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SKILLED LABOR CHALLENGES AND AUTOMATION IN THE CONSTRUCTION INDUSTRY

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SKILLED LABOR CHALLENGES AND AUTOMATION IN THE CONSTRUCTION INDUSTRY

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SKILLED LABOR CHALLENGES AND AUTOMATION IN THE CONSTRUCTION INDUSTRY

Abstract

Construction industry is labor-intensive, adding an average 8% gross domestic product (GDP) globally, reducing unemployment. While, a plague of skilled labor shortage and retirement persist, Covid-19 recently hastened baby boomers' retirement, necessitating viable alternatives. Automation an alternative and despite successes, still experiences lethargic adoption and use. This study analyzed data from U.S. bureau of labor statistics using forecasting and trend, through systematic literature review 9 technologies were identified to complement these challenges, improve performance, and attract younger generation. The study revealed consistent rise and decline among 15 occupations with total separation projected rise in 2023, inciting construction stakeholders towards automation.

Introduction

The construction industry has unique characteristics that set it out from other sectors. A few to mention are labor-intensive, worker variability, on and off-site construction techniques, construction lifecycle, and a large amount of documentation, along with a gross domestic product increasing over the years, averaging 8% globally. The aforementioned requires a vast amount of communication to attain success. In recent times, communications are transitioning to electronic from paper exchange (conventional methods) which is gradually fading along with the impact of Baby boomer retirement (Martínez-Rojas et al. 2016). The majority of available or transient knowledge is also fast declining along with retirement (Ogunrinde et al. 2021a), millennials and generation z's are not entering the workforce as much as the departing cohort, which requires critical attention (Karimi et al. 2017). According to (Associated Builders and Contractors Inc) ABC, 650,000 additional workers are needed to complement the average pace of hiring in 2022 to meet labor demand. Residential construction is experiencing the most shortage around the country, coupled with the most recent pandemic (Covid 19), fostering more retirement due to health concerns (Alsharef et al. 2021). These issues are frontiers that should guide the industry away from the conventional approach toward automation adoption and use.

The lifecycle for construction is divided into phases: planning/design, preconstruction, construction, and maintenance. Over several decades, each phase has had its bit of transition from traditional methods to the application of new tools and techniques. The planning/design phase now utilizes different design software that brings collaboration among all parties through cloud sharing to minimize conflict. Likewise, the preconstruction stage, which entails bidding, quantifying, scheduling, and estimating, now incorporates planning/design software independently or in integration with other technologies (Alsharef et al. 2021; Martínez-Rojas et al. 2016). Even with speed from equipment utilization for phases of construction, defects are still occurring that lead to short-time rehabilitation and maintenance work, with the cost of rework estimated as almost 6% of the contract sum. The use of similar equipment for maintenance results in the reoccurrence of the same issue depleting overall construction performance (Craig 2018; Martínez-Rojas et al. 2016). Construction workers fear that the adoption and use of technology will result in eliminating workers; however, transitioning from traditional methods to an innovative application has not reduced human capacity requirements but has helped eradicate persistent human errors (Bryde et al. 2013; Lee et al. 2015). According to (M. Pan et al. 2020) and (Trujillo & Holt 2020), the addition of automation devices to construction equipment has recorded success, but a gap still exists within the construction industry, majorly due to the snail approach toward innovation and lack of proper awareness. Evolution success in the construction industry depends on consistent adoption and use of technology which could be imitative from other industries already tending towards industrial revolution 4.0. Presently, the construction industry remains in a quest of indecision with several barriers determining precepts for most processes that could suffice as drivers for technology adoption and use if vehemently considered (Ogunrinde et al. 2021b; Trujillo et al. 2020).

The reluctance within the construction industry to adopt innovative processes calls for urgent attention. The barriers like the cost of technology, personnel training, employee job loss, changes in style within management, lack of innovative in-house capacity (shortage and retirement), etc. are issues troubling the industry (Gonzalez de Santos et al. 2008; Martínez-Rojas et al. 2016). A synergy among construction stakeholders will help dose the fear of transmission and system integration, most importantly if lessons are taken from existing knowledge about automated processes in construction (M. Pan et al. 2018). One school of thought emphasizes issues related to worker displacement and fear of job loss as a lingering concern, and another envisages the human-technology relationship as a fundamental integration to help attain performance (Ambra Cala et al. 2018; Y. Pan 2016). These researchers found better productivity delivery on projects that used automation than traditional delivery methods, which led to improved project outcomes like timesaving, waste reduction, rework elimination, reduced in-person evaluations, activity conformance, and several others (Ambra Cala et al. 2018; Ogunrinde et al. 2021a; Y. Pan 2016). Therefore, the need to investigate issues of shortage and retirement focusing on gradual migration to adoption and use of technology for processes in construction rather than the continued dependence on the fast-fading conventional methods that continue to show no sign of productivity improvement over the last two decades.

This research aims to determine skilled construction labor experiencing the most shortage and retirement slides proposing technological alternatives to complement the issues. To achieve this study, the researchers focused on three specific objectives: (1) identify the skilled labor group experiencing the most shortage, (2) compare the rate of retirement to job openings and hires, and (3) source information for automation to complement human activities. The study relied extensively on integrative literature review and data from BLS, then proposed the impact of automation adoption and use on shortage and retirement.

Literature Review

Prevailing issues with conventional or traditional methods in construction have been discussed, and major concerns are raised regarding construction performance metrics and productivity improvement, focusing on cost, safety, schedule, quality, and construction complex environment. However, this literature review will address aspects relating to skilled labor shortage, retirement, and automation adoption and use, focusing on their impact and the aforementioned metrics for the construction industry.

