselves. The construction output produced by the trainee generally needs to meet commercial standards of quality. However, unlike method 1, the business model of the organisation does not solely depend on that output, and it is generally acceptable for projects to take longer if this results in better learning outcomes. The training may be funded partially, or fully, by national or regional governments, education providers, or NGOs, or by a commercial entity to meet its own training requirements.

Similar to method 1, trainees start with simpler tasks and tools, and progress to more complex assignments and machinery as they gain proficiency. However, the consequences for re-doing poor quality work are generally lower than for a commercial operation, which can facilitate trainees to try new techniques sooner. With less commercial pressure, trainees can be given additional pastoral and educational support. Competencies may be assessed by accredited instructors, with qualifications being one of the key outcomes of the projects. Upon the conclusion of training, individuals seek employment with commercial companies. Generally, projects and organisations aim to have sufficient engagement from industry partners so that individuals have potential placements and options upon completion of their qualification.

Method 2: Pros

- It can be very similar to the actual job. Individuals learn hands-on skills in projects that can be run in a similar style to a commercial operation. This can improve both the signalling and matching problems.
- With less commercial incentives, the training can also be run with more pastoral and educational support to be a bridge to industry. It can be targeted to unemployed individuals to help them re-enter the workforce, or to school leavers to build up to full-time employment.
- There may be lower health and safety risks since projects, tasks, and job-sites can be planned assuming the limited knowledge and ability of the individuals involved. This is in contrast with method 1, where a fully qualified and capable worker is often assumed to be the default, resulting in potential issues when a less qualified trainee is undertaking tasks.
- Similarly there are usually lower consequences for failure or for re-doing work as all stakeholders understand the role of education and the number of students involved in the project. While the output is generally valuable to society, and must meet suitable standards, it does not face the same commercial pressures.
- It can be an efficient use of societal resources. If trainees need to dig a hole for practice, they might as well dig a hole that is needed. Projects can be designed or selected to better meet learning objectives and the training can be subsidised by the output produced.
- If the training organisation specialises in education, they can recruit or partner with instructors and experts who also have skills in education and teaching.
- In comparison to training on a large campus, (method 3), this model is applicable to many regions and needs. Method 3 requires scale that limits it to large sites in one or two major regions. Method 2 can be implemented at both small and large scale.
- It can be added to large commercial projects. For example, giving trainees experience on a major infrastructure project to earn entry-level qualifications. Note that this differs from method 1 in that the production of the qualified trainee is the main deliverable.

Method 2: Cons

- This method generally requires external funding from an agency that is prepared to pay per student enrolled. There may be a limited number of projects that are suitable for the training objectives in a given area. Projects are generally completed more slowly than commercial operations.
- Capital equipment costs are still high, unless suitable equipment can be borrowed from commercial entities. However, in that case, the training organisation may face an uncertain supply of equipment.
- If designed to specifically accommodate trainees, the projects may have lower health and safety risks than a commercial operation. However, significant risks remain in managing a job-site with heavy equipment. Similarly, while there may be lower consequences to re-doing poor quality work, there are still non-trivial costs involved.
- If funded by a commercial operation (for their own training provision), then they may have to take on more or less trainees than they need to meet a given project's requirements. If the project itself is commercially profitable, then there are incentives to defer training as skilled people will complete the task faster for the same (or lower) cost. There is a barrier to entry for small firms that cannot fund these sorts of projects.
- If run by a training institution, then care needs to be taken to ensure that there are places for students post-study and to align work and learning objectives with industry requirements. If the institution is paid per student by a non-industry agency, then incentives exist to push students through who may not be suitable in an industry setting, reducing the industry's trust in the quality of the graduates of these programs.
- May suffer from uncontrolled environments with different weather and projects which may lead to inconsistency in training standards.
- Unions may have issues with trainees competing with commercial paid work. However, worldwide unions often run these sort of projects as it helps recruit the next generation of workers and hence potential union members.

Method 2: Examples

Examples include:

- Western Institute of Technology at Taranaki, 'Build a Bridge' Program
- Auckland City Rail Link's Progressive Employment Programme

Method 3: Off-site campus hands-on training

This method involves teaching practical skills and knowledge in a dedicated training facility or campus, rather than on an actual construction site. The aim is to provide a controlled environment for trainees to learn and practice using techniques and machinery in a safe and repeatable manner. Unlike methods 1 and 2, the trainees do not produce any useful output, with education as the sole priority of the training. Similar to method 2, the training may be funded in whole, or part, by national or regional governments, education providers, or NGOs, or by a commercial entity to meet its own training requirements.

There are no commercial consequences for producing poor quality work, which allows trainees to try new techniques and generally advance much quicker than when producing commercial output. Similar to method 2, trainees can be given additional pastoral and educational support, which may be further enhanced by additional on-site facilities and agglomeration benefits from concentrating resources on a campus. Competencies may be assessed by accredited instructors, with qualifications being the only deliverable. Similar to method 2, trainees generally seek to move on to commercial employment upon the completion of their training.

Method 3: Pros

- A key benefit of this method is controlled environments making the training replicable and consistent. Unlike methods 1 and 2, tasks and projects can be tailored exactly to learning objectives, allowing a large degree of skill acquisition in a shorter period of time.
- Trainees develop practical skills with hands-on use of actual equipment in a safe environment with fewer hazards than a typical job-site.
- The only cost to producing poor quality work is the trainee's time, giving recruits the freedom to make mistakes and learn from experience. Without commercial pressures, trainees can learn and progress quickly.
- The campus may be able to use older or cheaper equipment. Commercial operations need to consider efficiency and quality, necessitating the constant upgrading of older machinery. However, for training purposes, a lot of older equipment may be perfectly serviceable.
- Gains from agglomeration make a campus operation eminently scalable, with advanced facilities and support that would not be economically feasible in smaller or more dispersed operations. This can enhance learning and provide significant capabilities for pastoral assistance.
- The campus can specialise in instructors with skills in education and teaching. Practical learning can be augmented by classroom instruction all in one location.
- Accommodation, hospitality, leisure facilities, and pastoral support such as child care, can be provided on-site. It may suit some individuals to engage in an intensive course over a couple of weeks, rather than spend a long time on specific job-sites to gain the same skills.

Method 3: Cons

- A campus requires a very high degree of capital investment and ongoing operational funding. This will generally need to be met from non-industry sources. This is justifiable when education is under-provided due to the private benefits to the individual or employers being less than the societal or industry-wide benefits. (Note that this is why education is generally subsidised by state entities through taxation). The lack of an existing commercial education campus for civil construction training in New Zealand shows that it is likely unviable for a training entity to meet its costs from course fees alone.
- Significant scale will be required to make investments in heavy capital machinery worthwhile, which suggests that such a campus is only replicable in a few regions in New Zealand
- This process is more inefficient in outcomes than methods 1 or 2. Recruits dig holes for practice just to fill them in again.
- Individuals have to come to the site to train, posing barriers for people out of the region and for people with additional duties, such as childcare responsibilities.
- While the site can be designed with low-skill individuals in mind, the operation of heavy machinery always carries some health and safety risks. However, education in this regard is a key deliverable, and needs to be learned before an individual can enter a job site.
- Care needs to be taken that skills taught meet industry requirements, and it is important to reinforce successful transitions between the campus and the workplace.

Method 3: Examples

Examples include:

- Major Oaks Safety Training (cater to industry with a user pays model, currently small-scale but with a proposal to expand)
- Watercare's Auckland site (small scale for Watercare's own training needs)
- Fulton Hogan / MSD / Accord Infrastructure Skills Centre (small-scale pilot)
- International Examples: This model is widely employed overseas, including some very large-scale centres, such as: The International Conference and Training Centre in the USA, the Construction Industry Training Board centres in the UK, Ritchie's Training Centre in Scotland, and the Construction Training Centre in Australia.

