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# Gender diversity in construction: demystifying the pipeline leaks in Australia, United States, United Kingdom and Brazil

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## ABSTRACT

Globally, the construction industry is a key contributor to the gross domestic product. However, compared to the gender diversity performance of the workforce in the world economy, historically, construction has been performing significantly poorly. Literature argued that these consistently poor performances in diversity, equity and inclusion were causing leaks in the education and career pipeline. However, a systematic investigation with evidence base was lacking. In this vacuum, the proposed study aims to explore the evolution of gender dynamics within the construction sector in Australia, United States, United Kingdom, and Brazil through quantitative evidence. This study collected industry gender representation data, gender pay gaps and tertiary degrees conferred from government agencies in four countries: Australia, the United States, the United Kingdom and Brazil. Quantitative data analysis was conducted with an exploration of factual figures, significant trajectories and fluctuations. Results were explored to understand local jurisdictions' possible causal relationships and interventions. Delving into findings from the education pipeline revealed declining trends and alarming opportunities for the education institutions to take a lead role in moving from a "challenge leaky pipeline" towards a "shared solution space" through international cross-sectorial collaborations with the paradigm shift in the construction industry with the emerging fifth industrial revolution.

## ARTICLE HISTORY

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## KEYWORDS

Gender diversity; women in construction; diversity, equity and inclusion; construction management; leaky pipeline

## Introduction

Globally, women are equally represented in workforce of developed economies with 50% in the USA (Women's Bureau 2023), 48% in Australia (WGEA 2023) and 48% in the UK. A similar representation of female workforce is evident in advanced emerging economies. For example, 44% female participate in the labour market as legally recognised employees in Brazil (MTE (Ministério do Trabalho e Emprego), 2021).

Construction is one of the largest industries and a major contributor to the world economy. However, the construction industry was referred to as a "non-traditional" industry for working women for more than three decades (Arriola 1990, Edirisinghe et al. 2023). This happens despite the attention from academia and industry to address the gender segregation issue in the sector, which is often perceived as a "leaky pipeline" (Regis et al. 2019; Amir Naser et al. 2023; Edirisinghe et al. 2023; Hickey et al. 2023).

Global and national legislations pledge to achieve gender equality, see for example, the United Nations Sustainable Development Goal Number 5 and workplace gender equality legislation in Australia (Workplace Gender Equality Act, 2012). The general arguments for gender equality is often with the viewpoint of ethical and social justice woven around notions of fairness and equity (Galea et al. 2015) as well as equality (Amir Naser et al. 2023). An economic perspective was brought in a

recent report (Women's Economic Equality Taskforce 2023) to this gender inequality issue and evidenced that Australia is underutilising 50% of its economic potential. The report describes that removing the barriers to women's equal participation in economic activity will realise AU\$128 billion to the Australian economy.

Consistent barriers to gender diversity and inclusion in the construction industry create a 'leaks in the pipeline' (Regis et al. 2019; Lekchiri and Kamm 2020; Amir Naser et al. 2023; Edirisinghe et al. 2023; Hickey et al. 2023; Kakar and Hasan 2023). However, a holistic understanding of "leaky challenge pipeline" with the viewpoint of moving from problem to the solution is a research gap (Edirisinghe et al. 2023). This study, to the authors' best of knowledge is the first to investigate the issues in the whole pipeline across multiple countries to explore the trends. The paper aims to demystify the pipeline leaks through evidence base of quantitative data from four countries: Australia, USA, UK and Brazil and calls for collaborative practical strategies and action items for various stakeholders towards a proactive response. These countries were selected to represent the trends in developed economies and advanced emerging economies and also to represent countries with high interventions from the government to inflate the gender diversity in construction. The findings of this study will be useful to explore if the existing government measures such as changes in policy are effective in terms of improving gender diversity. The female

representation in the construction industry, construction related tertiary education were analysed and also compared with similar industries and high performing industries. The analysis also shed some lights on gender pay gaps in the industry.

The challenges which were widely studied in the literature are summarised in the literature review section below. The article presents the research methodology adopted in this study. The findings are discussed in the results section. The discussions section provides practical insights with the perspective of moving from problems to the solutions. Finally, the conclusions are presented.

## Literature review

### *Academic and career pipelines*

The gaps and call for action in promoting construction degree programs at early stages of education, including high schools, and need to raise awareness has been echoed for over a decade (Lopez del Puerto et al. 2011; Wilkes et al. 2015; Callanan and Perri 2020). Research studies explored women's "non-traditional degree" choices in construction management (Moore and Gloeckner 2007; Sewalk and Niefeld 2013; Bigelow et al. 2015; King-Lewis et al. 2021; Washington 2022) and highlighted the role of academia in not only promoting and recruiting but also retaining and supporting female students in those degree programs. Literature highlights the education institutions' role in addressing gender bias in education settings (Sewalk and Niefeld 2013) and the importance of promoting a positive culture and a positive peer network in degree programs, which significantly impacts female students' self-concept (King-Lewis et al. 2021). Skills development through internships in education programs (Moore and Gloeckner 2007; Powell et al. 2010; Baruah 2018; Oo et al. 2020) also helps building self-efficacy and confidence of female students.

With a contribution of gender bias from education institutions (Walker 2019), poor culture of the construction industry has been received enormous criticism over more than three decades (Arriola 1990; Menches and Abraham 2007; Ness 2012; Francis 2017; Galea et al. 2020; Tapia et al. 2020; Ghanbaripour et al. 2023) with women experiencing spectrum of negative incidents, ranging from gender discrimination to alleged sexual assault (Holdsworth et al. 2020; Nyanga and Chindanya 2020). Literature argued that "conflict and aggression" dominated in the industry (Menches and Abraham 2007; Loosemore and Galea 2008), lack of inclusion and diversity in organisational leadership (Galea et al. 2020; Hickey and Cui 2020), female unfriendly work environments (Ghanbaripour et al. 2023; Pamidimukkala and Kermanshachi 2023), nature of rough work (Ness 2012; Sunindijo and Kamardeen 2017), lack of opportunities for women, lack of career advancement and promotion for women (Francis 2017; Ghanbaripour et al. 2023; Pamidimukkala and Kermanshachi 2023) are significant challenges to achieve gender equality in the construction industry.

The poor public image of the construction industry is seriously reducing its appeal as a career for women and girls (Gale 1990; Fielden et al. 2000; Greed 2000; Fielden et al. 2001; Amaratunga et al. 2006; Arditi et al. 2013; Hasan et al. 2021). The hostile, male-dominated work environment, with high levels of gender stereotyping, job segregation, bad language and sexism (Fielden et al. 2001; Ksiazek and Nowak 2017; Sewalk and Niefeld 2013), is not an appealing picture for girls or women. Added to that are concerns over long and rigid work hours (Ling et al. 2016), harsh weather and work conditions (Ksiazek

and Nowak 2017), environmental insensitivity (Fielden et al. 2000), poor work practices (Fielden et al. 2000) and lack of job security (Ling et al. 2016). Apart from these work environment-related concerns are the financial considerations, with construction industry wages being seen as low compared to other industries (Ling et al. 2016). Gender pay gaps and absence of transparent pay structures and equitable pay at company and industry levels has received significant scholarly attention (Greed 2000; Galea et al. 2015; Ling et al. 2016; King et al. 2019; Karakhan et al. 2021) as a significant barrier to achieve gender equality in the construction industry. This is important, because career choice is often driven by pay (Oo et al. 2020). Further, while factors such as mentoring and networking have sometimes been found not to aid career satisfaction (Francis 2017; Morello et al. 2018), perceptions of equal pay and factors could improve women's job satisfaction (Dabke et al. 2008; Morello et al. 2018).

The continuous challenges were assumed to create 'leaks in the pipeline' (Lekchiri and Kamm 2020; Amir Naser et al. 2023; Edirisinghe et al. 2023; Hickey et al. 2023; Kakar and Hasan 2023). However, to date there is no evidence-based investigation such leaks through a quantitative analysis where women and girls drop out of the construction industry at different stages in their careers, beginning during their education their time in the industry. In addition, such pipeline investigation through an analysis of multiple countries is lacking.

## Research methodology

This paper aims to investigate the pipeline leaks through evidence base of quantitative data of female representation in the construction industry, higher education and gender pay gaps from four countries: Australia, USA, UK and Brazil. Based on convenient sampling the data collection was limited to the selected countries. The selected four countries will represent developed economies and advanced emerging economies and they have a high level of government intervention through policies to improve gender diversity in construction.

In this study, desk research was undertaken to explore the career and education pipeline in four countries: the UK, US, Australia, and Brazil. Desk research is the process of collecting existing data without direct contact between the researchers and research participants (Hoover Green and Cohen 2021). Desk research is best to use when demystifying historical events. This study as it tries to explore the leakages in the pipeline of construction female workforce through evidence based quantitative data in the selected four countries. Therefore, desk research best suited to investigate the trends in female representations in various sectors to propose recommendations in achieving gender equality.