Skilled Labor Shortage

In the United States, construction is one of the largest economic industries with massive human employment, estimated to be the fastest-growing industry over the next decade (Albattah et al. 2015). However, the large amount of skilled workforce required to fill positions is diminishing, with millennials and gen z's not showing any interest in entering such skilled positions due to the low desire for automation in the construction sector. According to (Edlund & Nilsson 2007) and (Tolstikova et al. 2021), millennials who are classified as the internet generation began losing interest in skill trade, understanding that technology is transparent and key to success. On the other hand, gen z's were born into more advanced works of innovation, skewing them off the consideration for manual labor. The gaps this issue could bring soon, if not properly considered, could be likened to a tsunami waiting to happen in the construction industry. The stigma associated with skilled labor jobs is an issue and the factors identified are: unrewarding, menial, mostly construction-related, minimal education requirement, low and inconsistent pay, high fatality, physically challenging, etc. (Martínez-Rojas et al. 2016; Tolstikova et al. 2021). According to (Karimi et al. 2018), these lingering factors jeopardizing new entry opportunity are not helping project delivery, because undertaking projects with less-skilled workers due to knowledge drought and lack of adopting and using innovative means is detrimental leading to underperformance in the construction industry.

Skilled crafts persons are highly trained and experienced individuals who complete physical tasks or complex mental activities on a job. The mental complexity of the job should become more associated with technologies to reduce error and ease off physical fatigue (Ahn et al. 2019). Fatigue has been one issue researchers found exhausting skilled laborers in the construction industry, and it is due to overuse of energy from long-term requirements of the body and short-term overexertion. The new entrants (millennials and gen z's) are not considering the underlining work ethics as part of life (Sumarningsih et al. 2016; Tolstikova et al. 2021). As skill labor shortage issues continue to linger Karimi et al. (2018) emphasize the impact it has on cost performance, loss of productivity, excessive overtime and growth in hourly wage, frequent safety incidents, and schedule overrun. The result of their research draws back to superfluous costs given the complexity of factors requiring attention. Rohana (2019) and Vähä et al. (2013) stated that ameliorating these superfluous costs depends on how fast human-technology integration could lead construction processes. The skilled construction trades considered in this study are electricians, plumbers, roofers, carpenters, crane/machine operators, heating, ventilating, and air conditioning (HVAC) mechanics, painters, boilermakers, drywall and ceiling installers, iron and steel workers, cement masons and fillers, etc., which have had their share of drought in terms of labor shortage (Albattah et al. 2015; Karimi et al. 2018). Enhancing alternatives to mitigate labor shortage is perceived as the most vital solution, but this is not the case with fear of job loss already declining without new entries negatively impacting construction performance metrics (Karimi et al. 2018; Rohana 2019). Castro-Lacouture (2009) proposed automation and robotics for repetitive processes that reduce skilled laborers' efficiency on their tasks, indicating that a process driven by technology helps improve construction performance metrics and eliminate errors arising from conventional applications.

Retirement

Construction is the most labor-intensive industry, and one with the most fatalities and injuries (Castro-Lacouture 2009), Baby Boomers born between 1946 and 1965 are presently retiring from positions in construction due to aging, greying, and their high vulnerability to fatalities and injuries (Albattah et al. 2015; Schwatka et al. 2012). Though life expectancy plays a role other issues like social security benefits, private pension portfolios diminishing value, longevity, and increasing health issues are associated with an increase in retirement for these construction workers. The repercussion of injuries on this cohort (Baby Boomers) compared to the new generation is the burden of musculoskeletal disorder inflicting continuous pain to perform work bringing about limitations (Schwatka et al. 2012). Initially, the option for reducing retirement numbers was increasing remuneration, while this was of great delight to the workers, several episodes began to change their perception about an increase in remuneration. Among the episodes are expenses (out of pocket) required to get them in shape against grievous injuries. However, most of the monies were paid by insurance, co-pay, and additional cost of medicines, another benefit of the increased remuneration for workers involved in site accidents (MacKenzie et al. 2000; Schwatka et al. 2012). Another is the cost of living, to help cover up for work and family time they find proximity housing to the job site a better option, sometimes paying higher rent for ease to reach family and get to work early to reduce fatigued. The increased remuneration did not help in reducing retirement as Baby Boomers had age and injury concerns that prompted early retirement for the most (Schwatka et al. 2012) study outlined multiple objectives that left this cohort without options but resolved too early retirement when possible.

Most of the health issues identified with this class of retiree can be reduced with the introduction of automation (Castro-Lacouture 2009; M. Pan et al. 2018), though the gap is becoming wider and transient knowledge from one generation to the other is becoming narrower this should prompt urgency to mitigate information wealth gap that could help construction retain necessary knowledge and attain performance (M. Pan et al. 2018). A recent publication by Wellmark (2022), about the recent pandemic (Covid-19) shows that Baby Boomers are the generation with the highest risk to contract the virus, though vaccines became available they could not hold back the rounds of retirement in industries globally and construction was not left out (Gamil & Alhagar 2020; Rudolph & Zacher 2020). According to Albattah et al. (2015) and Chileshe et al. (2016), the alarming rate of Baby Boomer retiring from the construction industry will continue to contribute negatively to skilled labor shortage leaving this to slide will result in crisis for the construction industry. However, Trujillo et al. (2020) and M. Pan et al. (2020), advocate the need for stakeholders in construction to begin enforcing human-technology relationships to close this existing gap and help the new generation that is not interested in construction due to the conventional application to start seeing future in construction.

Automation Adoption and Use

Automation has become a fundamental part of other industries that pioneered its implementation with evidence of over 1000% improvement in performance metrics (cost, schedule, quality, safety, productivity, client satisfaction, etc.), moving towards a more advanced process of delivery but construction is not following the same path even with poor productivity over the last two decades (Ogunrinde et al. 2022; M. Pan et al. 2020). Innovation is gaining so much momentum in other industries that are presently gearing toward industrial revolution 4.0 through cloud integration, smart data sharing, internet of things (IoT), sensors, machine learning, etc., some of which have been integrated into aspects of construction but lack of industry relationship, continuity, and lay back attitude hampers success for technology integration (Bock 2015; Castro-Lacouture 2009). Automation is defined as the use of electronic tools managed and controlled by humans for data manipulation or product production, most times the process entails a combination of human-technology in the same operational space or a controlled room (Bock 2015; Ogunrinde et al. 2022).

