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Hazards of wood sawmills in Nigeria's cities: the role of fourth industrial revolution technologies

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Abstract

Purpose – Studies have proved that wood sawmill workers are exposed to high occupational risks if not well managed. In developing countries, many wood sawmills are found in urban and semi-urban areas. Studies exploring how residents near these wood sawmills perceive and react to these risks is scarce in Nigeria. The application of the fourth industrial revolution (4IR) technology is possibly one of the ways to manage the likely hazards. This study aims to investigate the possible hazards associated with timber sawmills in residential areas and the role of 4IR technologies in proffering feasible solutions to mitigate them in Nigeria's cities.

Design/methodology/approach – Data were sourced from three cities and nine sawmills across Nigeria. Face-to-face interviews were conducted with authoritative participants (residents, environmentalists, government agencies, sawmill owners, 4IR technology experts and medical experts) who have been championing the regulation and safety of timber sawmill locations within the cities (Lagos, Benin City and Owerri) via a phenomenology type of qualitative research and supplemented by secondary sources.

Findings – Findings show that timber sawmills are located across the three cities in Nigeria and may have contributed to the health and environmental challenges of the people living in the neighbourhood. The identified hazards were grouped into three sub-themes (physical, health and environmental hazards). Findings identify robots, modularisation, cyber-physical systems, the internet of things and services and human-computer interaction as the digitalised technology that can be used in sawmills to mitigate hazards for the benefit of mankind.

Research limitations/implications – The paper is limited to hazards that residents in timber sawmills locations may face in Nigeria's cities and data collected via face-to-face 23 interviews. The

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paper's referral to past publications in the findings and discussion section compensated for the small sample size.

Practical implications – As part of this paper's implications, the emerged recommendations will strengthen collaboration with relevant stakeholders regarding control measures via the use of 4IR technologies in timber sawmills. This will stir up policymakers to develop possible policies that will promote and create the platform for the implementation of 4IR technologies in city sawmills.

Originality/value – Apart from probably being the first paper to explore the hazards of residents in timber sawmill locations and proffer solutions via the usage of the 4IR technology, this paper's contribution emphasis the need for in-depth future studies regarding the risk perceptions of Nigeria's residents living in timber sawmill area.

Keywords Developing cities, Fourth industrial revolution (4IR), Health threat, Nigeria, Residents perception, Sawmill locations

Paper type Research paper

1. Introduction

Sawmill industry is one of the key forest industries involved in the processing of timbers. The industry is critical because its performance has implications for the present and future livelihood (Babatunde *et al.*, 2017). In developing countries, the timber sawmill business is lucrative. The sawmill industry is categorised under micro-enterprises. Micro-enterprises promote the economic growth of any nation (Ogundari, 2010). Babatunde *et al.* (2017) affirmed that the majority of the sawmills in Nigeria are old and lack maintenance. One of the possible reasons is the absence of an institutional framework to drive the maintenance policy. Over the years, high proliferation in the setting up of sawmills, especially in developing countries to meet the high demand for timber has been an issue. One of the consequences is the hazardous health challenge such as acute lower respiratory infections surrounding the operation. In 2016, the World Health Organisation shows that nearly one in five deaths is attributed to ambient air pollution and was caused by acute lower respiratory infections (Raimi *et al.*, 2020). The authors affirmed that the sawmill industry yields gaseous pollutants to the atmosphere during dust burning and can be hazardous to public health. Studies such as Anavberokhai (2008) found that nasal cancer and asthma are connected with continuous contact with wood dust and other substances used in the sawmill industry. This shows that the industry contributes to environmental pollution (Olalekan *et al.*, 2020). Both the avoidable and unavoidable timber waste from the sawmill contribute to environmental pollution. Thurston and Lippmann (2015) affirmed that pollution is known as a contributing factor to many non-communicable diseases. Examples are cancer in children, stroke, neurodevelopmental disorders, asthma, birth defects with heart disease, amongst others.