### *Data collection*

In this study, data was collected through official government data sources both publicly available and privately maintained. Woolley (1992) stated that desk research can be conducted using official statistics and national agencies. The data relating to the career pipeline was collected from the Australian Bureau of Statistics, the US Bureau of Labour Statistics, the Office for National Statistics for the UK, and the RAIS data set for Brazil. The data collection period spans from 1985 to 2023, ensuring a comprehensive analysis of long-term trends in female representation within the construction sector. This temporal scope enables a thorough exploration of patterns and shifts in the participation of women in the construction industry across the specified countries.

Subsequently, the Australian Government Department of Education website and the National Centre for Education Statistics for the USA helped to source the education gender representation data. For Australia, data was obtained through an email request. The data collection period encompasses the relevant years necessary for the analysis of enrolments, enabling the examination of trends and patterns within the specified timeframe.

Regarding gender pay gaps, the primary data sources are the Workplace Gender Equality Agency (WGEA) for Australia, the Office for National Statistics (ONS) for the United Kingdom, and the Bureau of Labor Statistics (BLS) for the United States. In Australia, WGEA reports contribute to a comprehensive understanding of gender pay gaps. Similarly, the ONS website is a key repository for data on gender pay gaps in the United Kingdom. The BLS website is a primary source of information on average weekly earnings used to calculate the gender pay gaps in the United States. The data collection period spans annually, offering insights into gender pay gaps from 2013 to 2023, and facilitating analysis of trends over this significant timeframe.

### Data analysis

The data collected represents the factual figures of the female population within the construction sector. They were converted into percentages using the total construction workforce to compare between different countries and to interpret the findings more realistically. Subsequently, a visual representation was employed, as depicted in Figure 1, to illustrate the trends across Australia, the UK, the USA, and Brazil. Through examination of trajectories and fluctuations over the years, comparisons between these countries were done to discern patterns and variations. Additionally, the analysis explores potential factors contributing to declining trends to understand what influences female representation within the construction sector.

With the data gathered for different industries (i.e. mining, transport, manufacturing, agriculture, education, and health care) the percentages of the female population were calculated using the total workforce for each of the industries. The study followed the industry classifications according to the country specific standards. After calculating the percentages of the female population in each industry, the trend graphs were produced for comparable industries (i.e. mining, transport, manufacturing, agriculture) with construction and for high performing industries in terms of gender representation (i.e. education, and health care) separately. A detailed examination of trends and percentages allowed to discern industry-specific dynamics and variations. The data gathered for different degree programs were classified into: (a) construction education, (b) architectural and related services, (c) civil engineering, and (d) construction management and construction engineering. Subsequently, percentages for conferred female representation were calculated using the total conferred population for each of the identified disciplines.

The gender pay gap is typically defined as the difference between the average earnings of men and women within a workforce. The formula for calculating the gender pay gap percentage is:

$$\text{Gender Pay Gap \%} = \frac{(\text{Average Earnings of Men} - \text{Average Earnings of Women})}{\text{Average Earnings of Men}} \times 100$$

This formula expresses the difference as a percentage of the average earnings of men. A positive percentage indicates that, on

average, men earn more than women, while a negative percentage would suggest the opposite. It's important to note that this formula provides a broad overview and may not capture all nuances of the gender pay gap, such as variations across different job roles, industries, or levels within an organization. More detailed analyses may involve adjusting for factors like education, experience, and job responsibilities to provide a more accurate assessment. The formula is a starting point for understanding the overall disparity but may not account for the complexities that contribute to the gender pay gap. Therefore, in this study, the gender pay gaps were sourced from WGEA, ONS, and BLS as discussed above. The analysis involved examination of trends over the years to identify patterns and variations in gender pay gaps.

## Results

### Female representation in the construction industry

The examination of female representation in the construction industry is a critical lens through which one can gauge the progress and address challenges associated with gender diversity in the workforce. Figure 1 serves as a comprehensive visual representation, spanning from 1985 to 2021 over 37 years illustrating the trajectories of female percentages in the construction industry for the four distinct countries: Australia, the UK, the USA, and Brazil. This analysis seeks to unravel the nuanced trends within each country, offering valuable insights into the evolution of gender dynamics within the construction sector.

Australia's journey in terms of female representation in construction is marked by a consistent declining trend. Beginning at approximately 14% in 1985, according to the trend analysis, female percentage decreased to around 13% in 2023. According to Figure 1, Australia's female percentage in construction decreased from around 13% in 2001 to around 11% in 2017. This sustained reduction raises questions about the factors contributing to the diminishing presence of women in the Australian construction industry. However, a notable increasing trend is noticed after the minimum value of about 11% recorded in 2014 and 2017. The federal legislation, Workplace Gender Equality Act 2012 (Australian Government 2024) might have impacted this increase.

The United Kingdom emerges as a beacon of progress, showcasing a positive trajectory in female representation within the construction industry. The journey from around 13% in 1997 to approximately 15% in 2023 highlights a commitment to fostering gender diversity. However, this upward trajectory faced a minor setback in 2008 when the female percentage dipped from around 13% to approximately 11% in 2009. Despite this temporary decline, the UK rebounded in subsequent years, showcasing a continued commitment to advancing gender diversity in the construction sector. The detailed breakdown of percentages in various periods emphasizes incremental growth, portraying a comprehensive picture of the UK's efforts in this realm.

The United States exhibits a different pattern, characterized by relative stability in female representation in construction. Hovering around 10% for the majority of the years, the data indicates a consistent gender gap within the US construction industry. While there are minor fluctuations, such as a dip to around 9% in the early 2000s and a peak of around 11% in 2021, the overall trend remains relatively flat. An increasing trend is noticed from 2017. Through the passage of the Women, Peace, and Security Act of 2017, the United States became the

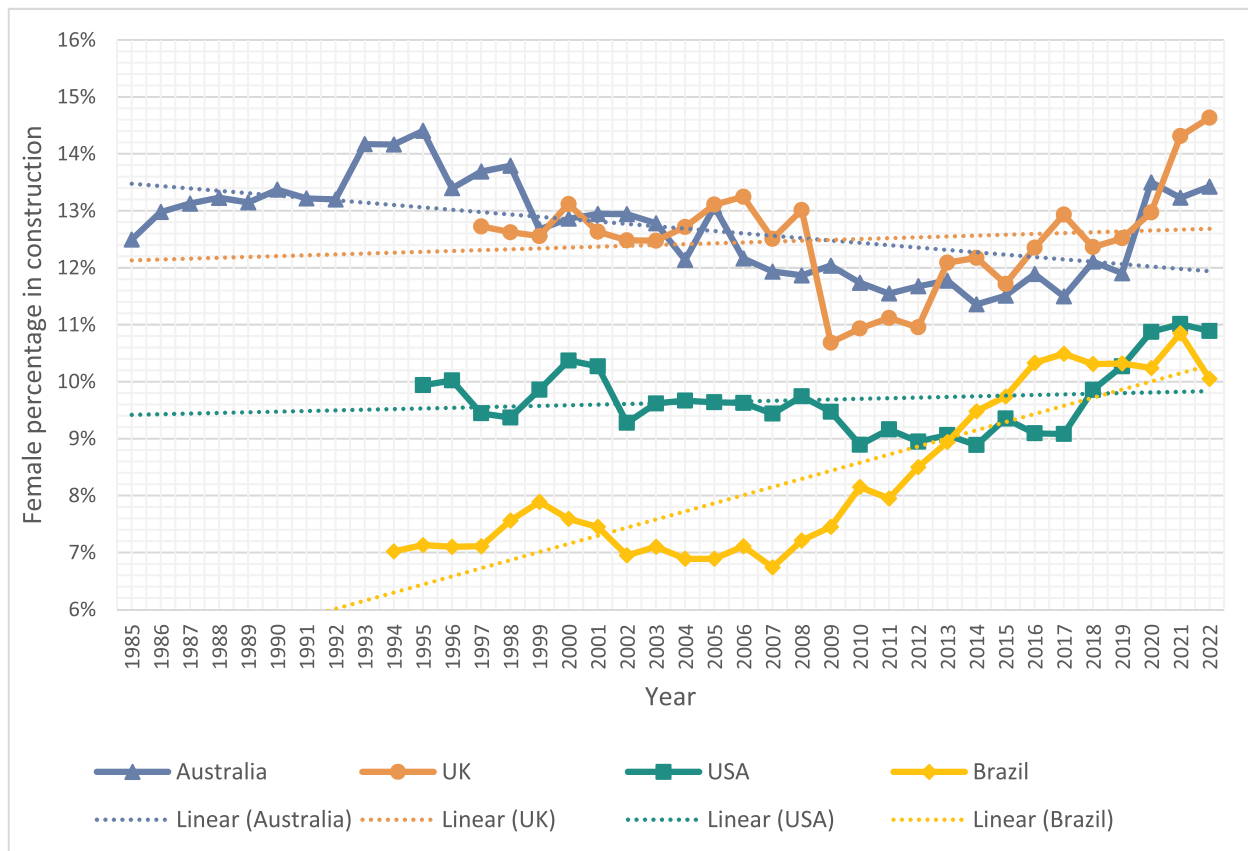


Figure 1. Female representation in construction industry in Australia, USA, Brazil and UK.

first country in the world with a comprehensive law on Women, Peace, and Security (WPS) (US Department of State 2024) which might have impacted this increase.