To expand this definition with emphasis on construction systems and activities Bock (2015) and M. Pan et al. (2018) defined construction automation as the engineering of any phase of construction by applying numerically controlled, teleoperated, autonomous, or semiautonomous equipment to attain the required performance eliminating human error. A high point from this definition is human-technology integration, improved performance, and elimination of human error, this is very much in tune with metrics listed by (Castro-Lacouture 2009) regarding motivators for relaying on automation operated processes. Given that human error is the major detriment for achieving the required performance on construction sites, alternatives (automation adoption and use) that have shown a paradigm shift towards client satisfaction should determine construction processes to help mitigate the drought envisaged from retirement and skilled labor shortage (Albattah et al. 2015; Castro-Lacouture 2009; M. Pan et al. 2018; Schwatka et al. 2012). M. Pan et al. (2018) advocate for construction automation and robotics with humans playing the most vital role in interacting with the robot to improve productivity, (Ahn et al. 2019) listed wearable devices that can be used for reducing safety issues on site attaining job performance bringing fatalities and injuries to the barest minimum. (Bryde et al. 2013) identified several project benefits from using building information modeling (BIM) on cost and schedule throughout the project cycle, also emphasis on the positive result from waste reduction, stakeholder communication, procurement and logistics success, time management, etc. Quality management processes have several technologies that have been integrated into construction equipment and other standalone identified to yield optimum requirements (Ogunrinde et al. 2021b). However, with all the success stories made available about automation adoption and use there seem to be barriers impeding innovation implementation in construction like construction cost, technology cost, government support and requirement, organization support and culture, in-house expertise, training, economic advantage, design, scalability, industry mentality, construction team attitude, societal barriers, etc. (M. Pan et al. 2020; Trujillo et al. 2020). These barriers should guide towards automation adoption and use rather than a push back, therefore, the need to source information to help utilize these factors as leeway that could help close the gap of labor shortage (Ambra Cala et al. 2018; Ogunrinde et al. 2021a).

Research Methodology

The research relied on a systematic literature review approach *(SLA)* to identify literature that focuses on the subject matter of this study, an approach to retrieve enough literature discussing issues on skilled labor shortage, retirement, and automation in construction. *According to Regona et al. (2022), SLA is a rigorous method that provides thorough, replicable, and impartial results when seeking multifaceted answers from certain keywords using the PRISM (Preferred Reporting Items for Systematic Reviews and Meta Analyses) protocol. The approach adopted in this study have been previously used (Mobaraki et al. 2021; Regona et al. 2022) a three-stage methodological following the PRISMA protocol, Stage 1 (planning): collecting literature using set keywords in abstract and topic "construction labor/craft shortage", "skilled labor", "construction industry", "impact on labor", "labor productivity", "construction automation", "technology", construction safety and quality", "productivity improvement", and an aging workforce. During stage one, 134 works of literature were retrieved from multiple databases. However, before they are classified as usable for stage 3 it was necessary to work through stage 2 (extraction). In stage 2, primary and secondary criteria are utilized. The primary inclusion criteria were articles that are peer-reviewed, available in full-text print, and published in English from January 2000 to March 2022, papers that do not meet these criteria and duplicates were excluded. The secondary inclusion criteria were skilled labor, automation, productivity, and* *construction industry, papers lacking two of these keywords were also excluded. First, a total of 32 duplicate papers were excluded leaving available papers to 102 from 134, second, the inclusion criteria combined further reduced the papers by 74 with only 30 left that was used.* The study also relied on data from (US Bureau of Labor Statistics) BLS to identify skilled labor shortages with the most downslide and retirement positions for the construction industry.

Review of Literature

Step 3 (review reporting): The following databases Google Scholar, Scopus, Web of Science, etc were the source for exploring the literature focusing on the subject matter *to answer the research objectives*. There were restrictions to papers used for the study and emphasis was on papers discussing skilled labor shortage, retirement, and automation adoption and use in construction. Other industries were also considered beyond just construction to help justify the use of technology. Table 1 shows a breakdown of some skilled labor trades in the construction industry that will be focused on in this study. Most of these trades have different responsibilities on the job site or in a plant yard. The U.S. Bureau of Labor Statistics has a full list of all construction occupations (skilled, unskilled, and professionals), and this study will investigate information for the listed occupations in Table 1. *The trades studied in this research basically focused on the top eight and least seven most employed in construction (U.S. Department of Labor 2022). Another factor necessitating the study on these selected skilled trades is the migration of some electricians, plumbing, equipment operating engineers, steel workers, etc., to other industries for better safety, higher pay, and job security due to the prevailing hazardous tendencies in construction (Albattah et al. 2015). The lack of skilled trade workers continues to negatively impact required quality delivery on project due employment of less skilled workers, such projects are likely to experience cost escalation (Albattah et al. 2015; Karimi et al. 2018). Eliminating this cost escalation is* *critical in construction therefore, the research focuses on* labor shortage, retirement, and process automation that can be presently utilized for achieving construction success. The 6-digit is the standard occupational classification code (SOC). This code will be used for most discussions, tables, and figure descriptions. Occupation 47-4011 is not in the construction trade worker category; however, this occupation was selected as one possible option that could leverage human-technology interaction.