Waste generation is a concomitant aspect of the sawmill industry. It cannot be eliminated but can be mitigated and well managed. Ogunbode *et al.* (2013) highlighted some of the issues associated with unmanaged sawmill waste, such as urban environmental degradation, reduce the aesthetic value of buildings in that vicinity, generate aggressive odours during the rainy season and pollute the air with smoke when the wastes are burnt irrepressibly. Reyes *et al.* (2015) identified the key aspects involved in the waste timber dilemma if not well managed. This includes forest degradation, global warming, smog formation, employment issues, human health and energy poverty. Thus, mitigating mechanisms via advanced technology such as the fourth industrial revolution (4IR) technologies are pertinent to abate dangerous health, social and environmental-related problems from the sawmills in cities. Examples of digital technologies are robots, blockchain, big data, cyber-physical systems (CPS), digital twins, augmented reality, amongst others (Hirschi, 2018; Ebekozien and Aigbavboa, 2021). Robotics support the vision of the smart factory (Oesterreich and Teuteberg, 2016). Rotatori *et al.* (2021) asserted that smart factories will dramatically improve quality of life, transform the workforce and promote learning on the job. Also, this will promote reskilling and collaboration with emerging digital technologies in a symbiotic approach (Schwab, 2018). In some developed countries such as the USA, there is a greater proportion of productive work because of the increased human-machine collaboration (Briggs and Buchholz, 2019). It is germane to integrate these technologies into timber sawmill factories because of their efficiency. The potential advantages of 4IR usage include the ability to recycle waste materials for other products, the ability for mass customisation of designs regarding functional and aesthetic uses, reduction in waste from specific material placement, amongst others (Goulding *et al.*, 2015; Shakor *et al.*, 2020). The use of these technologies is not without some hindrances (Lemieux and Lemieux, 2016; Dwivedi *et al.*, 2020; Ebekozien and Aigbavboa, 2021).

The implementation of pragmatic programmes and policies to regulate and possibly mitigate the negative impact of sawmill wastes in urban and semi-urban locations is needed, especially in developing countries such as Nigeria. Manyika (2017) affirmed that technology-driven smart devices are challenging long-standing assumptions concerning the nature of the job and the expected role in the future. The wood sawmills are not exempted as research is evolving. Studies have shown that sawdust waste from timber can be turned into bioenergy and other products (Batidzirai *et al.*, 2012; Stecher *et al.*, 2013; Reyes *et al.*, 2015). The continued use of fossil fuels that has resulted in the threat from climate change stirs up researchers to call for greener mechanisms like the practice of renewable biomass wastes from timber sawdust (IEA, 2010; Charis *et al.*, 2019). Dovetail Partners (2012) reported that technology in some advanced countries has cut down the wastes generated from sawdust to make pulp, paper, engineered timber products and energy in downstream companies. In Chile, policies that promote a shift from wood fuel to forest biomass are encouraged because air pollution from residential firewood combustion has become a source of concern (Reyes *et al.*, 2015).

There is evidence that dust exposure may cause hazardous health amongst the exposed sawmill workers. Examples of such health hazards are rhinitis, chronic bronchitis, contact dermatitis, a decline of pulmonary function and noise-induced hearing loss (Thepaksorn *et al.*, 2017, 2018, 2019). Occupation noise such as the noise generated from sawmill machines and other related construction machines is a harmful agent and one of the risk factors for hearing loss in factory workers and possibly responsible for approximately 16% of the adult-onset hearing loss in the world (van der *et al.*, 2016). There is a positive correlation between noise and hearing loss in workplaces that generate high noise (Lie *et al.*, 2016). Thepaksorn *et al.* (2017) affirmed that sawmill dust and wood sap have been reported to cause skin irritation. However, no studies have been conducted for near residents in urban and semi-urban sawmill locations regarding possible hazards to the best knowledge of this paper. In developing countries like Nigeria, waste-to-energy mechanisms are restricted to steam generation for kiln driers in the available few larger sawmills and domestic practices. Because of this, the bulk of the sawmill waste is wrongly disposed of Ogunwusi (2014). This poses threats in many ways. The inadequacies of downstream industries to engage sawmill waste is a challenge. This may have contributed to the surplus timber dust in sawmills across the Nigerian cities. The reason for not having adequate downstream industries to use the waste is beyond the scope of this paper. However, there is no empirical data to quantify the rate of accumulation of the sawmill and other solid wastes (Nwosu and Pepple, 2016). Hence, the need to investigate the probable hazards associated with the timber sawmills in residential areas. The paper's objectives as stated below attempt to provide a better understanding concerning likely hazards associated with residents living near timber sawmills and the role of 4IR technologies in proffering feasible solutions to mitigate these hazards:

- To investigate the perceived hazards associated with residents living near timber sawmills in Nigeria's cities.
- To examine how 4IR technologies usage can promote healthy and environment-friendly timber sawmill industry across Nigeria's cities.