Brazil is as represented by the green line, showing that Brazil's female percentage in construction has been significantly increasing over the years (1994 to 2023), from 7% to 10% to 11%. This increase is associated with the growth of the Brazilian economy (2007 to 2014). During this period, there was more public investment in infrastructure and housing projects in Brazil. Consequently, there was a rise in demand for qualified professionals, positively impacting the inclusion of female in workforce too.

### Comparative analysis

A comparative analysis of the female percentages in construction across the four countries reveals that Australia and the UK are leading in percentage terms. It also emphasizes the UK's current leadership position as well as the increasing trend over the years. In most years, the UK has the highest female representation, surpassing the USA, Brazil, and Australia. The upward trajectory in the UK stands out, highlighting consistent progress in gender diversity, especially when contrasted with Australia's declining trend. However, it's crucial to note that even in the UK, where progress is evident, there remains a substantial gender gap, as reflected in the female percentage of around 16% in 2021. This underscores the persistent challenges and the need for sustained efforts to further enhance gender diversity in the construction industry globally. Compared to other countries from developed economies, Brazil's female representation in construction was the lowest until a recent catch up with the USA which is notable from an advanced economy. Overall, Figure 1 shows that there is

still a significant gender gap in the construction industry across all four countries, with female representation remaining low.

### Comparison of female representation in construction with mining, transport, agricultural and manufacturing

Female representation of construction industry is analysed with similar comparable industries such as mining, transport, agriculture and manufacturing in four countries. The results over the past 10 years period are illustrated in Figure 2.

#### Agriculture, forestry and fishing

The UK consistently maintains a moderate level of female representation in the agriculture sector, ranging from 26 to 28%. There is a slight increase in 2020, which might be indicative of positive trends or specific initiatives. Australia shows a fluctuating trend, with a notable increase in 2015 and a peak in 2021 at 34%. This upward trajectory may signify efforts to improve gender diversity in this sector. The USA displays a steady increase in female representation, reaching 28% in 2022. This suggests a positive trend, reflecting changing dynamics. Brazil exhibits a stable but slightly increasing trend in female representation, ranging from 16 to 17%. The percentages indicate a gradual improvement in gender representation.

#### Mining

Australia shows a consistent increase in female representation in mining, reaching 20% in 2023. The upward trend reflects efforts to break gender stereotypes in traditionally male-dominated industries. The USA displays a positive trend in mining, with an

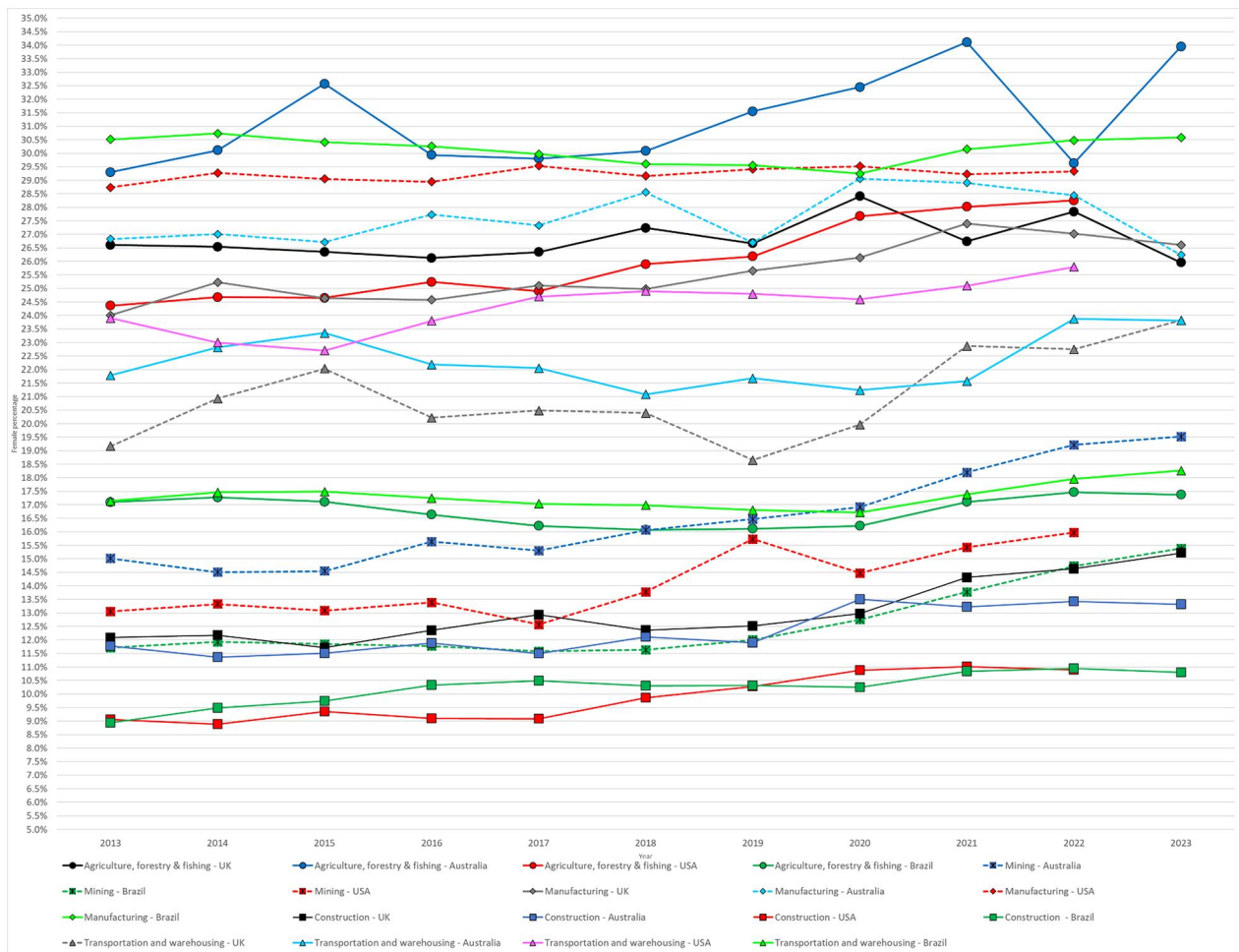


Figure 2. Female representation in construction with other comparable industries (mining, transport, agricultural and manufacturing) in Australia, USA, Brazil and UK.

increase from 13% in 2017 to 16% in 2022. This suggests evolving attitudes towards gender diversity. Brazil demonstrates a significant rise in female representation in mining, reaching 15.39% in 2023. Mining industry was excluded for UK from the industry representation comparison due to lack of availability of publicly available data.

Australia demonstrates a consistent increase, reaching 20% in 2023. The USA shows a positive trend, with an increase from 13% in 2017 to 16% in 2022. Brazil exhibits a significant rise, reaching 15% in 2023. Australia led in female representation in the mining sector, reflecting more inclusive practices.

### Manufacturing

The UK maintains a relatively stable level of female representation in manufacturing, ranging from 24 to 27%. Australia's manufacturing sector sees fluctuations, with a peak at 29% in 2020. The USA's manufacturing industry shows a steady trend, with percentages ranging from 29 to 30%. Brazil exhibits a consistent level of female representation in manufacturing, ranging from 29 to 31%. The UK maintains a relatively stable level of female representation in manufacturing, ranging from 24 to 27%. Australia exhibits fluctuations, with a peak at 29% in 2020. The USA's manufacturing industry shows a steady trend, with percentages ranging from 29 to 30%. Brazil exhibits a consistent level, ranging from 29 to 31%. The USA and Brazil lead in stable and higher percentages, suggesting sustained efforts for gender inclusivity.

### Transportation and warehousing

The UK's transportation and warehousing sector show fluctuations, with a peak at 24% in 2023. This suggests a positive approach to gender diversity, with potential industry-specific factors influencing the percentages. Australia exhibits a generally increasing trend in transportation and warehousing, reaching 24% in 2023. This positive trajectory may reflect industry-wide efforts to foster diversity. The USA's transportation and warehousing industry display a consistent trend, ranging from 23 to 26%. The percentages suggest a sustained effort to promote gender inclusivity. Brazil's transportation and warehousing sector show a gradual increase, reaching 18% in 2023. This suggests a positive shift towards gender diversity in this industry.

### Construction

Gender representation data in the construction industry over more than three decades represented in Figure 1 were discussed in the previous section. A closer look at of the data from past decade presented Figure 2 are discussed here as a basis of comparison with other industries. The UK's construction sector demonstrates a positive trend, with an increase from 12% in 2013 to 15% in 2023. This upward trajectory suggests initiatives to break gender barriers in construction. Australia shows a stable trend in construction, with percentages ranging from 11 to 14%. The percentages indicate a sustained effort to improve gender diversity in this industry. The USA's construction industry reflects a positive trend, with an increase from 9% in 2013 to 11% in 2022.