Method 4: Simulator training

This method involves the use of virtual or simulated environments to provide hands-on experience in a variety of construction settings. Simulators can be particularly effective at reproducing the operation of heavy machinery, such as cranes, excavators or bulldozers in an immersive setting. With appropriately constructed control systems, simulators can replicate the specific input methods and haptic feedback of a variety of heavy equipment, allowing individuals to train particular and transferable abilities in driving and controlling each vehicle. The environment is practically risk-free, allowing simulators to be used as tasters and inductions for zero-skill individuals. Simulators can also track a large number of metrics and outcomes, providing valuable feedback to enhance learning and making them useful tools for the assessment of current competencies.

Method 4: Pros

- Generally much cheaper to buy than real-world equipment, particularly when the ability of one simulator to replicate multiple different pieces of machinery is taken into account.
- Much easier to transport than real machinery.
- Simulators have very low health and safety risks, and no risks of trainees causing real-world damage.
- Simulators can be used to give zero-skill individuals a taster of the job or industry. Novelty and interest make them a useful recruitment tool and a way to increase exposure for a potential career path in civil construction.
- They are a safe way to recognise current competencies, and detailed feedback mechanisms make them useful training and assessment tools.

Method 4: Cons

- Simulators are not the real world, although the good ones are getting close, with very detailed immersion.
- Very good and very accurate simulators are expensive.
- Not all the training can be completed in a simulator. On-the-machine training is still needed to ensure accurate skill acquisition.

Method 4: Examples

Examples include:

Major Oaks Safety Training (In addition to a campus operation they also run simulator training)

Port Operations Crane Training (Simulator courses run at Auckland, Napier, and Nelson)

Method 5: Hire from overseas

This method involves hiring workers from foreign countries to fill job vacancies and skill shortages in the industry. Training occurs overseas in a number of settings, with a high degree of variability in skill sets between individuals trained in different environments, regulatory regimes, workplace cultures, and job-sites. This can make assessing competencies and comparing qualifications hard for employers and domestic accrediting bodies. It can also bring benefits with knowledge flows from overseas where the technical, practical, and regulatory frontier may be more advanced than in New Zealand. Due to more advanced or larger projects overseas, migrants might possess specialist skills which do not exist yet in New Zealand

Method 5: Pros

- This method is scalable, with a significant pool of potential overseas workers to draw on.
- Overseas workers may possess skills not available in New Zealand and may bring knowledge flows from overseas into New Zealand industries.
- If an individual with the appropriate skills can be found, and enticed to move to New Zealand at a suitable salary, then this method is a very low-cost and relatively quick way of 'training' new construction recruits, relying as it does on a company or institution overseas to have completed the training at some point in the past.

Method 5: Cons

- This method may have low resilience, as demonstrated by the border shutdown during Covid-19.
- In general, most individuals still require some specific on-the-job training, so this method is not training-free. There may be difficulty in performing significant training for individuals on temporary work visas
- Migrants are generally mobile and may decide to leave if conditions are better elsewhere. The existing workforce may also use this method to travel overseas. New Zealand is in an international competition for talent.
- Without suitable paths to permanent visas, family reunion, or support to integrate with the workforce or society, migrants on temporary visas may not remain in the country despite possessing skills in high demand.
- There may be difficulties recognising current competencies and qualifications earned overseas, which may cause issues for insurance and compliance with regulations. Migrant workers with unrecognised qualifications might be underutilised resulting in 'brain waste'. Alternatively, such workers may still perform skilled roles without the corresponding salary compensation.
- Without appropriate support and regulations, the potential for migrant workers to be exploited can be high.
- The time taken to reach, recruit, and onshore an overseas worker can be significant. Depending on the prevailing political and immigration environments, fulfilling visa and bureaucratic requirements may be burdensome for migrants and employers.

Method 5: Examples

Examples include:

- The significant recruitment drive and inflow of migrant construction workers following the Christchurch earthquakes.

3.2 The role of government and external agencies

There is a significant role for government and other non-industry agencies in facilitating civil construction training. As outlined in section 1, the skill shortages in the sector pose significant challenges to addressing the current infrastructure deficit and are likely impeding growth. As discussed in section 2 notable pressures and negative externalities are reducing the incentives for companies to train sufficient numbers of skilled workers for the overall needs of the industry. This lack of alignment between private and public benefits is in line with international evidence which shows that the societal return on investment for construction apprentices is higher than the private return on investment to the individual firm (Reed *et al.*, 2012; Manzo *et al.*, 2019).

The market failure to train enough skilled construction workers implies that gains can be made from an appropriate intervention from a public entity. Local governments and regional development councils have achieved some success in increasing the number of civil construction recruits through several pilot programs, however they lack the resources to scale up these initiatives (May and Bryant, 2022). Due to the high capital expenses involved with training civil construction recruits, traditional funding models under the TEC may be insufficient to cover the costs. Anecdotally, bureaucratic complications in accessing TEC funding can pose barriers to some training institutions, reducing their capabilities. MSD has funded successful schemes to transition unemployed individuals to employment through civil infrastructure training, however wide-scale funding for individuals other than the unemployed or other marginalised groups is limited. Given the national infrastructure deficit, an intervention by a national entity is a logical correction to the market failure.

New Zealand is behind the curve regarding civil construction training. Large campus training centres are in operation in the US[35], the EU[36], the UK[37] and Australia[38]. Many training organisations are run as non-profits, with multiple funding models depending on requirements. These include raising revenue through region-wide levees on construction activity in order to fund ongoing skill development and workforce recruitment. Similar to New Zealand, many of these regions also face constraints on strategic infrastructure construction due to skill shortages[39]. This has led some central and local governments

[35] See https://www.iuoe.org/training/international-training-and-education-center and https://heavyequipmentcollege.com/ for examples, accessed 05/06/23.
[36] See https://constructionblueprint.eu/partnership/construction-vet-providers/ for examples, accessed 05/06/23.
[37] See https://www.citb.co.uk/national-construction-college/, accessed 05/06/23.
[38] See https://ctc.qld.edu.au/, https://www.citc.com.au/, and https://constructiontraining.com.au/ for examples, accessed 05/06/23.
[39] See for example discussions in Karimi *et al.* (2018) and Infrastructure Australia (2021).

to cover training costs in full to encourage greater uptake of training services, with additional targeted funding to encourage women and marginalised groups to enter construction[40]. Early indicators suggest that these programs have significantly increased recruitment in some regions (Tasmanian Government, 2023). The civil apprenticeship systems are generally well developed with widespread uptake[41]. Where these programs are publicly funded, there is strong evidence of positive economic returns over and above the costs of providing the programs[42]. Finally, several entry-level and work-readiness courses provide potential new entrants or career-switches the requisite skills to be work-ready for a career in civil construction[43].