Table 1. Skilled Labor in Construction

S/No.	**Classification and code**	**Literature Sources**
1.	Electricians (Electrcns): 47-2111	(Albattah et al. 2015; Alsharef et al. 2021; Karimi et al. 2018; US Bureau of Labor Statistics 2021)
2.	Plumbers, pipefitters, & steamfitters (PPS) : 47-2152	(Albattah et al. 2015; Dubois & Gadde 2002; Hoonakker et al. 2010; US Bureau of Labor Statistics 2021)
3.	Roofers: 47-2181	(Albattah et al. 2015; Hoonakker et al. 2010; US Bureau of Labor Statistics 2021)
4.	Carpenters (Captrs.): 47-2031	(Albattah et al. 2015; Dubois et al. 2002; Hoonakker et al. 2010; Karimi et al. 2018; US Bureau of Labor Statistics 2021)
5.	Operating engineers and other construction equipment operators (OE & CEO): 47-2073	(Castro-Lacouture 2009; Holte et al. 2015; Karimi et al. 2018; US Bureau of Labor Statistics 2021)
6.	Construction laborers (Constr. labrs.): 47:2061	(Behm 2005; Holte et al. 2015; US Bureau of Labor Statistics 2021)
7.	Insulation workers mechanical (MIW): 47-2132	(Behm 2005; Holte et al. 2015; US Bureau of Labor Statistics 2021)
8.	Painters: 47-2141	(Behm 2005; Holte et al. 2015; Sumarningsih et al. 2016; US Bureau of Labor Statistics 2021)
9.	Construction building inspectors (CBI): 47-4011	(Albattah et al. 2015; Alsharef et al. 2021; Karimi et al. 2018; US Bureau of Labor Statistics 2021)
10.	Boilermakers: 47-2011	(Albattah et al. 2015; Karimi et al. 2018; US Bureau of Labor Statistics 2021)
11.	Drywall and ceiling tile installer (DCTI): 47-2081	(Behm 2005; Schwatka et al. 2012; US Bureau of Labor Statistics 2021)
12.	Steel metal workers (SMW): 47-2211	(Behm 2005; Dale 2013; US Bureau of Labor Statistics 2021)
13.	Cement masons and concrete fillers (CM & CF): 472051	(Behm 2005; Sumarningsih et al. 2016; US Bureau of Labor Statistics 2021)
14.	Brick and block, masons (B & B m): 47-2021	(Ahn et al. 2019; Hoonakker et al. 2010; Sumarningsih et al. 2016; US Bureau of Labor Statistics 2021)
15.	Structural iron and steel workers (SI & SW): 47-2221	(Behm 2005; Dale 2013; US Bureau of Labor Statistics 2021)

Tools for Data Analysis

Statistical Package for Social Sciences IBM 25 and Excel were utilized to perform general analysis for this study. The research uses a 15-year data bracket from 2007 to 2021 from the U.S. Bureau of Labor Statistics, to identify skilled labor with the most drop using percentages and graphs.

Percentage Comparison, Forecast, and Trend

Construction research uses percentage comparison to group or identifies factors in the order of importance, it is also to evaluate how critical an item is to other factors or items from a similar group. The study also utilized forecasts and trends to project expectations for the near future, this method has been used by other researchers in the construction space (Regona et al. 2022; Sharma et al. 2016). *According to Sharma et al. (2016), a trend pattern is used to determine how particular entities will perform in the future using previously available data, while forecast leverages on the same available data with the allowance for upper and lower bounds which is referred to as cone of probability (Regona et al. 2022). These tools were necessary for answering objectives one and two to forecast a possibility for the future a similar approach that has been adopted for the data used in this study by (US Bureau of Labor Statistics) BLS and other researchers.*

Analysis, Results, and Discussion

The analysis of data involves three steps: (1) identifying the skilled labor group experiencing the most shortage, (2) comparing retirement with job openings and hires, and (3) source information for automation adoption and use that could help complement shortage and retirement.

Identifying Skilled Labor with the most Shortage

The U.S. Bureau of Labor Statistics data will focus on the construction sector NAICS 23 (North America Classification System) which is divided into three subsectors: 1. Construction of Buildings: NAICS 236; 2. Heavy and Civil Engineering Construction: NAICS 237; and 3.

Specialty Trade Contractors: NAICS 238. According to (US Bureau of Labor Statistics), the construction sector establishment comprises primarily construction workers engaged in building and engineering projects, it may be new work, addition, remodeling, refurbishing, alterations, or repairs and maintenance. This type of project is always space specific and some organizations could have multiple sites, these jobs are done in different contract forms and this study is not considering the form of contract used for a project. The information provided from the data analysis does not reference self-employed workers in the same industry (US Bureau of Labor Statistics). Table 2 shows the percent distribution of skilled labor employment from 2007 to 2021 (15 years) using a simple percent distribution after ranking the occupation from highest to lowest, considering weight (group population divided by general population) for each year circle. This is a common simple approach for predicting or forecasting a trend for the future and has been applied in other research (Albattah et al. 2015; Alsharef et al. 2021; Veneri 1999). To expand insight, Fig. 1 is a graphically interpret of the outcome, all occupations have almost a similar web shape through the years considered. Occupations 47-2031, 47-2111, and 47-2152 increased from 2007 to 2008 and drop going forward 2009 thereafter stayed fairly the same, most of the other occupations had