This suggests evolving attitudes towards gender inclusivity in construction. Brazil's construction sector displays a stable trend, with percentages ranging from 9% to 11%. The data suggests ongoing efforts to enhance gender diversity in construction. The UK's construction sector demonstrates a positive trend, with an increase from 12% in 2013 to 15% in 2023. Australia shows a stable trend, with percentages ranging from 11% to 14%. The USA reflects a positive trend, with an increase from 9% in 2013 to 11% in 2022. Brazil displays a stable trend, ranging from 9 to 11%. The UK leads in the construction sector, indicating notable efforts to break gender barriers.

### Comparative analysis

Agricultural and manufacturing sectors showed a mixed results across the countries whereas they showed the highest female representation across the three countries. Australia often leads in achieving higher peaks in female representation, suggesting having robust efforts to promote gender diversity across comparable industries. The USA consistently maintains stable and positive trends in most industries, reflecting a sustained commitment to gender inclusivity. The UK shows positive trends in agriculture, manufacturing, and construction, indicating multifaceted efforts to improve gender diversity. Brazil demonstrates gradual but stable increases, especially in mining and construction, signifying ongoing initiatives for gender inclusivity. Fluctuations in certain years across all countries may be influenced by external factors,

and a deeper analysis is needed to understand these variations better.

### Comparison of female representation in construction with high performing industries

Female representation of construction industry is analysed with high performing industries such as education, health care and social assistance in four countries. The results over past 10 years are illustrated in Figure 3.

In the education sector, the percentage remains constant at approximately 70%. This baseline provides context for understanding the comparatively lower representation of females in the construction industry in order to achieve the gender balance which construction industry is aiming for. Within the health care and social assistance sector, the percentage hovers around 75–80% in 2013 to 13.2% in 2019. This upward trend underscores the varying degrees of female representation across industries, with healthcare experiencing a relatively higher share.

The stability of female representation in the UK's construction industry can be contrasted with the percentages observed in the education and health sectors, providing insights into the unique dynamics of female representation in construction. The education sector maintains a consistent representation at approximately 70%, setting a benchmark for understanding the proportions in other industries. Within the health care and social assistance sector, the percentage remains around 75–80% till

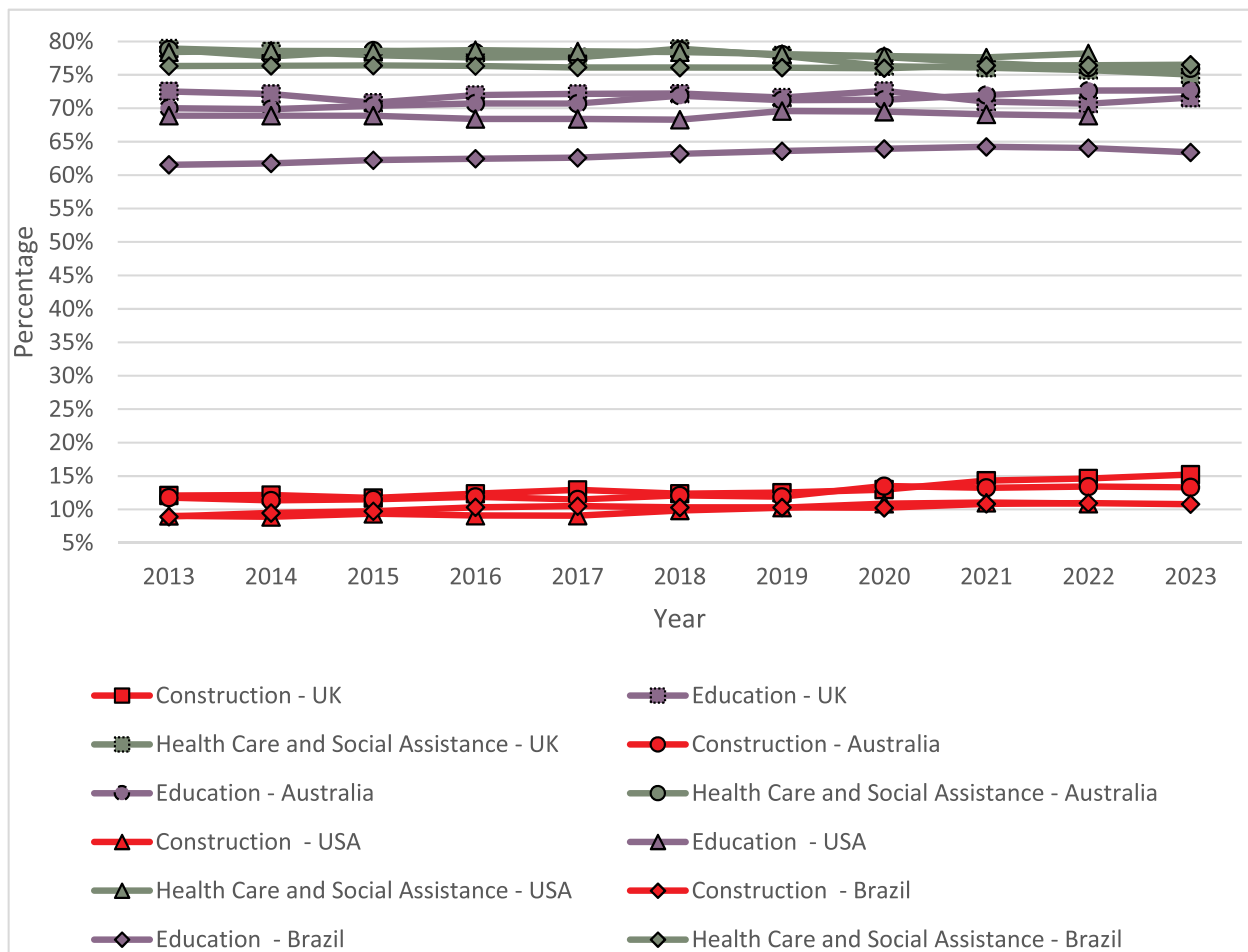


Figure 3. Female representation in construction with high performing industries: education and health in Australia, Brazil, USA and UK.

2020 and gradually shows from a declining trend after 2020. Comparing this growth with the construction industry sheds light on the disparities in female representation across these sectors.

In the US Construction industry, the percentage increases after 2017 from 9 to 11% in 2023. This growth provides insights into the nuances of female representation in construction compared to the education and health sectors. The education sector maintains a consistent representation at approximately 70%, serving as a reference point for understanding the proportions in other industries. Within the health care and social assistance sector, the percentage varies from 75 to 80%.

Examining the data for female representation in the construction industry in Brazil from 2013 to 2023, the percentage increases gradually from 8% in 2013 to 10.8% in 2023. This upward trend suggests a slow but consistent growth in the representation of women in the construction sector in Brazil. In the education sector, the percentage is steady in the 60–65%. Within the health care and social assistance sector, the percentage remains relatively stable, ranging from 75%. This sector exhibits a consistent representation of women, possibly reflecting a stable demand for female professionals in healthcare and social assistance.

#### Comparative analysis

Health care sector exhibits a consistent representation of women, in the range of 75–80% in all four countries possibly reflecting a stable demand for female professionals in healthcare and social assistance. Education sector represents a slightly

higher demand in countries with developed economies in the range of 62–73% compared to Brazil representation ranges from 60 to 65%. Poor performance in construction industry compared to the high performing industries is emphasised in Figure 3 in four countries in the range of 9–15%. This sheds some lights on opportunities to adopt learnings and best practices from high performing industries in to the construction sector, which is a call for future research.

#### Gender pay gaps (GPG)

Examining the gender pay gaps is useful in exploring possible discrimination across industrial sectors. However, different gender pay gaps can be calculated to explore a variety of issues within the sectors. According to the Australia Bureau of Statistics (ABS), the gender pay gap is calculated using average earnings, weekly and hourly earnings, and ordinary time earnings. WGEA (Workplace Gender Equality Agency) has standardized part-time and casual earnings by creating a full-time equivalent (FTE) figure to compare remuneration between genders across all states of employment. WGEA has calculated the gender pay gap using the data captured through 4 million employees who work across medium to large Australian private and not-for-profit organizations.