3.3 Funding structures

As touched on in the previous section, a number of different funding models exist to cover educational expenses. Conceptually, these systems generally fall into one of four categories outlined below. Note that many funding structures operate as a combination of the following modes:

3.3.1 Public funding

In numerous countries around the world, vocational education is partially or fully subsidised by government expenditure. This effectively represents a transfer from the wider economic system through taxation. The transfer is justified when the social return from education outweighs the costs. For construction vocational education, the return to the wider economy is estimated to be substantial. Reed *et al.* (2012) found that publicly funded apprentice programs, which cost an average of $720 USD in the year 2000, resulted in an average economic benefit to society of $59,000 USD over the subsequent 9 years post enrolment. Furthermore, funding can be targeted to achieve additional socially desirable outcomes, such as providing opportunities for marginalised and disadvantaged groups to re-train or engage with

[40] See for example the significant commitments to funding undertaken by the Victorian and Tasmanian state governments, at https://www.vic.gov.au/funding-and-grants and https://keystone.com.au/training/funding/ respectively, and the commitment to a pathways program for women and First Nations peoples to enter civil construction developed in Victoria, https://www.ccfvic.com.au/pathways/. URLs accessed 05/06/23.

[41] Data from https://www.apprenticeship.gov/data-and-statistics shows a steady year-on-year growth in apprentice numbers in the US. Apprenticeships are widely used in EU countries (Cedefop, 2021), and Australia, https://www.ncver.edu.au/news-and-events/media-releases/number-of-apprentices-and-trainees-in-training-continues-to-grow. URLs accessed 06/06/2023.

[42] See Reed *et al.* (2012) and Manzo *et al.* (2019).

[43] See https://holmesglen.edu.au/Courses/Building-and-Construction/Civil-Construction/Course-in-Civil-Construction-Pathway/ and https://www.iuoe.org/training/iuoe-job-corps for examples in Australia and the US respectively, URLs accessed 06/06/23.

the workforce[44], stimulating growth in specific industries, and ensuring availability of a skilled workforce for strategic infrastructure requirements. Centralised funding can mitigate the problems of aggregate under-provision of training, and of some firms being too small to undertake education.

A difficulty with this funding structure is that it can be hard for the government to know in advance what programs are likely to produce an economic return. Similarly, there may be less incentive for education providers to meet industry needs, since industry is not paying for the education services explicitly. In general, funding is geared towards incentives that service the bureaucracies providing the funding and education, which may not always align with the output industry desires. Furthermore, large public bureaucracies can be slow and unwieldy in the face of changing circumstances and industry requirements. Smaller private training providers may be more agile, and more motivated to change due to their profit incentive. In addition, when the taxation system is underdeveloped, the government may not be able to capture a significant enough proportion of the societal economic benefits to recoup its costs. Finally, since employers, students, and education providers may not face the full costs of training, 'over-consumption' of education may occur whereby programs are inflated with additional skills that are not required in order to justify higher fees, or individuals engage with programs that they are not suited to just because they are free at point-of-use. Well-designed education systems can take account of many of the issues raised above, and the gains to society may more than make up for any inefficiencies.

A subset of public funding is transfers via donations to an NGO or charity. Typically, these are designed to target a specific objective. For example, the Ara Education Charitable Trust's Māori and Pasifika Women in Construction project aims to build a pathway to construction for Māori and Pasifika women through training, experience, connections and support[45]. The benefits of such projects are that they can be highly focused and tailored to their objectives, make use of significant local knowledge, and leverage a variety of resources, connections, and donations from a number of individuals and entities to make a meaningful difference. The downside of this type of funding is that it is generally underfunded and under-resourced. Donations of money, time and equipment can be irregular and uncertain, which can prohibit long-term planning or the ability to deliver outcomes at scale. The reliance on donations also poses questions of fairness, with non-donating individuals able to free-ride on the societal benefit from the payments made by others. To the extent that the objectives of the charity are societally desirable

[44] Examples in New Zealand are the programs funded by the Ministry of Social Development to provide opportunities for unemployed individuals to gain entry-level skills and begin a career in construction.
[45] See https://www.araeducation.org.nz/pasifika-women-in-construction-project, accessed 30/09/2023.

and beneficial, this report considers general funding from a more comprehensive tax to be preferable to relying on donations from a handful of motivated individuals. In the absence of such a tax, funding via charitable organisations is generally better than nothing at all.

3.3.2 Indirect industry funding

Indirect industry funding involves raising levees or charges on industry participants to fund education in the sector. This report classifies the funding as indirect because it generally applies to all firms, regardless of whether they are currently taking on recruits or are actively engaged with training. This report also considers union-funded training to be a form of indirect industry funding. The rationale is that any union with enough resources to fund significant training in the sector will also likely be able to bid up wages through collective bargaining. The higher wages are paid for by industry and will, in part, go towards the high union fees required to maintain the training. In the circumstances where wages are not bid up by union action, then training funded via union fees represents indirect worker funding, and is more similar to public funding via a targeted tax aimed at just workers in that industry.

One example of funding via levees is the UK's Apprenticeship Levy, which is a yearly charge to most employers with an annual wage bill over £3 Million[46]. This is used to fund apprenticeship schemes, including in construction. In addition, the UK also has a specific levy raised by the Construction Industry Training Board, which is charged to all employers engaged wholly or mainly in construction activities, regardless of size[47]. This is used to support training development through grants and funding, promote the construction industry as a career, identify skill shortages, and develop occupational standards and qualifications. Both charges are calculated as a small percentage of the company's overall wage bill[48].

The benefits of tying the levy for training to wage bills are that the funding grows with employment in the industry, providing a signal to the education sector to broaden recruitment and training as the industry expands. These structures can incentivise industry to make use of their levees and engage in greater amounts of reskilling and upskilling of their workforce. It can also empower industry to exert much greater control over where the money goes, as compared to a less directly attributable transfer

[46] See https://www.gov.uk/guidance/pay-apprenticeship-levy, accessed 22/08/2023.
[47] See https://www.citb.co.uk/levy-grants-and-funding/citb-levy/, accessed 22/08/2023.
[48] In New Zealand, a similar scheme is used to fund academic research in the construction sector. The Building and Research Levy applies to 0.1% of the contract value of every construction project greater than $20,000 NZD and is payable by the builder. The funds are generally charged and collected by building consent authorities and paid to the Building Research Association of New Zealand (BRANZ), a research association which uses the funds to undertake and commission research, provide product testing assurance, and consultancy services. See https://www.branz.co.nz/about/, accessed 17/09/2023.

from general taxation. For example, some construction education in Victoria, Australia is funded through levees raised by the Construction, Forestry, Maritime, Mining and Energy Union. Suppliers of training services must be re-accredited every year by the union in order to be eligible for this funding. This means that the output from the training must be directly relevant to the industry participants, or else they will reallocate funding in the next period. This can mitigate the signalling and matching problems and help build trust in the education sector to provide for the industry's needs.

Additional benefits of a universal levy, applied as a small proportion of wage costs, are that it mitigates the problems: with poaching; with firms being too small to undertake training; and with the aggregate under-provision of training and recruitment. This is because all firms, regardless of whether they engage in training, contribute to an industry-wide education fund. This pool of resources can also be used more efficiently than with multiple small-scale training operations.

The downside of such schemes is that they can impose additional costs on firms that may already have tight margins. For firms that undertake a lot of training, the levy is likely to cost them less than they would otherwise need to spend on education. However, for firms that rely on recruiting already skilled workers, their costs will likely be higher than without the charge. Levees overseas are generally around 1-2% of a company's wage bill, so this cost may not be too onerous. Furthermore, if the pooling of resources improves the efficiency of the overall education system, training costs might decrease sufficiently for there to be a net benefit for the industry.

If the levy raises costs, it will generally be passed on to customers as marginally higher prices for construction, (although firms whose training costs have now decreased may be able to lower prices). An alternative funding system used in France, which achieves the same result, is to charge levees against each construction site and as a proportion of the total project value. In any case, the societal benefit from mitigating skill shortages and upskilling the construction workforce is likely to significantly outweigh any increase in construction costs.