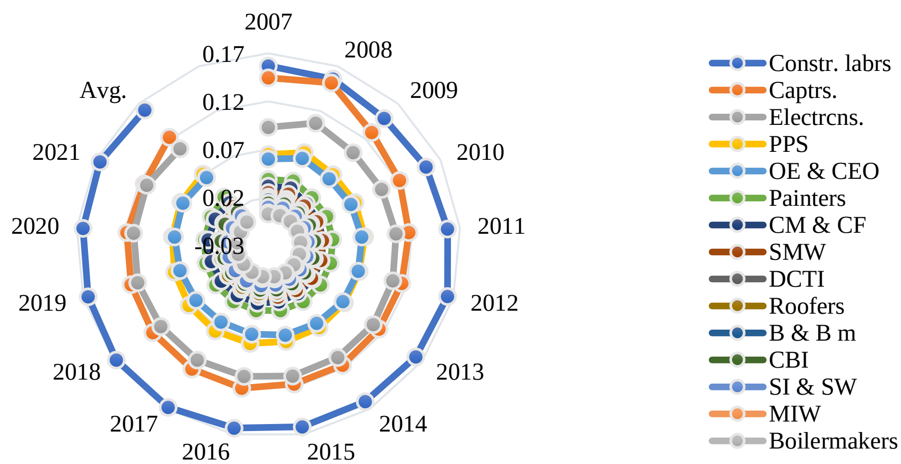


Figure 1. Graphical employment weighting

Table 2. Group employment weighting from total employment in construction

	Percent change per year (2000)															
SOC	**‘07**	**‘08**	**‘09**	**‘10**	**‘11**	**‘12**	**‘13**	**‘14**	**‘15**	**‘16**	**‘17**	**‘18**	**‘19**	**‘20**	**‘21**	**Avg.**
Constr. labrs.	0.16	0.16	0.15	0.15	0.16	0.16	0.16	0.16	0.16	0.16	0.17	0.17	0.16	0.16	0.17	0.16
Captrs.	0.14	0.15	0.13	0.12	0.12	0.11	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.11	0.12
Electrcns.	0.09	0.11	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
PPS	0.06	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07
OE & CEO	0.06	0.07	0.06	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.07	0.07	0.07	0.07
Painters	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
CM & CF	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
SMW	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
DCTI	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Roofers	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
B & B m	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
CBI	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
SI & SW	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
MIW	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boilermakers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

a similar web shapes. An exception is occupations 47-2021 and 47-4011 that could alternate positions, 47-2021 dropped from 2010 while 47-4011 increased and both stayed the same till 2021. It could therefore be stated that all occupations are experiencing almost equal shortages using the total employment for each year's circle.

Following the breakdown of employment using percentages, the researcher decided to investigate for possible skewness in data using forecasting and trend analysis. Forecasting is a method used to determine the probability of a future occurrence with an upper and lower boundary (cone of probability) for plans to mitigate future risk contingencies (Regona et al. 2022). Alternatively, trend analysis help to estimate if values will increase or decrease for a certain period to determine gradual future values from past data (Sharma et al. 2016). Before considering forecast and trends for the top and last five occupations, data for total employment from 2009 to 2021 was used to compare forecast to actual from 2016 to justify the use of cone of probability for forecast and trend line. Fig. 2 is an illustration of the total employment in construction for the period in consideration, at a 95% confidence interval (CI) with a mean absolute scale error (MASE) of 0.92 the observation presents the outcome. According to (Sharma et al. 2016) and (Regona et al. 2022), the MASE less than 1 implies the actual forecast will perform better than any other model type while a value of 0.5 implies the model has double prediction accuracy. The outcome shows that actual values from 2016 to 2021 were in the cone of probability towards the upper confidence bound, the trend was thereafter used to project a probability or likelihood for 2022 and 2023. A rise could be possible for the period with anticipation of values beyond 6 million employees for these periods Fig. 2. According to (US Bureau of Labor Statistics 2021), a projection of 6% growth for total construction workforce is a probability from 2020 to 2030, analysis of data for the year 2022 have an anticipated 4.2% increase of 6,093,996 compared to 5,848,950 of 2021. Leveraging on this information similar analysis is done for the top and bottom five occupations to project the possibility for shortfall during the same period.

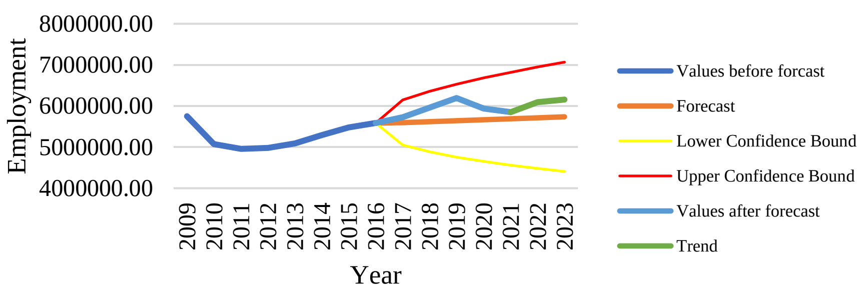
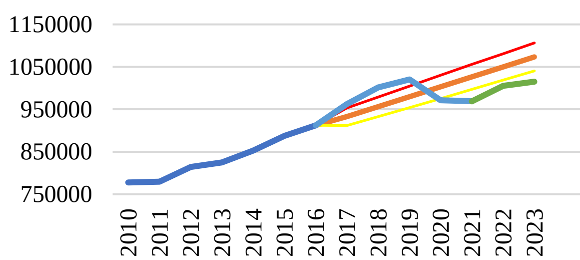


Figure 2. Construction employment comparison and projection

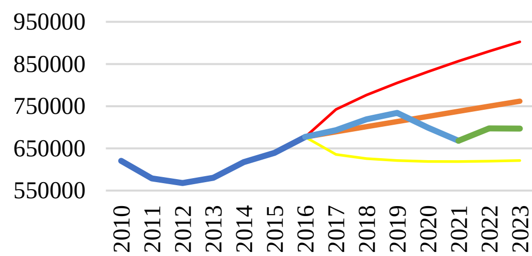
Forecast for top five occupations

Using the same method to project shortage for the top five occupations at 95% CI, occupations 47-2061 Fig. 3a with MASE 0.34 and 47-2073 Fig. 3e with MASE 0.69 were identified to have outliers from the probability cone. While 47-2061 experienced an upper and lower outlier from the cone bracket, the trend projection is also an outlier at the lower boundary. Though outside of the probability cone, it follows the trend of growth expected for this occupation and helpers from (US

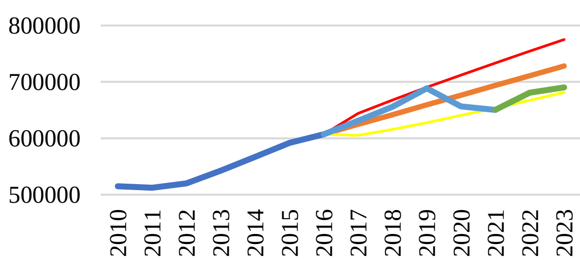
Bureau of Labor Statistics 2018). After 2017, occupation 47-2073 projected outside the upper bound and dropped in 2020 which could also be Covid-19 related, thereafter, a slight increase in 2021 and the trend indicates an increase above 420,000. Using the same metrics 95% CI the following occupations 47-2111, 47-2152, and 47-2152 Fig. 3 b, c, and d respectively show an increase in the projection trend till 2023 all within the cone of probability lower bound, the MASE score are 0.80, 0.47, and 0.52 accordingly making the prediction to have some sort of accuracy to project a future trend. The results for all five occupations indicate the need for more workers which presently is not the case with the industry needing to fill up spaces that millennials and gen z's have no interest in, therefore, the need to leverage on innovative alternatives that could help attract these cohorts. (Albattah et al. 2015; M. Pan et al. 2018). The same legends from Fig. 2 suffice for the line colors used in all the figures.