Figure 4 shows the trend of gender pay gaps in Australia for comparable industries such as mining, transport and manufacturing. The data was captured through the WGEA (Workplace Gender Equality Agency) reports. The gender pay gap in Australia for construction ranges between 25 and 30% from 2013

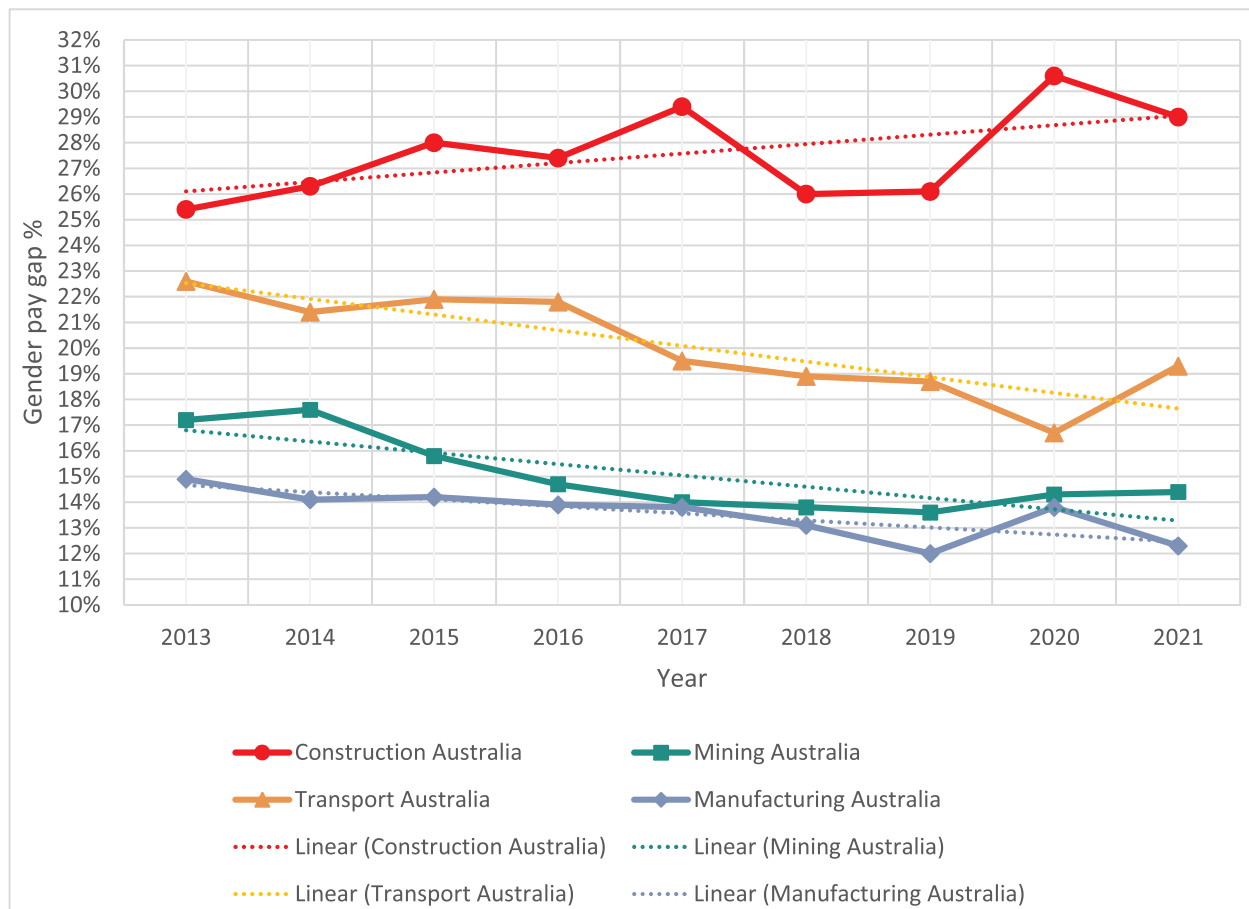


Figure 4. GPG for Australia in construction, mining, transport and manufacturing sectors.



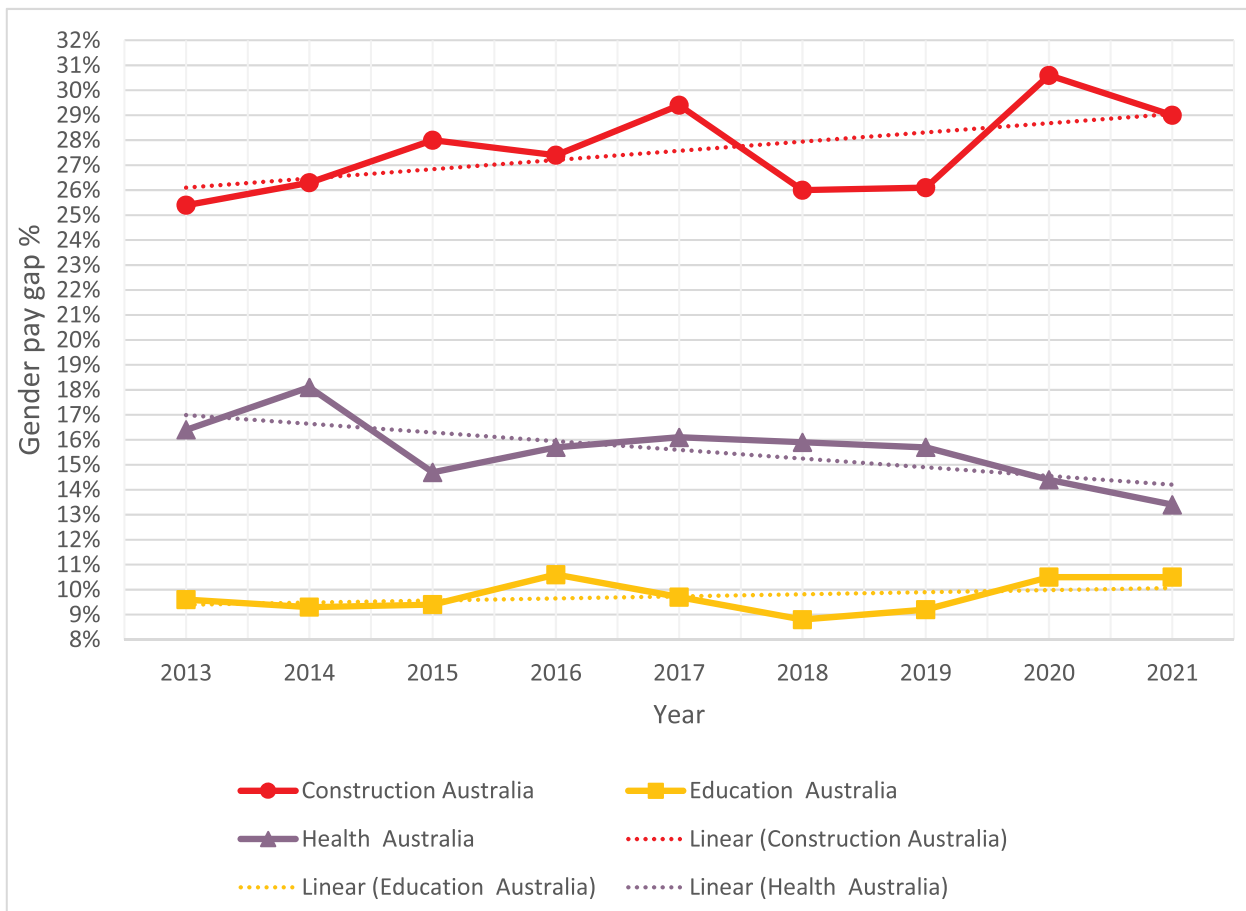


Figure 5. GPGs of Australians' construction, education and healthcare sectors.

to 2021. Women employed full-time can expect to earn 25% to 30% less each year than men employed in the Australian construction industry. When considering the trend of the gender pay gap in Australia for construction, it has slightly dropped in 2018 and 2019 and in recent years it is in increasing trend which is confirmed through the trend line in the graph. The construction industry showed the highest gender pay gap across the comparable sectors which was then followed by transportation, mining, and manufacturing. Interestingly, the trend lines confirm that the gender gap is decreasing for all other industries except for construction which needs further investigation.

The GPGs in construction were compared with industries which are high performing in gender representation such as education and healthcare and similar industries such as mining, transport and manufacturing in Australia.

Figure 5 shows the GPGs in Australia across construction, education and healthcare. The said comparison also confirmed that the gender pay gap is the highest in construction followed by healthcare (in around 15%) and education (around 10%). The presence of GPGs in all sectors shed some lights on requirements of influential interventions such as national level policy across all sectors with more attention to poor performance in the construction sector.

In the UK, the mean gender pay gap has been calculated using the median hourly rate for male and female employees using the same general formula for gender pay gaps. Unlike Australia the standardisation of full time and part time earnings were not able to perform for UK due to lack of data availability. Therefore, the data was captured through the publicly available data from Office for National Statistics where the fulltime hourly

earnings was used in the calculation. Full-time is defined as employees working more than 30 paid hours per week (or 25 or more for the teaching professions)

The gender pay gap for construction in the UK shows a declining trend over time starting from 17% in 2012 and 6% in 2020 (Figure 6). The transport and the mining industries showed the lowest gender pay gap between comparable industries followed by manufacturing and construction industries showed the highest. All the industries showed a sharp decline in GPGs in 2020 due to coronavirus (COVID-19) pandemic although GPGs for construction in 2021 and 2022 records the lowest values. The significant declining trend in all industries from 2017 is possibly due the UK Government's legislation introduced in 2017 to report the gender pay gaps annually for organisations with more than 250 employees.

Figure 7 compares the gender pay gaps in UK across construction, education and healthcare. Accordingly, the gender pay gap is the highest in the health care sector followed by education and construction industry showed the lowest gender pay gap. In the UK, GPS is calculated as the difference between average hourly earnings (excluding overtime) of men and women as a proportion of average hourly earnings (excluding overtime) of men and full-time defined as employees working more than 30 paid hours per week (or 25 or more for the teaching professions). Presence of more causal and part-time roles in education and health care sectors might be the reason for higher gender pay gaps in the UK.