3.3.3 Direct industry funding

Direct industry funding involves employers procuring training services directly to meet their staffing requirements. This can be achieved through in-house training, or through engaging with an external provider. The benefits of this system are that it is efficient at the firm level, because companies only pay for the training they need, and education providers must produce outputs that are directly relevant

to the industry. However, as detailed extensively in this report, relying on firms to directly fund training results in an under-provision of training at the industry level. Small firms may lack the capacity to train, and uncertainty and high costs may reduce the willingness of larger firms to invest.

3.3.4 Direct student funding

Direct student funding involves the learner financing their own study. For example through fees up front, or a direct tax on their future earnings in the form of a student loan. This method is justified on the assumption that the learner's earning potential will increase as they invest in their human capital through education. Individuals can then use a portion of this increase in earnings to cover the expense of their education. Note that Reed *et al.* (2012) find that the lifetime earnings of civil construction apprentices are significantly higher than for similar individuals who do not undertake apprenticeship training.

One benefit of this system is that learners may be more motivated and more selective of courses when their own money is on the line. However, a downside is that it expects individuals who are generally young and inexperienced to choose and fund an education and career path without full information on the potential outcomes, or if the path is even suitable for them. Learners may stick with a poor choice due to the sunk-cost fallacy of money they've already spent[49], or because they can't afford to swap to another option. A further problem is that it either requires individuals to have money available now, or take on significant debt, in exchange for a promise of potential future earnings.

In addition, the lifetime earnings of an apprentice are higher than non-apprentices because the individual is more skilled. Their increased salary is reflective of the increased benefits they provide to their employer, and they contribute more tax with their higher incomes. A core thesis of this report is that a skilled workforce is also of significant value to society, and is currently being under-provided at an industry scale in construction in New Zealand. Both of which justify significant public funding. In this context it seems illogical that funding for vocational education should be taken solely from the private return to the individual from their training, when that return: is based on the gains the individual provides to their employer; is taxed; and doesn't include the wider economic benefit their education provides to industry or society as a whole.

[49] The 'sunk-cost fallacy' is the irrational behaviour of 'throwing good money after bad'. Logically, if a course of action becomes unprofitable going forward, then individuals should cease that action or change course, no matter how much time, money or effort has been invested to date. Previous costs are 'sunk' and should be ignored. However, studies show that individuals are more likely to stick with an unprofitable course of action when they have already invested significant resources into it. For an example, see Haita-Falah (2017).

4 Recommendations

There is unlikely to be a one-size-fits-all approach to solving the current skills shortage. The development of a civil worker is a long-term, ongoing process requiring sustainable mechanisms for entry to industry, initial skill acquisition, and continuous professional development. This report has identified four key areas to target:

1. **Significant and ongoing engagement with industry**. Many of the issues raised in this report are things civil construction firms have been saying for years. Industry voices need to be amplified and integrated with any proposed solution to these problems so that their needs are met. Collaboration is required with regular feedback loops to identify changing industry needs and to develop and update training programs accordingly. Communication is also a two-way street, with a need for targeted and informed recommendations to enable industry to take advantage of a more diverse workforce with alternative expectations around working hours and work-life balance.

2. **Substantial and sustained funding at scale** to develop multiple training options. The significant public benefit justifies public funding, either through a transfer from taxation, or an industry-wide levy, as discussed in section 3.3. This report recommends substantial industry involvement to help direct these funds to the most effective uses and fulfil industry needs. This could take the form of reviewing and accrediting the major educational institutions on an ongoing basis. When assessing program performance, completion rates should have reduced focus, while a greater emphasis should be placed on post-study outcomes and employability. The core goal is the alignment of education outcomes with industry requirements**.**

3. **A large campus for training at scale on civil construction equipment and heavy machinery.** One of the primary reasons for underinvestment at the industry level in education is high costs. This is, in part, due to high capital costs in training individuals on large and specialised machinery. One or more dedicated campuses are a key component in helping address this underinvestment, and are the norm in training structures overseas. Industry needs better options for civil training and there is a clear gap in the programs offered by the tertiary sector that misses education on large and complex equipment. Civil construction firms in New Zealand, unacquainted with this method, may need reassurance about the capability of educational campuses to replicate an actual worksite accurately. The location choice and relative accessibility of the site also needs careful consideration to minimise potential barriers. Finally,

distributed service delivery may also be a promising avenue. This is where some of the capabilities of a large campus are designed to be mobile, providing resources for pop-up training locations close to where services are required. Investigation of the significant employment of such facilities overseas can help provide a suitable template for New Zealand.

4. **An integrated training pathway**. The large campus would sit inside of an integrated training pathway. Education should move away from isolated projects and disjointed training and focus on construction vocational education as a cohesive whole. This is discussed more in the following section.

4.1 An integrated training pathway

A key goal should be to establish an integrated pathway which can onboard recruits to civil construction from a variety of sources, backgrounds, and skill levels, and progress these recruits through to the competencies and skills that are in high demand in industry. A coordinated approach is required that scales up successful pilot programs regionally and retains, supports, and disseminates the knowledge developed. Engagement and buy-in from industry is necessary at each step of the process.

A plan for an integrated training pipeline could function as follows:

Initial Exposure High-engagement drivers such as simulators and heavy equipment should be showcased at schools, career days, and community events. Current recruitment programs for unemployed and marginalised individuals should be expanded. Advertisement and communication of demand and opportunities in the industry should be increased, along with potential career trajectories. A focus should be on reaching and engaging with women and other under-represented groups. Importantly, the nature of construction work should be made clear upfront, along with the rewards for this type of work, and what the next steps are in recruitment. Networking events should reduce the reliance on informal networks.

Work Readiness For individuals with limited skills and experience, or who need help transitioning to employment, induction and work-readiness courses should provide basic experience and skills such as: site-awareness; health and safety; communication; and assistance with consistency, reliability, and time management. Additional pastoral care should be provided to those who require it, along with assistance to acquire a full driver's licence if needed. The location for training could be at regional or local skill centres, or a large campus or polytechnic. The training opportunities should be readily available and

consistently implemented across New Zealand.

Entry-Level Training For work-ready individuals, entry-level training should be facilitated at either an education provider, (such as a local skills centre, a large campus or a polytechnic), or thorough on-the-job training through employers prepared to take on a cohort of new entrants, for example as part of a tender for a large infrastructure project. This training would focus on entry-level skills in tools and techniques in the field, and on health, safety and environmental requirements for industry, along with the ability to work well in a team. Screening should be most prevalent at this stage to identify individuals not suited to civil construction and to encourage and facilitate a transition to other industries and employment. Once again training opportunities for civil construction need to be ubiquitous and consistently applied across the regions of New Zealand.

Skill Development For skilled and semi-skilled individuals, this training should provide further skill growth and development on more advanced equipment. This could take place through intensive programs on skill campuses and simulators or through traditional apprenticeships. This step, along with the previous steps, should screen for individuals not matched to industry requirements, so that employers have strong trust in, and engagement with, the apprenticeship programs. Further skills and competencies can continue to be improved through subsequent courses as an individual's career in construction continues to develop.

An important note needs to be made regarding the process of screening for unsuitable potential employees. While this screening must be sufficient for industry to value and engage with the qualification process, it must not be overly strict. Care must be taken to ensure that assessments of suitability are not subjective, or biased by the assessor's prior beliefs, culture, or expectations. Recognition is needed of the multiple ways of learning and skill development, and accommodations should be made for individual circumstances and the short and long-term challenges each learner may be facing. Developing multiple pathways for success can help in this regard. An individual may not be suited to campus-based learning, but may thrive in workplace training. Similarly, they may not match the culture at one institution, or the match with one supervisor, but may excel in an alternative environment. Finally, they may have tried courses unsuccessfully in the past, but changing life circumstances means that they are now able to succeed. Dropping-out, transferring between programs or supervisors, retraining, or repeating courses at different times, should be normalised as part of the 'matching' process of education, as should trying

different education pathways. Individuals should have multiple opportunities and should be encouraged and facilitated to explore these options.