2. Theoretical background

2.1 Hazards in timber sawmill

In 1909, the first recognised sawmill was established (In Mackay's study as cited in Ekpe (2011). The latter author asserted that in many developing countries, the sawmilling sector is dominated by private business owners and the majority in small-scale. Charis *et al.* (2019) affirmed that the sector is the largest of the timber industry and has sustained a positive growth trend, especially in developed countries. This is because of the downstream industries that rely on their waste to either generate power or produce their products. Charis *et al.* (2019) asserted that there is unquantified sawmill waste left from harvesting or retreating of timber in the form of tree offcuts and tops. Ebute-Metta is recognised as the first pit sawing in Nigeria with over 200 sawmills as of today. During the processing and conversion of logs, it has been projected that the bark constitutes about 12% of the residue whilst trimmings slabs and edgings amount to 34% and 12% is projected for sawdust. Another 8% of waste may occur because of further processing in the form of sawdust, 2% trim end and 6% plainer shavings (In Koopmans and Koppejan as cited in Ekpe, 2011). The demand for sawmill waste is not greater than the amount generated from the majority of the sawmill factories in developing countries (Charis *et al.*, 2019).

Majority of the sawmills in developing countries are operated by small entrepreneurs (Charis *et al.*, 2019). Thus, many cannot afford kiln drying equipment, though located within the city centre across the country. There is a huge, unquantified sawdust waste at sawmill sites across Nigeria (Ogunbode *et al.*, 2013; Raimi *et al.*, 2020). These heaps spoil the aesthetic appeal of the vicinities with unpleasant odours. Fire hazards cannot be exempted from these heaps because sawdust can impulsively ignite (Thepaksorn *et al.*, 2018). Charis *et al.* (2019) found that sawmill waste either dry or wet state is infamous for burning gluttonously with fires. Arimoro *et al.* (2006) and Effah *et al.* (2015) identified common waste disposal approaches. This includes burning in tee-pee incinerators, municipal dumpsites if available, dumping at sawmills or in open air. The latter authors affirmed that wet sawmill wood waste generates wood residue leachate. The residue contains toxic pollutants for aquatic life and high contents of dissolved organic matter which can mobilise transition metals from soil. Charis *et al.* (2019) opined that unused sawmill wood waste over 20 years could constitute a key environmental issue and hazard for the region if not used.

Several scholars, for example, Ediagbonya *et al.* (2013), Ediagbonya *et al.* (2014), Tobin *et al.* (2016), Okedere *et al.* (2017), Awosan *et al.* (2018), Thepaksorn *et al.* (2019) and Raimi *et al.* (2020) found that wood dust inhalation is connected with lower and upper respiratory symptoms in human beings. This indicates a high occupational risk for workers in the sawmill factories, especially in developing countries where safety has not been given its priority. The symptom includes shortness of breath, wheezing, cough and sputum production (Thepaksorn *et al.*, 2019). Tobin *et al.* (2016) highlighted some of the likely symptoms. They are simple chronic bronchitis, mucus membrane irritation syndrome, organic dust toxic syndromenon-asthmatic chronic airflow obstruction, cancer of the larynx and pharynx. Preliminary investigation reveals that the majority of these sawmills are located in residential urban and semi-urban across Nigeria's cities covered in this study. The fate of the near residents despite the potentially hazardous nature of the timber sawmill factory is one area that is yet to receive in-depth study. This has become necessary because a study conducted by Awosan *et al.* (2018) found that more than 80% of the sawmill workers had good knowledge of prevention of exposure to the hazards from the wood sawmill. The governments (federal, state and local) that ought to regulate the establishment and possibly relocate the timber sawmills have not helped the matter. Also, the limited evidence of published data on wood dust exposure on sawmills within the country calls for concern. This is because many of these timber sawmills are operating below optimal safety standards. Thus, this study was designed to investigate the possible hazards associated with timber sawmills in residential areas in Nigeria's cities and proffer feasible solutions to mitigate them. The findings from this study intend to add to the body of knowledge concerning near residents in timber sawmill vicinities in Nigeria and proffer feasible policy solutions to mitigate the likely hazards. Also, this will become an avenue of advocacy to government and wood sawmill owners for the planning and design of interventions targeted towards mitigating wood sawmill wastes in the wood industry.