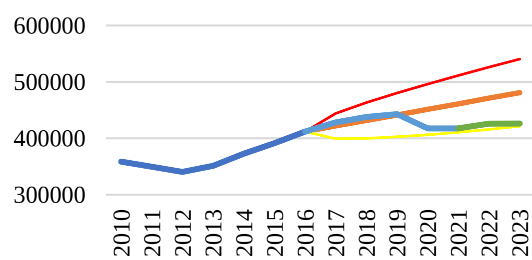
a. Construction laborers



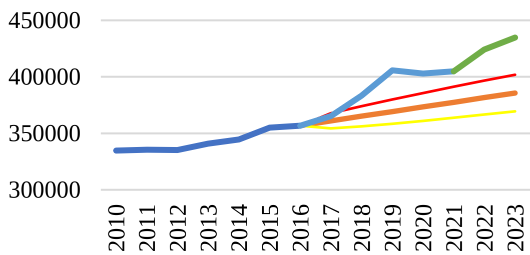
b. Carpenters



c. Electricians



d. Plumbers, Pipefitters, & Steamfitters

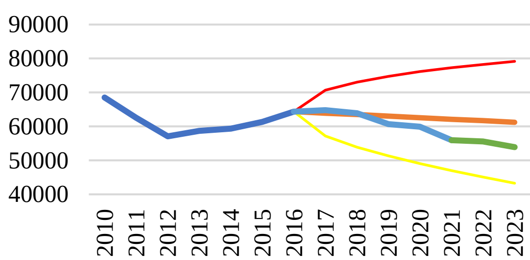


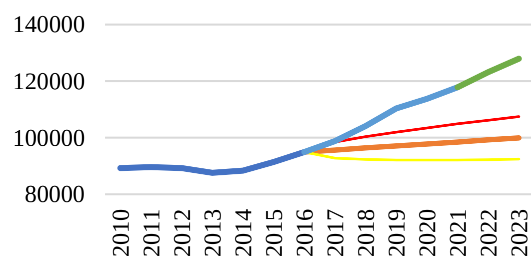
e. Operating engineers & other construction equipment operators

Figure 3. Top five occupation forecast and trend

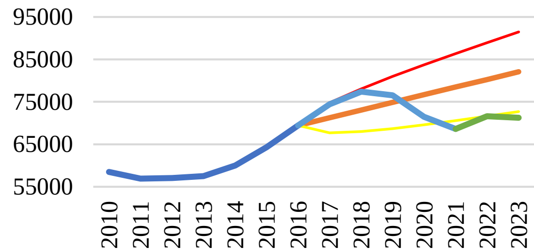
Forecast for bottom five occupations

Unlike the top five, the bottom five occupation had just one outlier 47-4011 Fig. 4b is completely out of the cone of probability in the upper bound comparing the actual and trend to the forecast, though this occupation is not categorized as trade workers urgent attention is required. However, occupations 47-2021 Fig. 4a and 47-2011 Fig. 4e are anticipated to drop in the lower bound cone of probability, and occupation 47-2221 Fig. 4c dropped out of the cone of probability thereafter a rise in 2022 and dip in 2023. Fig. 4d had a drop out of the probability cone from 2016 until 2018 comparing actual to forecast, back in the cone from 2019 in the lower bound rising to the upper bound through 2021. The trend projection for 2022 and 2023 is in the cone of probability upper bound region, with an increase in 2023. There is more drop than an increase among these occupations. These data were analyzed at 95% CI, and the MASE scores range from 0.78 to 0.51 making these analyses acceptable. A common occurrence among three of these figures (a, c, and e) is the projected drop for workers, this calls for urgent attention.