It should be noted that the figures do not show differences in rates of pay for comparable jobs, as these are affected by factors such as the proportion of men and women working part time or

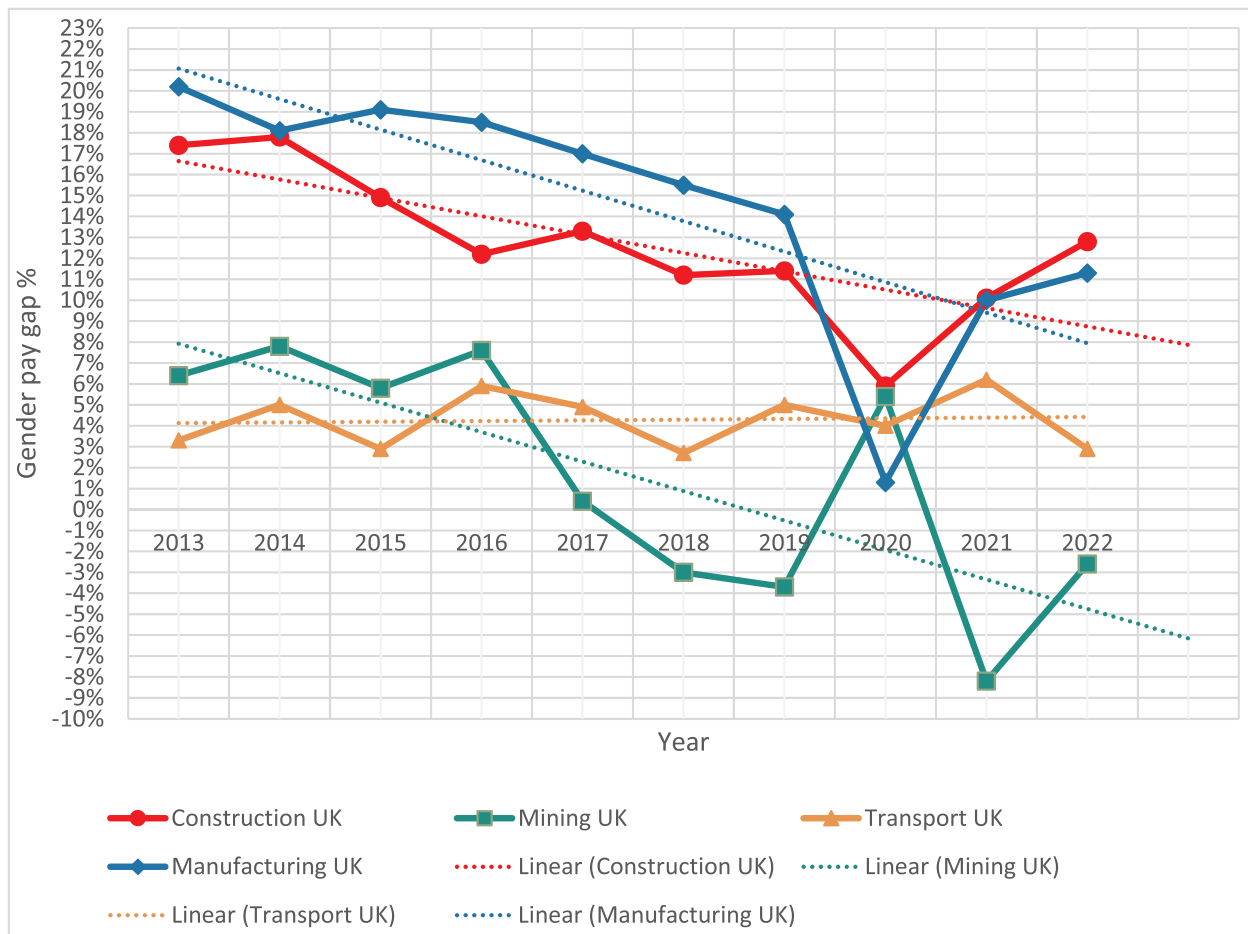


Figure 6. GPGs of construction, mining, transport and manufacturing sectors in the UK.

in different occupations. For example, a higher proportion of women work in occupations such as administration and caring, which tend to offer lower salaries.

Figure 8 illustrates the GPGs for construction industry in the USA, which were calculated using the median weekly earnings of full-time wages for male and female employees using the same general formula for gender pay gaps. The GPGs in construction are ranging between 8 and -10%. The highest gender pay gap was reported in 2019 and after that, it is in a declining trend. Given that the weekly earnings were considered in the USA, impact of casual and part-time workforce is higher. The noticeably high GPG in education and health sectors might be due to this reason.

### Gender representation in higher education

More specific data were analysed regarding the educational journey of men and women through undergraduate degree conferral. Investigation involved analysing the percentage of degrees conferred to women in related civil engineering, construction management, construction engineering, architecture and related services. These data were only available for Australia and the USA from 2011 to 2021, as shown in Figure 9.

The data revealed that architectural and related services is a female dominated degree programme consistently throughout the years in both countries with 40–55% enrolments, however more popular in Australia among female students (50–60%). This discipline also shows an increase in numbers from 2016

through to 2021 in both countries. Civil engineering is a popular programme among females in USA (20–27%) compared to Australia (15–20%) across the years. Construction engineering and management degree programmes have a similar percentage of degrees conferred across the years ranging from 8 to 15% female representation in the USA. Australia has a slightly higher percentage of degrees conferred for construction engineering and management degree programmes across the years compared to USA.

## Discussions

### Moving from global 'leaky challenge pipeline' to a 'shared solutions space'

Results from education pipeline within the AEC (Architectural, Engineering and Construction) sector revealed that female students were more attracted to Architectural and related services degree programmes consistently throughout the years compared to Construction Engineering and Management degree programs. The literature found evidence of gender bias, poor culture and lack of support for female students in the tertiary education settings. Literature highlighted the education institutions' role in addressing gender bias in education setting (Sewalk and Nietfeld 2013) and the importance of promoting positive culture and positive peer network in degree programs which significantly impacts female students' self-concept (King-Lewis et al. 2021). Skill development through internships in education programs (Moore and Gloeckner 2007; Powell et al. 2010; Baruah 2018;

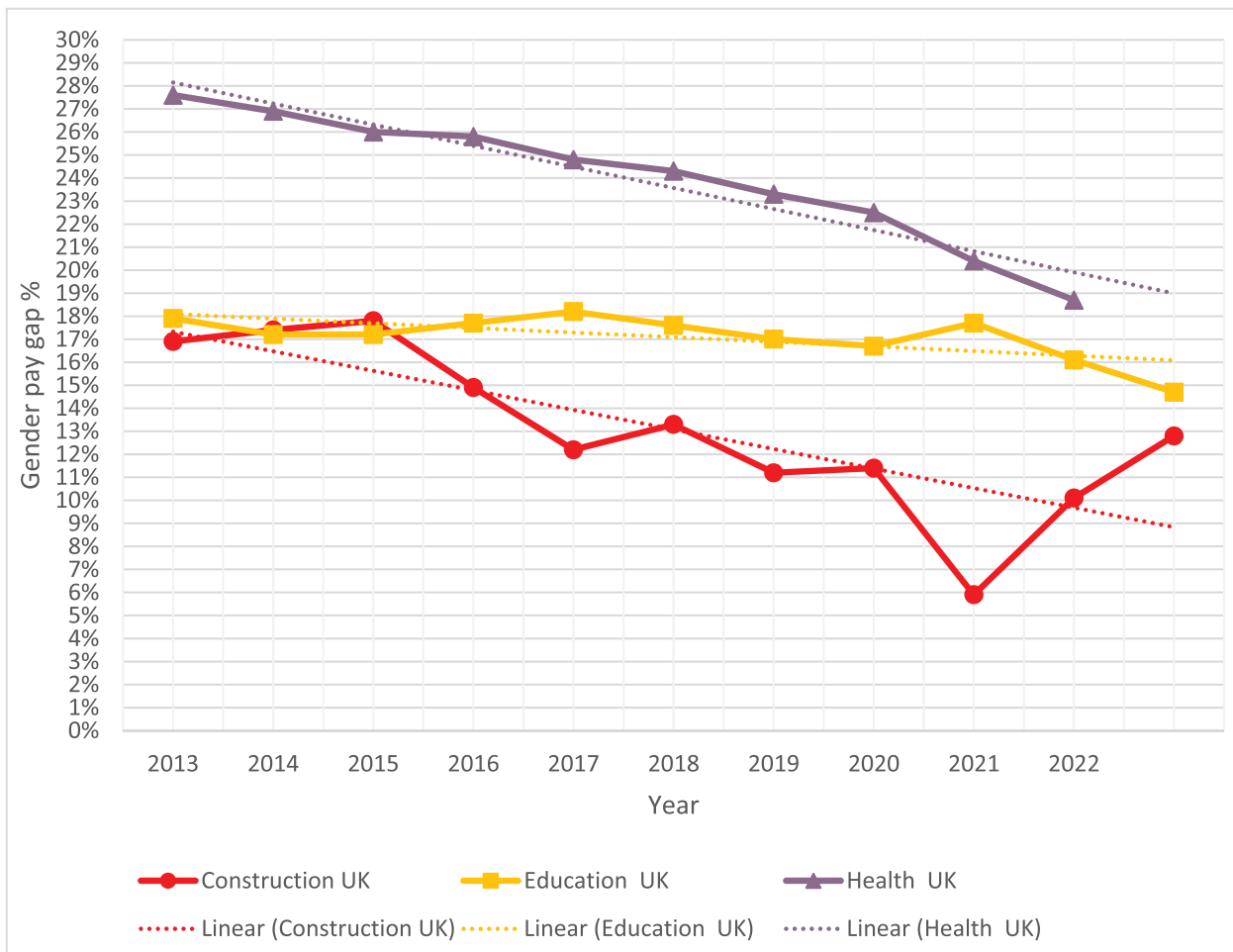


Figure 7. GPGs of construction, education and healthcare sectors in the UK.