In Nigeria, several studies, for example, Arimoro *et al.* (2006), Ogunbode *et al.* (2013), Ediagbonya *et al.* (2013), Eziyi *et al.* (2015), Tobin *et al.* (2016), Okedere *et al.* (2017), Awosan *et al.* (2018) and Raimi *et al.* (2020) conducted studies regarding sawmill hazard but none concerning near residents' hazards. Majority of the existing published works focussed on sawmill owners and their workers' safety. Arimoro *et al.* (2006) investigated the impact of sawmill waste on rivers and fish communities in the Niger Delta region of Nigeria and it found that the sawdust is a threat to the lives of the fishes in the river. Ogunbode *et al.* (2013) examined the management of sawmill wastes and found that the majority of the mills are not willing to comply with the rules and regulations governing the management of sawmill waste. Ediagbonya *et al.* (2013) found that inhalable fractions in the sawmills captured in the south-south region of Nigeria exceeded the standard set by the National Ambient Air Quality Standard. The daily average US Environmental Protection Agency (USEPA) National Ambient Air Quality standard level concentration is 150 and 65 μg/m3 for inhalable and respirable particles, respectively. Eziyi *et al.* (2015) examined three variables (knowledge, attitudes and practice) of sawmill employees and owners with an emphasis on the implication of noise pollution and recommended the use of the protective hearing gadget. Tobin *et al.* (2016) investigated the occurrence of respiratory signs and lung function irregularities from sawmill field workers exposed to wood dust in Edo State, Nigeria and suggested the need for policy to promote dust control in the sawmill industry. Raimi *et al.* (2020) investigated the impact of sawmill sites on air quality and the consequences if not regulated and controlled by the appropriate authority. The authors found that not less than six to nine million deaths will be recorded in a year by 2060, globally from air pollution. This is a projection that should be subject to further verification and empirical evidence.

2.2 The role of fourth industrial revolution technologies: the way forward

The role of 4IR technologies in the manufacturing and construction industries has become germane to today's world. One of the reasons is that digitalisation is developing at a fast rate (Bogue, 2018). The 4IR can be described as the increase in digitisation and automation of the manufacturing environment (Schmidt *et al.*, 2015). The output will enhance the formation of a digital value chain from the factory to the final finished product. The timber sawmill industry is a component of the construction industry and cannot be left behind. The adverse effect of hazards emanating from wood dust has become a source of concern especially in developing countries (Olalekan *et al.*, 2020). The benefits of the 4IR technologies era will possibly mitigate the hazards from the timber sawmill industry. Several studies, for example, Okedere *et al.* (2017), Obiebi *et al.* (2017), Awosan *et al.* (2018) and Olalekan *et al.* (2020) have been conducted concerning the impact of the sawmill, but none connected to near residents' perception and the role of the 4IR technologies to mitigate the hazards. Many modules of robots are at an innovative stage of development whilst few that are in practice seek to mechanise conventional building practices (Bogue, 2018). These robots may be useful in sawmill factories and can mitigate wastage. Oesterreich and Teuteberg (2016) affirmed that modularisation is one of the concepts of 4IR. This is also known as prefabricated construction (Ebekozien and Aigbavboa, 2021). This technique offers many advantages such as better quality and safety whilst mitigating waste and costs (Hong *et al.*, 2016; Schwartz *et al.*, 2019). These technologies are faced with some challenges, especially in developing countries like Nigeria. Many of the sectors in Nigeria is yet to embrace 4IR technology. Ebekozien and Aigbavboa (2021) identified the construction section as one of the sectors behind ICT development in Nigeria.