Additional support may be needed to improve gender diversity in the sector and to reach previously untapped pools of talent. This may take the form of encouraging companies to provide facilities for women on job-sites or it could be through working with employers to re-design workplaces and roles to accommodate less extreme working hours with more flexibility. Support for childcare and caring responsibilities will also provide access for a greater number of individuals. Free communal transport to and from job-sites can overcome logistic barriers, particularly for more remote work.

Finally, cultural and social barriers to progression need to be investigated and addressed. For example, anecdotal evidence suggests that, until they ask explicitly for specific duties, apprentices are often not given all the relevant jobs that will further their qualification process. However, it appears that pākehā apprentices are generally more confident and comfortable making these requests when compared to Māori and Pasifika trainees. Furthermore, anecdotal reports suggest that pākehā apprentices often have an easier time finding placements at alternative job-sites when the opportunity to acquire the relevant skill is lacking in their current workplace. The extent of this problem needs further investigation, with appropriate structural remedies developed as required, so that workplace training progresses efficiently for all individuals.

4.2 Current Stakeholders

4.2.1 WDCs, education providers, funders and accreditors

The WDCs and the education system have an important role to play in addressing some of the issues raised in this report. A key focus should be ensuring qualifications are a reliable signal that a person is suitable for the role in industry by centring the voice of industry in the education process and holistically assessing outcomes. This could entail a greater investigation of post-study outcomes and a focus on the performance of an individual in industry as an indicator of the quality of their learning.

More extensive use of capstone assessments may be used to further evaluate well-rounded individuals. Learners currently receive qualifications showing that they have been assessed on skill X and skill Y, but there is minimal assessment of whether they are capable of knowing when to use one skill or the other.

Additional responsibilities for the WDCs and the education system could be to evaluate the ability of workplace training providers to deliver and assess the qualifications prior to training taking place.

Often instructors and assessors are skilled or senior practitioners, but little consideration is given to their skills as educators and evaluators. Furthermore, little assessment is made to determine if the range of equipment and tasks available at a given business meets all the requirements for a learner to achieve a given qualification. Arrangements for learners to move to other businesses to fill experience gaps need to be formalised, documented, and funded prior to study commencing. This should aim to ensure consistency and avoid learners being stuck if circumstances change. Consistent gaps or limited equipment availability, e.g. on the most specialised machinery, should be noted as this equipment may be a high priority for adding to a dedicated civil industry school, rather than relying on the few industry partners who operate this gear to train all recruits. In addition, moderating workplace examinations is labour-intensive. Additional resources may need to be directed to Te Pūkenga to ensure appropriate assessments can take place.

Engagement with industry training providers should help identify: why they don't participate in some funding structures; if this is contributing to an under-provision of skilled recruits; and what changes need to be made to streamline the process for applying for funding. In addition, there appear to be only a few sub-contracting relationships with Māori training providers, some of which are primarily pastoral-focused. Discussions can help ascertain how might existing providers enter this space, how can they be engaged, and what different approaches might these providers bring in terms of teaching and assessment.

4.2.2 Industry partners

Industry partners should have a strong voice in shaping the requirements the WDCs are providing. The WDCs are aiming to fill training gaps and provide advice on what TEC should fund, writing skill standards and assisting NZQA with qualifications. This needs to be guided by industry requirements, which requires significant engagement from members of the construction sector.

Part of this engagement should indicate what would increase trust in the outputs from Te Pūkenga and the wider education sector. When improvements are made, the large firms need to make use of the new system, so that it signals to the smaller players that they should engage with it. Further input is required to determine what decision-making skills are in demand on job-sties in order to design relevant capstone assessments.

4.2.3 Government ministries and regional and local governments

Ministries such as MSD have targeted funding to assist unemployed individuals to enter the industry and are willing to support connection with learning and development opportunities. While this is a valuable component of the education system, it does not satisfy the entirety of industry needs due to being only one source of talent. There is a current lack of funding from other agencies to support other career-changers entering the sector or for ongoing development for individuals other than marginalised groups. Given that the pressing infrastructure deficit may be exacerbated by skill shortages in the construction sector, it would be within the remit of a number of ministries to help address these issues. Ideally, a single, sustained source of funding would provide for the bulk of education requirements.

Regional and local governments have funded a number of small-scale schemes designed to improve outcomes for construction education in their region, stimulate the local economy, and improve local employment. Such schemes offer a chance for innovation and to meet local or regional objectives. A coordinated approach is required to incorporate the lessons from successful pilots, disseminate this knowledge to other regions, and scale up the processes to a national level where appropriate.

5 Conclusion

This report underscores the urgency and critical nature of addressing the skills shortage in New Zealand's civil construction industry. The challenges faced by the industry are substantial. Persistent skill shortages are exacerbated by an ageing workforce, low gender diversity, and an underinvestment in training opportunities. These are constraining growth in the sector and hindering the response to the infrastructure deficit. This problem is expected to worsen over time. Immediate, coordinated, and sustained action is required to prevent further delays and challenges in meeting the country's critical infrastructure demands.

While industry has consistently expressed concerns about skills shortages, little progress has been made in addressing the issue over the years. It is crucial that industry stakeholders are set up both to be heard and actively involved in shaping and implementing solutions. Effective communication and collaboration between industry representatives, policymakers, and training institutions are imperative to ensure that the industry's needs are met.

The factors behind an underinvestment in training are endemic to civil construction. High training costs, signalling problems (difficulty in assessing trainee quality), matching difficulties (mismatch in

expectations and inflexible work models), and an uncertain project pipeline for individual firms reduce the incentives and capability to undertake training. This report identifies a number of options to help alleviate these factors.

One of the key recommendations is the establishment of one or more large training campuses dedicated to civil construction equipment. These campuses are essential to bridge the investment gap in education and provide access to vital resources for training. It is important to align intake capacities with the needs of the industry pipeline, ensuring that the right number of skilled workers enter the workforce when required.

Significant and sustained funding is necessary to sufficiently resource training opportunities. This funding is best collected from communal sources, such as taxation or industry-wide levies, with a focus on directing these funds to the most effective and relevant training programs using significant input from industry partners. The success of such programs should be judged based on post-study outcomes, to align education outcomes with industry requirements.

There is no one-size-fits-all solution to the skills shortage in the civil construction industry. However, there is substantial desire and enthusiasm in this space to make improvements and drive change. By addressing the key issues raised in this report and fostering strong industry partnerships, New Zealand's civil construction sector can overcome its current challenges and thrive in the future.

References

ACE New Zealand (2021): 'Skills Shortage, Recruitment and Immigration Challenges in the Construction Sector', ACE New Zealand, https://assets.nationbuilder.com/acenz/pages/1837/attachments/original/1628110740/2021_4_August_Industry_Partners_MIQ_survey_Report_V6_FINAL.pdf.

Agapiou, A. (2002): 'Perceptions of gender roles and attitudes toward work among male and female operatives in the Scottish construction industry', *Construction Management and Economics*, 20(8), 697–705, http://dx.doi.org/10.1080/0144619021000024989.