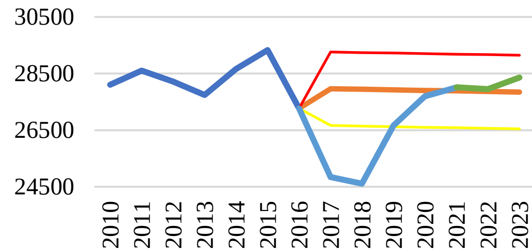




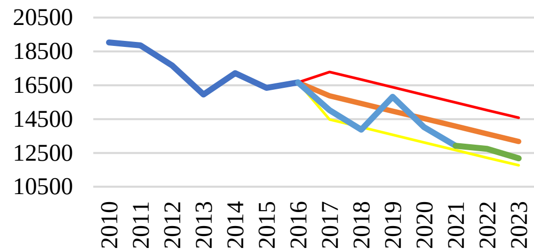
a. Brick & block masons



b. Construction building inspectors



c. Structural iron & steelworkers



d. Insulation worker, mechanical

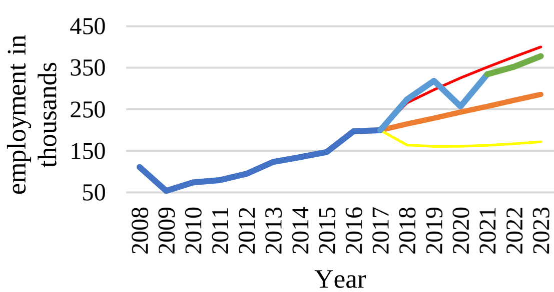
e. Boilermakers

Figure 4. Bottom five occupation forecast and trend

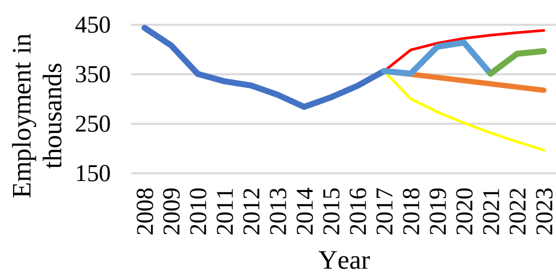
Retirements, openings, and hires

Several issues like work, aging, and the most recent pandemic (Covid-19) have led to an increased retirement in the construction industry (Rudolph & Zacher 2020), Baby boomers who have reached or nearing their retirement age are transitioning out faster than any incoming cohort into construction (Albattah et al. 2015; Schwatka et al. 2012). According to (US Bureau of Labor Statistics 2022), 42% of the employed persons in construction are 45 years and above while 58% are 44 years and below of the latter class 16 to 24 years only make up for 16%. Innovation seems to be the order of the day for this cohort bracket (16 to 24 years) and the very slow pace for adoption and use is not persuasive enough to influence their decision about joining the industry. Data (not seasonally adjusted) from the U.S. Bureau of Labor for job openings, hires, and total separation was analyzed to further explain the challenges that the future could bring for the construction industry. According to BLS, not seasonally adjusted data do not remove the effect of recurring seasonal influences from economic series leaving the data raw enough for manipulation, projecting the worse, most likely, and present occurrence. Also, total separation is a combination of retirement, relocation from one trade to another in the same industry, and relocation out of the industry completely is another option.

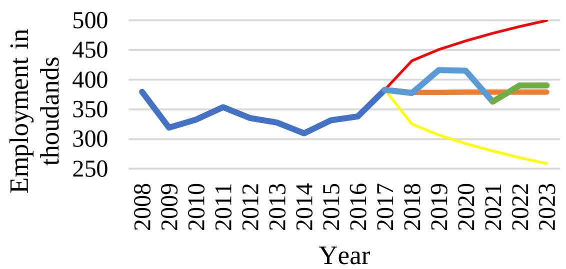
The same analysis method used above was adopted for projecting outcomes for 2022 and 2023, however, the data was not specific to only the 15 listed occupations in Table 1, the data comprises all employee information in construction and the average for each year was used. Forecast and trend analysis in Fig. 5 was done at 95% CI, with MASE score ranging from 0.62 to 0.88, job opening Fig. 5a is anticipated to keep rising in the upper bound probability cone though the actual values compared to forecast from 2017 to 2019 was outside the cone. Total separation Fig. 5b in the upper bound of the probability cone projected trend shows the possibility to rise going into 2023, hire Fig. 5c is also projected to rise but remain the same into 2023. The information below implies there will be a rise in job opening and total separation but not the same for hires that could remain flat between 2022 and 2023, economic forces could change these findings but there are somewhat similar to the projection on (U.S. Department of Labor 2022).



a. Job opening



b. Total separation



c. Hires

Figure 5. Forecast and trend for opening and entry

Automation adoption and use vs convention method

Researchers have identified better output with automation integration for construction processes as compared to relying on conventional methods, outlining several factors that could prompt faster acceptance within the construction space but this effort is considered fragmented as only a few practice this approach of development to allow practitioners and researcher provider more insight (Ahn et al. 2019; M. Pan et al. 2020). It is often thought that human displacement is the option that comes with automation adoption and use, but most of these researchers have continued to emphasize that human-technology integration is the alternative solution (Ogunrinde Okpala Hatamleh et al. 2022; M. Pan et al. 2018; Regona et al. 2022). Though construction has continued to evolve over the years with offsite fabrication and onsite installation to reduce wastage, save time and cost, achieve safety, and improve quality, it cannot be comparable to enclosed production from start to finish leaving it extremely unique (Chileshe et al. 2016; Regona et al. 2022). According to Bock (2015), M. Pan et al. (2018), and Ogunrinde et al. (2022), the conventional approach is dwindling the fabric of construction causing more set back than steps to move forward toward advanceable innovation and following this trend of innovation could help mitigate performance shortfalls and reduce human error. The acceptance of software applications for manual data collection from preconstruction to construction stage should guide the industry toward technology integration for other processes from preconstruction to maintenance of constructed facilities but this is not the case with present construction workers seeing innovation as human displacement while new entrants are more innovative driven.

Technologies that have been successfully adopted and used in construction for most of these occupations are listed in Table 3, techniques utilized in the research are human-technology integration, this is sufficient to clear any doubt that exists among construction workers about the adoption and use of technology leading to more human displacement in construction. This is not the case and is not envisaged to quickly take over processes because construction is unique in all aspect, stability and sustainability of structure is essential meaning structures are not built in an enclosure and taken to a location given the need to ascertain soil stability (Regona et al. 2022). Fabrication of components is possible which has over the years improved construction performance metrics but did not displace the required onsite installation processes that still depends on human and equipment for installation, integration of existing and emerging technologies with these machines and humans will help lure more industry entry which could also improve project performance (Bock 2015; Regona et al. 2022).

Bock (2015), Ahn et al. (2019), and Regona et al. (2022), generally classified most of the construction skill positions and concluded that through lab procedures and few site works the technologies (Table 3) have proved to be effective and reduced redundancy. The result findings from their research found electricians, plumbers, roofers, and carpenters who used 3D printing, BIM, wearables, sensors, and robotics eliminate errors associated with conventional methods, improves safety, and increases workers' delivery time with less fatigue. However, the technologies are still not in high demand due to the industry's lethargic process for adoption and use of these technologies. Fatigue is one issue that has continued to impact construction workers likewise depriving millennials and gen z's of showing interest in construction trades, some of the *technologies are viable alternatives to help with this issue (Ahn et al. 2019). Pan et al. (2018), defined construction robotics as advanced construction equipment with the capacity to be teleoperated, the ability to acquire and analyze data, and execute tasks, also concluded that all skilled labor can integrate robotics into construction activities eliminating fatigue.*