It is pertinent to replace obsolete machinery with new technology to reduce wood sawmill waste that is hazardous to the environment. Caldera and Amarasekera (2015) recommended the upgrading of machinery by using thin kerf saws. Upgrading of machinery has become pertinent because of the possible threat to the people living in the surrounding environment. Tobin *et al.* (2016) suggested mechanisms to mitigate the hazard effect of wood sawmill dust on the workers' health. Firstly, sawmill workers should be educated on safety protective devices. Secondly, there should be regulation regarding permissible sawmill dust exposure levels for sawmill workers in Nigeria. The conversion of waste to energy has been suggested as a viable option that should be explored in developing countries, including Nigeria (Okedere *et al.*, 2017). This is a capital-intensive project (Reyes *et al.*, 2015). Thus, the government needs to create an enabling environment for this project to succeed. If successfully implemented, it will be a win-win scenario and at the same time improving energy generation in the country. Awosan *et al.* (2018) emphasised the need for the government at all levels to enforce compliance with occupational health and safety regulations of the timber sawmills across the country. Whilst Obiebi *et al.* (2017) suggested new work processes and health education to the workers. There is a need to extend the health education to near residents of the sawmills because of the possible effect of open sawdust burning on the near residents' health (deficits in pulmonary function- lung function impairment). OSHA (2017) recommended routine surveillance and monitoring for physical examination of sawmill workers and environmental samplings. Ebekozien and Aigbavboa (2021) suggested that companies should make budget provisions to accommodate the procurement and installation of advanced digitalised technologies. Also, policies concerning standardisation of imported 4IR technologies should be simplified.

3. Research method

This study is qualitative research because it is entrenched in interpretivism (Chandra and Shang, 2019). Ebekozien (2020a) affirmed that the concept "interpretivism" is a social construct used to describe a scenario where researchers aim to understand the meaning of people's actions and view reality subjectivity. Also, qualitative research offers an in-depth perspective through subjective interpretations of interviewees' experiences and creates a suitable mechanism to deal with work contexts (Garcia and Gluesing, 2013; Sekaran and Bougie, 2016). The study adopted a phenomenological-driven longitudinal viewpoint. Paley (2016) described the term "phenomenological" as a concept used to derive the meaning of a phenomenon via interviewing a small group of persons. Then, "longitudinal", used to investigate the viewpoints to the hazards of the near residents over time (Neale, 2018). The semi-structured interviews and reviewed literature were the two data collection tools used. This is in line with Abdul-Aziz *et al.* (2020), Ebekozien (2021) and Ebekozien and Aigbavboa (2021) that adopted a similar approach. Purposeful elite sampling technique was adopted because it targets individuals who are considered persuasive and knowledgeable in the subject matter (Marshall and Rossman, 2006).

In total, 23 participants and nine sawmills (A to I) were engaged. This cut across three of Nigeria's cities (Lagos, Owerri and Benin City) from September 2020 to February 2021 and saturation was achieved. Crouch and McKenzie (2006) asserted that when the qualities of a phenomenon are dependent on the trust of words, the sample size becomes insignificant. The strength of purposeful elite face-to-face interviews is that they can "shed light on the hidden elements" (Tansey, 2007, p. 767). The semi-structured face-to-face questions started with general questions before following explicit questions based on their replies and ensured that the stated two objectives were addressed. Theme analysis technique was adopted to analyse the collated data. This method allows for identifying, analysing and reporting themes (Stysko-Kunkowska, 2014) and to enhances the validity, reliability and replicability of the study. The study adopted researcher reflexivity, triangulation and member checking as the validity methods (Creswell and Creswell, 2018). The face-to-face interview took an average of 60 min for each meeting.

The gathered data were coded (Corbin and Strauss, 2015), in line with Ebekozien (2020a, 2020b) that coded their oral data. This study used themeing, narrative and invivo methods in the data coding (Saldana, 2015). From the 23 document data, 145 codes emerged and eight categories developed from the 145 codes. Two themes (perceived hazards associated with residents and 4IR technologies usage in sawmill industry across Nigeria's cities) emerged from the eight categories. The semi-structured questions and the covering letter with flexibility are presented in Appendix. The collated primary data were validated through secondary sources (Sekaran and Bougie, 2016). The interviewees' identities were hidden as presented in Table 1. The participants were residents with a radius of 60 metres from the sawmill (P1 to P9), environmentalists (P10 to P12), policymakers in the relevant government ministries/agencies (P13 to P15), sawmill owners (P16 to P18), 4IR technology experts (P19 to P21) and medical experts (P22 to P23). The interviewees' position indicates that those engaged have reliable insight regarding hazards associated with the timber sawmill in Nigeria's residential areas. For example, Participants P4 and P8 are residents, Chemical Engineering and Pharmacy as their background, respectively. Participant P12 has over 30 years of experience in one of the federal universities and Participant P10 is partnering with an international non-government organisation (NGO) with a focus on sustainability and greening of cities.