Albattah, M. A., Goodrum, P. M., and Taylor, T. R. B. (2015): 'Demographic influences on construction craft shortages in the U. S. and Canada', in '5th International / 11th Construction Specialty Conference', 169–176, http://dx.doi.org/10.14288/1.0076372.

Allan, N., Yin, Y., and Scheepbouwer, E. (2008): 'A Study into the Cyclical Performance of the New Zealand Construction Industry', CAENZ, New Zealand Centre for Advanced Engineering, http://hdl.handle.net/10092/11524.

Apatov, E. and Sundaram, A. (2020): 'Immigration and 'Brain Waste': an analysis of APEC immigrants in New Zealand', *Policy Quarterly*, 16(4), 50–58, http://dx.doi.org/10.26686/pq.v16i4.6630.

Ayodele, O. A., Chang-Richards, Y., and González, V. A. (2022): 'A framework for addressing construction labour turnover in New Zealand', *Engineering, Construction and Architectural Management*, 29(2), 601–618, http://dx.doi.org/10.1108/ECAM-05-2020-0358.

Bridges, D., Wulff, E., Bamberry, L., Krivokapic-Skoko, B., and Jenkins, S. (2020): 'Negotiating gender in the male-dominated skilled trades: a systematic literature review', *Construction Management and Economics*, 38(10), 894–916, http://dx.doi.org/10.1080/01446193.2020.1762906.

Brossoit, R. M., Crain, T. L., Leslie, J. J., Hammer, L. B., Truxillo, D. M., and Bodner, T. E. (2019): 'The effects of sleep on workplace cognitive failure and safety.', *Journal of Occupational Health Psychology*, 24(4), 411–422, http://dx.doi.org/10.1037/ocp0000139.

Brucker Juricic, B., Galic, M., and Marenjak, S. (2021): 'Review of the Construction Labour Demand and Shortages in the EU', *Buildings*, 11(1), 17, http://dx.doi.org/10.3390/buildings11010017.

Byrne, J., Clarke, L., and Van Der Meer, M. (2005): 'Gender and ethnic minority exclusion from skilled occupations in construction: a Western European comparison', *Construction Management and Economics*, 23(10), 1025–1034, http://dx.doi.org/10.1080/01446190500310759.

Caicedo, S., Espinosa, M., and Seibold, A. (2022): 'Unwilling to Train? - Firm Responses to the Colombian Apprenticeship Regulation', *Econometrica*, 90(2), 507–550, http://dx.doi.org/10.3982/ECTA18911.

CCNZ (2021): 'Construction Industry Survey', , Civil Contractors New Zealand, https://civilcontractors.co.nz/Pages/SYSTEM/Utility/Download.aspx?id=adbf4bf4-ec01-41e3-862a-139d31090b3f.

CCNZ (2022): 'Construction Industry Survey', Civil Contractors New Zealand, https://civilcontractors.co.nz/Pages/SYSTEM/Utility/Download.aspx?id=fa9b7f82-40ac-4c33-8fa5-0d381a1824a3.

CCNZ (2023): 'Construction Industry Survey', , Civil Contractors New Zealand, https://civilcontractors.co.nz/Pages/SYSTEM/Utility/Download.aspx?id=1c6f13fa-a1fd-4ded-b995-dfe48815dee1.

Cedefop (2021): 'How many apprentices are there in the EU?', Luxembourg: Publications Office., http://data.europa.eu/doi/10.2801/786704.

Chang-Richards, Y., Wilkinson, S., Seville, E., and Brunsdon, D. (2017): 'Effects of a major disaster on skills shortages in the construction industry: Lessons learned from New Zealand', *Engineering, Construction and Architectural Management*, 24(1), 2–20, http://dx.doi.org/10.1108/ECAM-03-2014-0044.

Coleman, A. and Karagedikli, Ö. (2018): 'A Note on Construction Worker Migration to New Zealand 1962-2018', Reserve Bank of New Zealand Analytical Note Series, AN2018/08, Reserve Bank of New Zealand, https://www.productivity.govt.nz/assets/Research/636d124c56/A-Note-on-Construction-Worker-Migration-to-New-Zealand-1962-2018.pdf.

Czopp, A. M., Kay, A. C., and Cheryan, S. (2015): 'Positive Stereotypes Are Pervasive and Powerful', *Perspectives on Psychological Science*, 10(4), 451–463, http://dx.doi.org/10.1177/1745691615588091.

Daniel, E. I., Oshodi, O. S., Gyoh, L., and Chinyio, E. (2019): 'Apprenticeship for craftspeople in the construction industry: a state-of-the-art review', *Education + Training*, 62(2), 159–183, http://dx.doi.org/10.1108/ET-02-2019-0041.

Detsimas, N., Coffey, V., Sadiqi, Z., and Li, M. (2016): 'Workplace training and generic and technical skill development in the Australian construction industry', *Journal of Management Development*, 35(4), 486–504, http://dx.doi.org/10.1108/JMD-05-2015-0073.

Diamond, P. A. (1982): 'Wage Determination and Efficiency in Search Equilibrium', *The Review of Economic Studies*, 49(2), 217–227, http://dx.doi.org/10.2307/2297271.

Doan, D. T., GhaffarianHoseini, A., Naismith, N., Ghaffarianhoseini, A., Zhang, T., and Tookey, J. (2021): 'Examining critical perspectives on Building Information Modelling (BIM) adoption in New Zealand', *Smart and Sustainable Built Environment*, 10(4), 594–615, http://dx.doi.org/10.1108/SASBE-04-2020-0043.

Durdyev, S. and Hosseini, M. R. (2020): 'Causes of delays on construction projects: a comprehensive list', *International Journal of Managing Projects in Business*, 13(1), 20–46, http://dx.doi.org/10.1108/IJMPB-09-2018-0178.

Dzeng, R.-J., Lin, C.-T., and Fang, Y.-C. (2016): 'Using eye-tracker to compare search patterns between experienced and novice workers for site hazard identification', *Safety Science*, 82, 56–67, http://dx.doi.org/10.1016/j.ssci.2015.08.008.

Fernando, P. G. D., Fernando, N. G., and Gunarathna, L. M. A. C. (2016): 'Skills Developments of Labourers to Achieve the Successful Project Delivery in the Sri Lankan Construction Industry', *Civil and Environmental Research*, 8(5), 86–97, https://researchportal.northumbria.ac.uk/en/publications/skills-developments-of-labourers-to-achieve-the-successful-projec.

Forcael, E., Ferrari, I., Opazo-Vega, A., and Pulido-Arcas, J. A. (2020): 'Construction 4.0: A Literature Review', *Sustainability*, 12(22), 9755, http://dx.doi.org/10.3390/su12229755.

George, M. and Loosemore, M. (2019): 'Site operatives' attitudes towards traditional masculinity ideology in the Australian construction industry', *Construction Management and Economics*, 37(8), 419–432, http://dx.doi.org/10.1080/01446193.2018.1535713.

Haig, R. (2004): 'Age Trends in the New Zealand and Australian Trades Workforce 1991 to 2001', *Labour, Employment and Work in New Zealand*, http://dx.doi.org/10.26686/lew.v0i0.1295.

Haita-Falah, C. (2017): 'Sunk-cost fallacy and cognitive ability in individual decision-making', *Journal of Economic Psychology*, 58, 44–59, http://dx.doi.org/10.1016/j.joep.2016.12.001.

Hanna, A. S., Taylor, C. S., and Sullivan, K. T. (2005): 'Impact of Extended Overtime on Construction Labor Productivity', *Journal of Construction Engineering and Management*, 131, 734–739, http://dx.doi.org/10.1061/(ASCE)0733-9364(2005)131:6(734).