Regona et al. (2022) defined AI as intelligent controlled devices that perform task while operated automatically with the aid of self-controlling mechanical and electrical devices. AI can help construction inspection with project administration and planning, assist machine operators and construction laborers to reach optimized work delivery when integrated into the work equipment, also help other skilled labor (steel metal workers, painters, HVAC mechanics, cement mason and filler, and brick and block masons) through computer aided vision for quantifying work scope reducing error associated with conventional methods. IoT is used to communicate information via cloud-based integrating technologies (sensors, drones, VR, wearables, BIM, etc.) in one space where all parties can easily access data without delaying or infringing on work. This can easily bring all skilled construction labor data into a single space allowing a seamless workflow and swift project delivery with quick conflict identification prompting successful project delivery as compared with conventional delays. Technology adoption and use is a solution to the dwindling challenges of skilled labor the construction industry continues to experience, research has shown improved productivity, health, and safety through implementation but issues like cost, in-house expertise, regulations, client requirements, training, etc., still controls lack of adoption and use making the younger age cohorts less interested in skilled construction trades.

Table 3: Available innovative alternatives to conventional methods

S/no	**Technology**	**Sources**
1.	Robotics	(Bock 2015; M. Pan et al. 2018; Rohana 2019; Trujillo et al. 2020)
2.	Artificial intelligence (AI)	(Chamola et al. 2020; M. Pan et al. 2018; Regona et al. 2022)

3.	Internet of things (IoT)	(Chamola et al. 2020; Regona et al. 2022)
4.	Wearables	(Ahn et al. 2019; Bock 2015; Chamola et al. 2020; Y. Pan 2016)
5.	Drones	(Chamola et al. 2020; M. Pan et al. 2018; Regona et al. 2022)
6.	Virtual reality (VR)	(Chamola et al. 2020; Regona et al. 2022; Rohana 2019)
7.	BIM	(Bryde et al. 2013; M. Pan et al. 2020; Regona et al. 2022)
8.	Sensors	(Ahn et al. 2019; Bock 2015; Regona et al. 2022; Rohana 2019)
9.	3D printing	(M. Pan et al. 2018; Regona et al. 2022)

The need and gap posed for employment issues by the cohort (millennials and gen z's) in construction should increase the plight for embracing these innovative alternatives in Table 3 for construction processes, commercial contractors lament the challenges faced getting skilled workers with inexperienced skilled labor spending more time to finish tasks resulting to financial losses (M. Pan et al. 2020; Regona et al. 2022; Trujillo et al. 2020). Automation and robotics are foreseen as the best possible solution while educating the present construction workforce is fundamental to attaining the innovative concepts laid down already about the use of existing and emerging technologies (Bryde et al. 2013). The benefits of technology adoption and use outweigh the barriers given the ability shown for improved construction performance, consistent use is a solution for eliminating error, cost reduction, and learning improvement for existing technologies (Ogunrinde et al. 2021; M. Pan et al. 2020; Regona et al. 2022).

Contribution to Knowledge and Practice

The following are the contribution of this study to research and practice:

- This study is the first to compare total employment in construction with the skilled labor trade to estimate which trade is experiencing the most shortage.

- This study identified that notwithstanding the rise and drop in total construction employment, all 15 analyzed occupations experience the same amount of increase and drop during the same period.
- The top five occupations are anticipated to experience more demand for workers, while most of the bottom five are anticipated to lose workers.
- With total separation increasing retirement number jumping is a possibility in construction, though job openings and hires are anticipated to increase projecting into 2023.
- Automation adoption and use is a solution for attracting millennials and gen z's into the construction trades.

This finding should help guide research and practice on policies that should best determine viable steps within the construction environment, given that construction spending is going to keep increasing but the workers needed for the jobs are insufficient.

Conclusions, limitations, and future studies

Despite the positive result from the adoption and use of technology, there is still very little acceptance of innovation for processes in the construction industry. A ton of shortage is increasing incessant for skilled labor shortage and retirement is ticking and winding down faster due to several issues along with the most recent pandemic (Covid-19), this has not guided the industry to embrace existing and emerging technologies a prospect that could mitigate the shortfall. *According to Bock (2015), M. Pan et al. (2020), and Regona et al. (2022), the benefits derived from adoption and use of automation are viable to entice newer cohort into the industry and primarily the technology compliments construction workers both on-site and off-site. However, the authors stated that more research on human-technology integration in construction still experiences shortfalls that has continue to hamper swift automation transitioning.* To complement this gap, this study investigates

15 occupations in the construction industry focusing on 14 skilled trades and 1 general construction role based on the prevailing shortage issue. The finding of this study indicates that all occupations experience an increase, and a dip as total employment rises or falls in construction, implying all position is in a state of worker shortage though brick and block mason and boilermakers have the most dip, the trend pattern for all occupation is similar with total employment. The total separation which includes retirement is also projected to increase into 2023 a few thousand higher than hires while job opening is less compared to both, this trend is not very good for the industry with 44 years and above occupying almost 60% of present employment class while millennials and gen z's are not interested to join the construction trade workforce. The introduction of technology and integration with humans is one viable option to help ameliorate the looming issues of worker shortage with several applicable means already existing and emerging, this study *through literature review identified* some possible technology that could help *complement* workforce demand and improve construction performance metrics.

In summary, the research was able to identify that the skilled labor shortage issue in construction is holistic, retirement on the other hand, is inevitable majorly because of the cohort occupying most positions, these issues require urgent attention by gradual migration to adoption and use of technology (human-technology interaction). However, the research also had limitations that future studies must consider: 1. Investigate other occupations in construction; 2. Which occupations are experiencing the most retirement; and 3. Investigate the resulting outcome of technology adoption and use for specific occupations. This study added knowledge to practice in terms of understanding the concept and challenges of labor shortage and retirement with emphasis on all occupations considered, therefore, stakeholders in construction can leverage on this to help mitigate impending issues while sourcing available alternatives (technologies). Impact for research is leveraging on this result to expand more finding and work on the limitation to create more awareness for the society at large.

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