Oo et al. 2020) also helps building self-efficacy and confidence of female students. Hence, educational institutes around the globe have a leading role in not only promoting and recruiting but also retaining and supporting female students in construction discipline. This paper calls for research in developing such validated set of guidelines and recommendations for institutions to follow.

At a macro-level, analysis of industry pipeline revealed that construction sector is severely underperforming in gender representation in Australia, United States, United Kingdom and Brazil not only compared to sectors such as education and health but also compared to similar industries such as mining, manufacturing and transportation and warehousing. Possible root causes and challenges ranging from lack of female friendly uniforms to more significant issues such as sexual assault due to poor industry culture were widely studied for more than three decades of the 'leaky pipeline' (Edirisinghe et al. 2023).

It is a timely call for research to move from problems to solutions by mapping this 'leaky challenge pipeline' towards a 'shared solution space' where best practices and guidelines are shared globally which is the next phase of this ongoing study. This shared space will include the strategies derived through learnings from high performing industries such as health and education around the world. Learnings from similar industries such as mining, transportation and manufacturing are also yet to unpack which would immensely assist addressing gender segregation issue in construction.

### Best practices and guidelines in the 'shared solution space'

As the results indicated, each country has made strides in promoting gender diversity across industries, Australia often stands out with higher peaks in female representation. The USA, the UK, and Brazil also show positive trends, indicating a global shift towards greater gender inclusivity in the recent past. However, a more detailed investigation into the specific initiatives in specific industries would provide deeper insights.

Moreover, delving into declining trends in the past provides opportunities to unpack lessons learnt, which is crucial component of the 'shared solution space'. For example, in Australia a significant drop in female representation in construction was noticed from around 10% in 2005 to approximately 7% in 2013. The sustained decrease prompts an exploration of potential factors contributed to this decline. Economic shifts, changes in demand for construction jobs, or alterations in government policies and industry practices could be contributing factors. Further research and analysis are warranted to unravel the intricacies of this to inform best practices for future with implications for policy-making, organizational practices, and broader societal attitudes.

The trend analysis revealed that the UK emerges as a leader in fostering gender diversity while Australia faces a concerning decline. The source for Australia lacks specific reasons for the declining trend may require further research for a comprehensive understanding. The United States and Brazil exhibit relative stability, with distinct patterns that warrant further exploration.

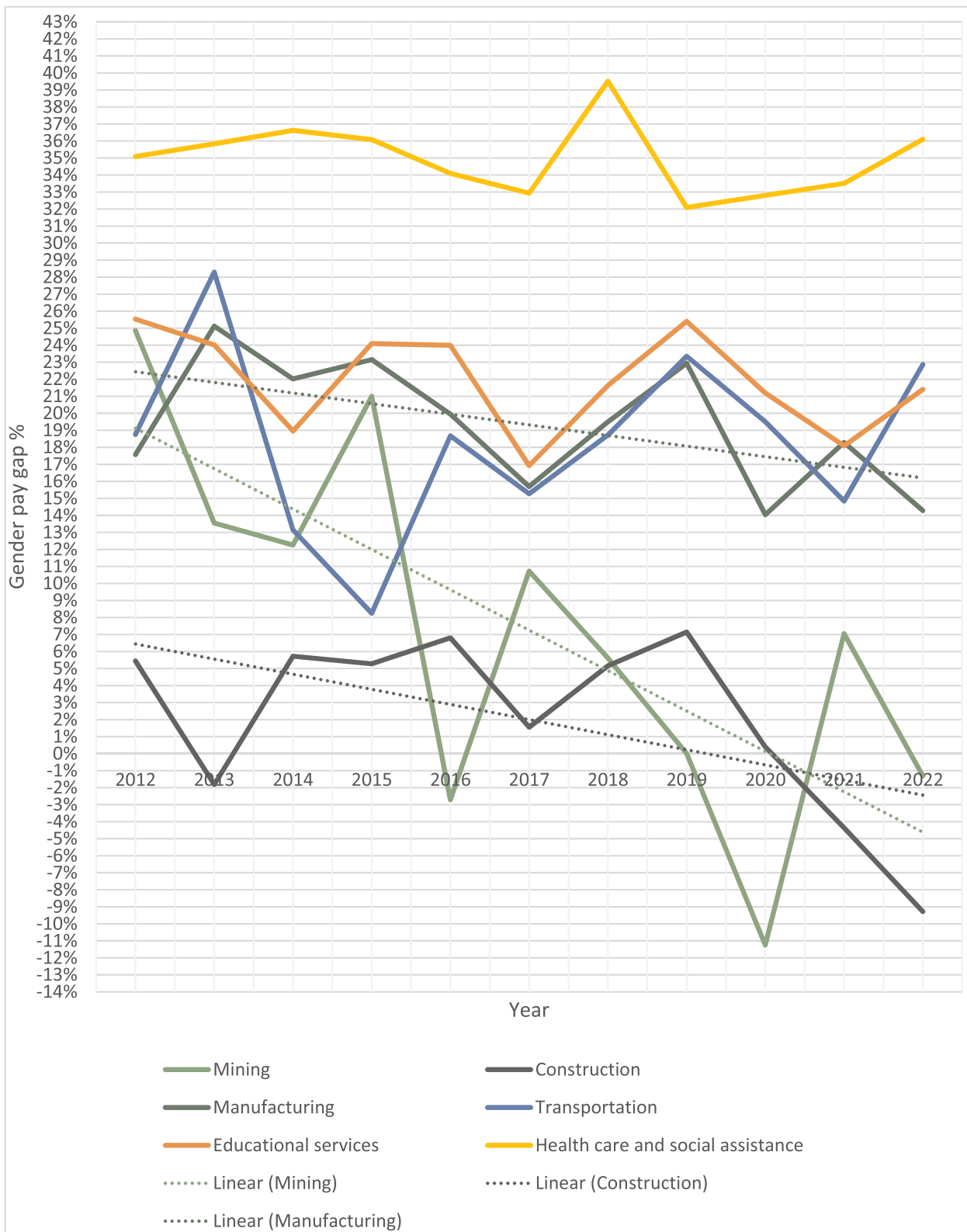


Figure 8. GPGs of construction, education and healthcare sectors in the USA.

This study emphasizes the imperative for continued efforts globally to address gender imbalances in the construction sector, recognizing the multifaceted nature of the challenges and the need for tailored strategies in each context.

It is worth noting that while the UK has been making progress in increasing female representation in the construction

industry over the years, there is still a significant gender gap in the industry, indicating that there is still much work to be done. There are various initiatives and organizations in the UK that are working towards the goal of achieving greater gender diversity in the UK construction industry. For example, the UK government has set a target to increase the proportion of women