Hasan, A., Baroudi, B., Elmualim, A., and Rameezdeen, R. (2018): 'Factors affecting construction productivity: a 30 year systematic review', *Engineering, Construction and Architectural Management*, 25(7), 916–937, http://dx.doi.org/10.1108/ECAM-02-2017-0035.

Ho, P. H. K. (2016): 'Labour and skill shortages in Hong Kong's construction industry', *Engineering, Construction and Architectural Management*, 23(4), 533–550, http://dx.doi.org/10.1108/ECAM-12-2014-0165.

Hyman, P. (2017): *Hopes Dashed?: The Economics of Gender Inequality*, Bridget Williams Books, http://dx.doi.org/10.7810/9780994135469.

Infrastructure Australia (2021): 'Infrastructure workforce and skills supply - A report from Infrastructure Australia's Market Capacity Program', October, https://www.infrastructureaustralia.gov.au/sites/default/files/2021-11/InfrastructureWorkforceandSkillsSupplyreport211117.pdf.

Jaffe, A. B. and Chappell, N. (2018): 'Worker Flows, Entry, and Productivity in New Zealand's Construction Industry', Motu Working Paper 18-02, Motu Economic and Public Policy Research, http://dx.doi.org/10.2139/ssrn.3164043.

Karimi, H., Taylor, T. R. B., Dadi, G. B., Goodrum, P. M., and Srinivasan, C. (2018): 'Impact of Skilled Labor Availability on Construction Project Cost Performance', *Journal of Construction Engineering and Management*, 144(7), 1–10, http://dx.doi.org/10.1061/(ASCE)CO.1943-7862.0001512.

Kay, A. C., Day, M. V., Zanna, M. P., and Nussbaum, A. D. (2013): 'The insidious (and ironic) effects of positive stereotypes', *Journal of Experimental Social Psychology*, 49(2), 287–291, http://dx.doi.org/10.1016/j.jesp.2012.11.003.

Kelly, M., Wilkinson, L., Pisciotta, M., and Williams, L. S. (2015): 'When Working Hard Is Not Enough for Female and Racial/Ethnic Minority Apprentices in the Highway Trades', *Sociological Forum*, 30(2), 415–438, http://dx.doi.org/10.1111/socf.12169.

Kitching, J. and Blackburn, R. (2002): 'The Nature of Training and Motivation to Train in Small Firms', Research Report RR330, Small Business Research Centre, Kingston University, http://dera.ioe.ac.uk/4691/1/RR330.pdf.

Lee, W., Migliaccio, G. C., Lin, K.-Y., and Seto, E. Y. (2020): 'Workforce development: understanding task-level job demands-resources, burnout, and performance in unskilled construction workers', *Safety Science*, 123(April 2019), http://dx.doi.org/10.1016/j.ssci.2019.104577.

Lerman, R. (2019): 'Do firms benefit from apprenticeship investments?', *IZA World of Labor*, (October), 1–11, http://dx.doi.org/10.15185/izawol.55.v2.

Lessing, B., Thurnell, D., and Durdyev, S. (2017): 'Main Factors Causing Delays in Large Construction', *Journal of Management, Economics, and Industrial Organization,*, 1(2), 63–82, https://ssrn.com/abstract=3044315.

Likita, A. J., Jelodar, M. B., Vishnupriya, V., Rotimi, J. O. B., and Vilasini, N. (2022): 'Lean and BIM Implementation Barriers in New Zealand Construction Practice', *Buildings*, 12(10), 1645, http://dx.doi.org/10.3390/buildings12101645.

Lingard, H., Nette, A., Harley, J., Pirzadeh, P., Clarke, J., Yazidjoglou, A., Strazdins, L., and Sargent, G. M. (2021): 'Triple Wins: Work Hour Cultures for Health, Safety and Gender Equality in Construction', Construction Work Health and Safety Research, RMIT University, https://www.rmit.edu.au/content/dam/rmit/au/en/research/networks-centres-groups/cwhsr/triple-wins-april-2021.4.pdf.

Lobo, Y. B. and Wilkinson, S. (2008): 'New approaches to solving the skills shortages in the New Zealand construction industry', *Engineering, Construction and Architectural Management*, 15(1), 42–53, http://dx.doi.org/10.1108/09699980810842052.

Loosemore, M., Alkilani, S., and Mathenge, R. (2020): 'The risks of and barriers to social procurement in construction: a supply chain perspective', *Construction Management and Economics*, 38(6), 552–569, http://dx.doi.org/10.1080/01446193.2019.1687923.

Loosemore, M., Alkilani, S. Z., and Hammad, A. W. (2022): 'Barriers to employment for refugees seeking work in the Australian construction industry: an exploratory study', *Engineering, Construction and Architectural Management*, 29(2), 619–642, http://dx.doi.org/10.1108/ECAM-08-2020-0664.

Manzo, J., Manzo, F., and Bruno, R. (2019): 'The Impact of Construction Apprenticeship Programs in Minnesota: a ROI Analysis', https://mntrades.org/wp-content/uploads/2019/10/mepi-uiuc-impact-of-apprenticeships-programs-in-minnesota-final.pdf.

May, F. and Bryant, J. (2022): 'Developing a skilled civil construction workforce', Civil Contractors New Zealand, https://civilcontractors.co.nz/filescust/CMS/Documents/Developing_a_Skilled_Civil_Construction_Workforce_final_report.pdf.

MBIE (2021): 'Introduction to construction sector workforce issues', August, Hīkina Whakatutuki - Ministry of Business, Innovation and Employment, https://www.mbie.govt.nz/dmsdocument/19152-introduction-to-construction-sector-workforce-issues.

MBIE (2022a): 'Building and Construction Sector Trends - Annual Report', Hīkina Whakatutuki - Ministry of Business, Innovation and Employment, https://www.mbie.govt.nz/dmsdocument/16973-building-and-construction-sector-trends-annual-report-2021-pdf.

MBIE (2022b): 'National Construction Pipeline Report 2022: A Forcast of Building and Construction Activity', Hīkina Whakatutuki - Ministry of Business, Innovation and Employment, https://www.mbie.govt.nz/dmsdocument/23241-national-construction-pipeline-report-2022.

Meehan, L., Mitchell, L., and Pacheco, G. (2023): 'A note on KiwiSaver and migrants on temporary visas', *New Zealand Economic Papers*, 57(1), 9–17, http://dx.doi.org/10.1080/00779954.2022.2134813.

Meehan, L., Pacheco, G., and Turcu, A. (2022): 'Underutilised workers in New Zealand', New Zealand Work Research Institute, https://workresearch.aut.ac.nz/__data/assets/pdf_file/0008/725228/Underutilisation-Report_Final_051022.pdf.

Meyer, J. (2011): 'Workforce age and technology adoption in small and medium-sized service firms', *Small Business Economics*, 37(3), 305–324, http://dx.doi.org/10.1007/s11187-009-9246-y.

Monti, A. (2020): 'Re-emigration of foreign-born residents from Sweden: 1990-2015', *Population, Space and Place*, 26(2), http://dx.doi.org/10.1002/psp.2285.

Morrison, E. and Thurnell, D. (2012): 'Working hours in a large New Zealand Construction Company', in Smith, S. D. (ed.) 'Procs 28th Annual ARCOM Conference', Association of Researchers in Construction, Edingburgh, http://hdl.handle.net/10652/2449.

Mortensen, D. T. (1982): 'The Matching Process as a Noncooperative Bargaining Game', in McCall, J. J. (ed.) 'The Economics of Information and Uncertainty', University of Chicago Press, 233–258, http://www.nber.org/chapters/c4437.

Muehlemann, S. and Wolter, S. C. (2014): 'Return on investment of apprenticeship systems for enterprises: Evidence from cost-benefit analyses', *IZA Journal of Labor Policy*, 3(1), 25, http://dx.doi.org/10.1186/2193-9004-3-25.

New Zealand Infrastructure Commission (2021): 'Investment gap or efficiency gap? Benchmarking New Zealand's investment in infrastructure', December, Te Waihanga - New Zealand Infrastructure Commission, https://www.tewaihanga.govt.nz/assets/Uploads/Infrastructure-Challenge-Report.pdf.

New Zealand Infrastructure Commission (2022a): 'Economic performance of New Zealand's construction industry', Te Waihanga - New Zealand Infrastructure Commission, https://tewaihanga.govt.nz/media/fsbjr2fh/economic-performance-of-new-zealands-construction-industry.pdf.

New Zealand Infrastructure Commission (2022b): 'Rautaki Hanganga o Aotearoa - New Zealand Infrastructure Strategy', New Zealand Infrastructure Commission / Te Waihanga, https://tewaihanga.govt.nz/the-strategy.

Nolan, T. (2005): 'Engaging with SMEs: Power, Politics and Communication', *International Journal of Sociology and Social Policy*, 25(8), 1–17, http://dx.doi.org/10.1108/01443330510629063.

Ojelade, A. and Paige, F. (2020): 'Virtual Reality Postural Training for Construction', in 'Construction Research Congress 2020: Safety, Workforce, and Education', American Society of Civil Engineers, Reston, VA, 565–573, http://dx.doi.org/10.1061/9780784482872.061.

Oo, B. L., Liu, X., and Lim, B. T. H. (2022): 'The experiences of tradeswomen in the Australian construction industry', *International Journal of Construction Management*, 22(8), 1408–1419, http://dx.doi.org/10.1080/15623599.2020.1717106.

Pissarides, C. A. (1985): 'Short-run equilibrium dynamics of unemployment, vacancies, and real wages', *American Economic Review*, 75(4), 676–690, http://www.jstor.org/stable/1821347.

Reed, D., Liu, A. Y.-H., Kleinman, R., Mastri, A., Reed, D., Sattar, S., and Ziegler, J. (2012): 'An effectiveness assessment and cost-benefit analysis of registered apprenticeship in 10 states', *Mathematica Policy Research Reports*, https://ideas.repec.org/p/mpr/mprres/1b5795d01e8a42239b3c98dcc1e1161a.html.

Schiff, A. (2022): 'Case study: Construction industry and migration', The Productivity Commission, https://www.productivity.govt.nz/assets/Documents/Case-study_Construction-and-migration.pdf.

Sense Partners (2021): 'New Zealand's infrastructure challenge: Quantifying the gap and path to close it', https://tewaihanga.govt.nz/media/lhhm5gou/new-zealands-infrastructure-challenge-quantifying-the-gap.pdf.

Sivam, A., Trasente, T., Karuppannan, S., and Chileshe, N. (2017): 'The impact of an ageing workforce on the construction industry in Australia', in Emuze, F. and Smallwood, J. (eds.) 'Valuing People in Construction', Routledge, London, chap. 5, 1st edn., http://dx.doi.org/doi.org/10.4324/9781315459936.

Smith, L. (2013): 'Trading in gender for women in trades: embodying hegemonic masculinity, femininity and being a gender hotrod', *Construction Management and Economics*, 31(8), 861–873, http://dx.doi.org/10.1080/01446193.2013.833339.

Spence, M. (1973): 'Job Market Signalling', *Quarterly Journal of Economics*, 87, 335–374, http://dx.doi.org/10.1016/B978-0-12-214850-7.50025-5.

Stockinger, B. and Zwick, T. (2017): 'Apprentice Poaching in Regional Labor Markets', Discussion Paper 17-013, ZEW-Centre for European Economic Research, http://dx.doi.org/10.2139/ssrn.2926358.

Tam, V. W., Shen, L., and Kong, J. S. (2011): 'Impacts of multi-layer chain subcontracting on project management performance', *International Journal of Project Management*, 29(1), 108–116, http://dx.doi.org/10.1016/j.ijproman.2010.01.005.

Tasmanian Government (2023): 'Training and Workforce Development System Performance Report 2023', Skills Tasmania, Department of State Growth, Tasmanian Goverment, https://www.skills.tas.gov.au/___data/assets/pdf_file/0010/440848/Skills_and_Training_2022_Performance_Report_April_2023_Final.pdf.

Tichon, J. and Diver, P. (2010): 'Plant operator simulation: Benefits and drawbacks for a construction training organization', *Cognition, Technology and Work*, 12(3), 219–229, http://dx.doi.org/10.1007/s10111-010-0140-9.

Tipper, A. (2012): 'Labour productivity, real wages, and workforce age structure', in '53rd New Zealand Association of Economists Conference', Palmerston North, https://www.nzae.org.nz/wp-content/uploads/2012/06/Tipper-productivity-real-wages-and-workforce-age-structure-final.pdf.

Torku, A., Bayrak, T., Ogunlana, S. O., Chan, A. P. C., and Owusu-Manu, D.-G. (2021): 'Are the Ageing Workforce Satisfied with the Construction Work Environment?', in Ahmed, S., Hampton, P., Azhar, S., D., and Saul, A. (eds.) 'Collaboration and Integration in Construction, Engineering, Management and Technology. Advances in Science, Technology and Innovation', 101–106, http://dx.doi.org/10.1007/978-3-030-48465-1_17.

Torshizian, E. and Maralani, M. (2022): 'Great Decisions are Timely: Benefits from more Efficient Infrastructure Investment Decision-Making', Infrastructure New Zealand, https://infrastructure.org.nz/wp-content/uploads/2022/10/Cost-of-delay-in-infrastructure-decisions-Principal-Economics-report-Oct-2022.pdf.

Turner, M., Holdsworth, S., Scott-Young, C. M., and Sandri, K. (2021): 'Resilience in a hostile workplace: the experience of women onsite in construction', *Construction Management and Economics*, 39(10), 839–852, http://dx.doi.org/10.1080/01446193.2021.1981958.

Vahdatikhaki, F., El Ammari, K., Langroodi, A. K., Miller, S., Hammad, A., and Doree, A. (2019): 'Beyond data visualization: A context-realistic construction equipment training simulators', *Automation in Construction*, 106, 102853, http://dx.doi.org/10.1016/j.autcon.2019.102853.

Viles, E., Rudeli, N. C., and Santilli, A. (2020): 'Causes of delay in construction projects: a quantitative analysis', *Engineering, Construction and Architectural Management*, 27(4), 917–935, http://dx.doi.org/10.1108/ECAM-01-2019-0024.

Waldman, M. (2016): 'The dual avenues of labor market signaling', *Labour Economics*, 41, 120–134, http://dx.doi.org/10.1016/j.labeco.2016.05.001.

Wang, X. and Dunston, P. S. (2005): 'Heavy Equipment Operator training via Virtual Modeling Technologies', in 'Construction Research Congress 2005', American Society of Civil Engineers, Reston, VA, 1–10, http://dx.doi.org/10.1061/40754(183)121.

Yusoff, N. S. M., Rahim, F. A. M., and Chuing, L. S. (2021): 'The Relationship of Skilled Labour Shortages and Project Performance in Construction Industry: A Conceptual Framework', *Journal of Project Management Practice*, 1(1), 1–21, http://dx.doi.org/10.22452/jpmp.vol1no1.1.