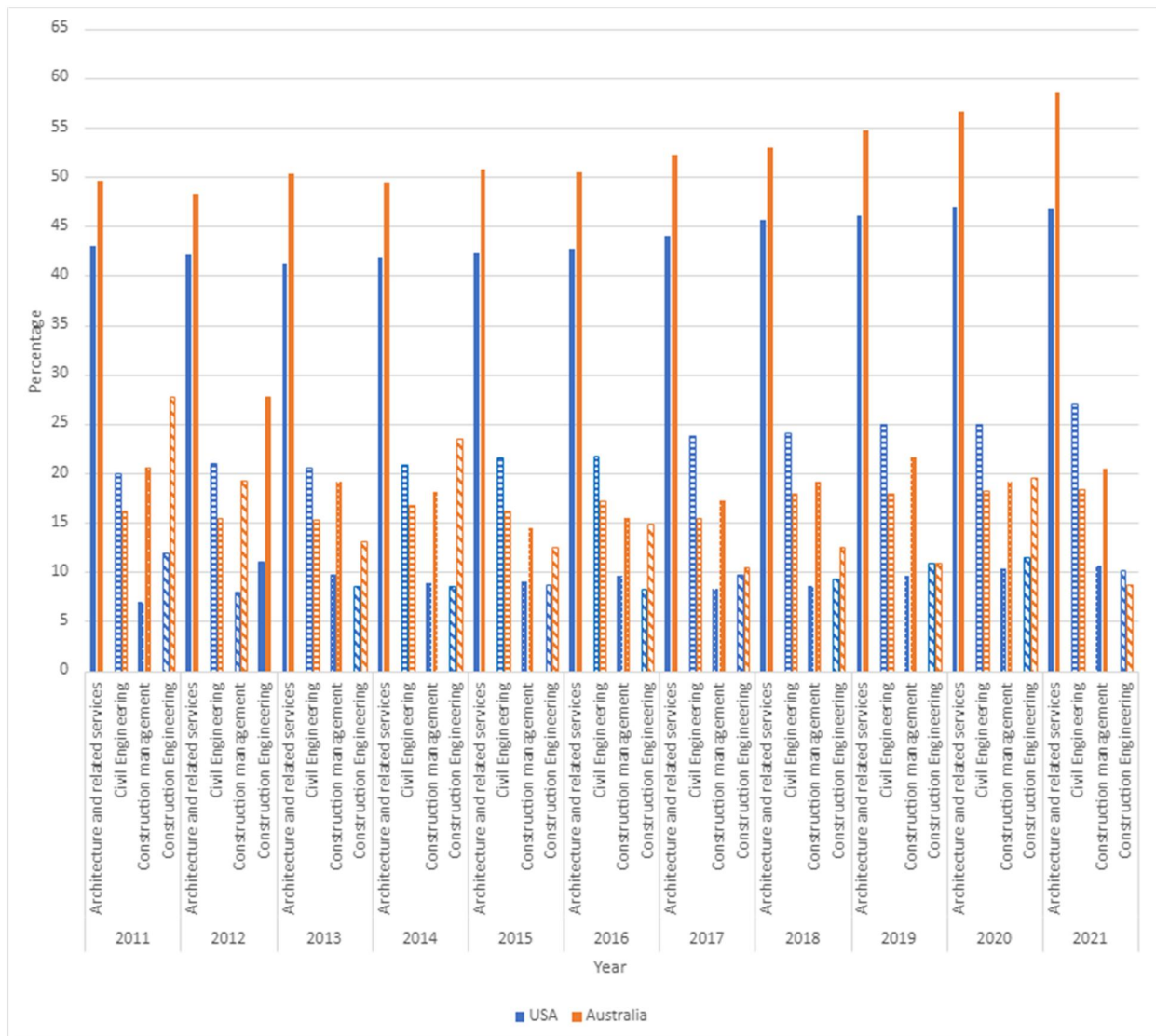


Figure 9. Female representation in conferred construction related degree programmes.

in STEM occupations, which includes the construction industry, to 30% by 2030.

Additionally, there are organizations such as Women into Construction in the UK and the National Association of Women in Construction (NAWIC) in Australia, the UK and the USA that provide support, training, and networking opportunities for women in the industry. Range of industry initiatives to increase diversity and inclusion, such as setting targets for female representation and providing mentoring and leadership programs for women by these industry associations in each country is worth noted in the shared solution space. For example, NAWIC in Australia has set an ambitious target of 25% female representation by 2025.

#### ***Policies and local jurisdictions in the 'shared solution space'***

According to the results, the stability of representation observed in the US may prompt further exploration into the factors contributing to the persistent gender gap. Understanding the dynamics at play can inform targeted interventions aimed at breaking down barriers and fostering an inclusive environment for women in the construction sector. For example, the impact

of passage of the Women, Peace, and Security Act of 2017, the United States became the first country in the world with a comprehensive law on Women, Peace, and Security (WPS) and impact of other legislation are worth exploring.

While Australia is showing a declining trend in female representation, the effectiveness and the potential impact period of existing policies is worth exploring. Causal relationships between female representation and relevant policies are yet to be reported. For example, the impact of National Gender Equality Act 2012, Victorian Building Equality Policy (BEP) 2022 and other legislations on gender diversity of Australian construction industry yet to be validated, particularly the BEP's project-specific small gender equality targets are anecdotally criticised by the practitioners as ineffective for a radical change compared to gender quotas. In Australia, particularly while there is a labour shortage in the industry and increasing development of infrastructure, in order to improve declining trend of gender representation in the construction industry it vital and a pressing need to have a policy with a clear roadmap with support structure.

Similarly, in the UK, the significant declining trend in all industries from 2017 is possibly due the UK Government's legislation introduced in 2017 to report the gender pay gaps annually for organisations with more than 250 employees. Under the

legislation, the organisations are required to report on their own website as well using the dedicated Governmental reporting portal. These impacts are yet to be validated.

In Australian construction sector, women employed full-time can expect to earn 25% to 30% less each year than men employed. These results align with literature, arguing for prevalent wage discrimination in construction (Sewalk and Nietfeld 2013; Devi and Kiran 2014; Rotimi et al. 2023). It is worth noting the legislation moves such as amendment passed by Federal Parliament in March 2023 in Australia to Gender Equality Act 2020 (Closing the gender pay gap). The legislation strengthens the Act and Workplace Gender Equality Agency's focus on gender equality, highlighting equal remuneration between women and men, and caring responsibilities as key dimensions, which potentially will help closing the GPGs in all sectors including construction.

However, literature highlighted the limited effectiveness of inherently gendered formal institutional policies in improving gender equality (Galea et al. 2015) and the importance of inclusiveness of both top-down and bottom-up measures (Edirisinghe et al. 2023).

While the academic debate over top-down policy vs industry driven bottom-up policy is ongoing, various industry associations have also initiated standards and policies which are worth noting. Construction Industry Culture Taskforce in Australia is instrumental in setting standards for flexible work in the construction sector. Australian Constructors Association (ACA) represents leading construction and infrastructure contracting companies have pledged to establish workplace flexibility policies.

### ***Innovation in societal perception***

The poor public image of the construction industry is seriously reducing its appeal as a career for women and girls (Ling et al. 2016; Hasan et al. 2021). These norms and beliefs are very persistent throughout the pipeline, from education to industry, holding girls and women back from a career in construction (Powell et al. 2010; Kakar and Hasan 2023).

Changing the perception from 'leaky challenge pipeline' to a 'shared solutions space' will have a significant impact on shifting the public image. This will generate opportunities to solve the gender segregation issue in construction industry which has been historically perceived as a 'chicken egg problem' where 'increased representation will enhance the public image' and 'enhanced public image will increase representation'.

### ***Industry 5.0 and impact on gender diversity in construction***

Results indicate that education and health seem to provide gendered roles for women. In healthcare sector a consistent representation of women, possibly reflects a stable demand for female professionals due to positive image of the industries and societal norms. While the growth is relatively modest, it indicates an increasing presence of women in the education field over the specified years shedding some lights on education sector's improvement in providing more female friendly work environments.

The future of construction is changing with the industrial revolution, Construction 5.0. This transformation with digitalisation, automation, and less manual intense work will make a paradigm shift for the construction industry (Forcael et al. 2020). With change of work practices and nature of work being changed there are enormous opportunities to address some of the root causes of

gender segregation such as long/rigid work hours, unsuitable work practices, inflexible work arrangements and excessive workloads (Ling et al. 2016; Clarke et al. 2017; Oo et al. 2020; Amir Naser et al. 2023). Also, there are opportunities for innovative approaches for structural change in the industry and to be safer for both men and women. There will also be opportunities to apply female friendly work policies present in healthcare and education sector for construction sector to make it more attractive to women with the structural change in the industry.

### ***Cross-sectorial collaboration led by academia to address the global issue***

Fixing leaks in isolation is no longer effective. The holistic investigation of the leaks in the pipeline should also be fixed through a holistic approach (Hasan et al. 2021; Edirisinghe et al. 2023). Menches and Abraham (2007) argued that change in the industry's image and culture should happen through a collaboration between academic institutions, professional bodies and labour unions. Edirisinghe et al. (2023) suggests cross-sectorial collaboration of all the stakeholders—including the whole AEC sector, regulatory bodies, schools and government as the driving force to enable a systemic change. Achieving gender equality requires a collaborative, systemic approach involving all stakeholders. However, academic institutions have a responsibility to take central roles in such collaborations and to eliminate gender biases in education programs at the early stages of the pipeline.

## **Conclusions**

This article revealed the evolution of gender dynamics within the construction sector over more than three decades through quantitative evidence in Australia, United States, United Kingdom and Brazil. The female representation in the construction industry, construction related tertiary education were analysed. The industry data were also compared with comparable industries such as mining, manufacturing and transport and high performing industries such as education and health. The investigation of gender representation across entire education and career pipelines enabled a better understanding of the pertaining national and global issues for "pipeline leaks" through sound quantitative dataset from four countries: Australia, USA, UK and Brazil. The findings shed some lights on opportunities to adopt learnings and best practices from high performing industries into the construction sector, which historically records poor performance in order to achieve the construction sector's gender balance. Emphasis is placed on educational institutes around the globe have a leading role in not only promoting and recruiting but also retaining and supporting female students in construction discipline. The findings also enabled identification of areas for further exploration to move from problems to the solutions. Hence this paper calls for research to move from "challenge leaky pipe line" towards a "solution space" and calls for collaborative practical strategies and action items for various stakeholders towards a proactive response. Developing such validated set of guidelines and recommendations for all stakeholders is also yet to be reported.

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## Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

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No potential conflict of interest was reported by the author(s).

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