4. Results and discussion

The hazards from timber sawmills on exposed workers have been researched over the decades. It was found that workers without protection may develop adverse health effects. Findings show that sawmills are located across many residential cities in Nigeria, including the study areas. However, studies exploring how near residents in sawmill locations perceived the hazards associated with sawmills in a residential environment and the role 4IR technologies can play to mitigate these hazards have not been well researched. Therefore, the results and discussion were examined under two themes as pursues:

Table 1. Summary of participants' description

ID	Participant	Sawmill (Code)	Location	Years of experience/living there	Rank (if applicable)
P1	Resident	A	Lagos	18 years resident	Civil servant
P2	Resident	B		15 years resident	Architect with a private firm
P3	Resident	C		10 years resident	Self-employed
P4	Resident	D	Owerri	15 years resident	Chemical engineer in a private firm
P5	Resident	E		14 years resident	Property agent
P6	Resident	F		20 years resident	Transporter
P7	Resident	G	Benin City	40 years resident	Medical doctor
P8	Resident	H		25 years resident	Pharmacist, self-employed
P9	Resident	I		15 years resident	Lawyer
P10	Environmentalist		Lagos	25	Senior staff with NGO in environment matters
P11	Environmentalist		Owerri	17	Environment consultant
P12	Environmentalist		Benin City	30	Environmentalist in academics with ICT background
P13	Policymaker/government		Lagos	22	Assistant director
P14	Policymaker/government		Owerri	20	Senior staff
P15	Policymaker/government		Benin City	25	Senior staff
P16	Sawmill owner	B	Lagos	35	CEO with 14 staff
P17	Sawmill owner	D	Owerri	28	Manager with 11 staff
P18	Sawmill owner	G	Benin City	25	Director with 15 staff
P19	ICT expert in construction		Lagos	17	Hard and software expert in heavy-duty equipment
P20	ICT expert in construction			20	Software expert in construction equipment
P21	ICT expert in construction			25	Equipment and safety coordinating manager
P22	Medical expert		Lagos	35	Public health consultant
P23	Medical expert		Benin City	21	Pediatrician in a public hospital

4.1 Theme 1: Perceived hazards associated with residents

This sub-section offers an opportunity to the participants to identify key hazards associated with residents in sawmill vicinity across Nigeria's cities. With the exemption of Participants P16 and P18, findings show that participants are not comfortable that sawmill factories are located in urban and semi-urban areas. Participant P18 says:

> [. . .] security of our equipment and cables is one of the challenges being faced by sawmills located in isolated places even when a security guard is engaged [. . .] so, we hardly have issues of theft in residential areas. Also, the connection of electricity is easy and accessible to customers [. . .].

This indicates that some of the sawmill owners may not be bothered even if their operation causes hazards to the near residents. This can only happen in a system where there are lax regulations and enforcement by the appropriate authorities. One of the germane ideas which emerge from theme one is the classification of the perceived hazards associated with near residents in sawmill locations. They are physical, health and environmental hazards as presented in Table 2.

Participant P12, an environmentalist, opines those physical hazards comprise noise and pollution (smoke). These perceived hazards have connections with other hazards (Participants P2, P5, P11, P15 and P19). Majority of the residents in the study's cities' neigbourhood apart from Participants P4 and P8 are not aware of the damaging effects of noise and burnt wood smoke emerging from the sawmill on their health. The educational background of Participants P4 and P8 may have contributed to their knowledge to appreciate the consequences if precautionary measures are not observed. Participant P8 says, "[. . .] I don't allow my children to play within the compound any time I observe sawmill people are burning dust or waste wood because of the respiratory implications [. . ..]" Participant P17 agrees that there is high noise during operation, but the factory provides an ear protector for the workers. What becomes the fate of near residents without ear protectors? Findings show that every Saturday is the longest exposure of near residents (average of 10 h) to noise and smoke from burnt dust. For other days, it is within the average of 2 h for near residents in a normal working schedule of 8 a.m. to 5 p.m. daily except for night operation. Participants P2, P5, P8 and P9 lament that on some of the weekends, Sawmills B, E, H and I operate at night and it is difficult for them to sleep because of the noise from their machines. Participant P16 confirms the allegation of night work but insists that it is not frequent, "[. . .] may be less than six times a year, depending on the job demands [. . .]" said P16. The frequent occurrence may develop to the hearing problem if no provision for protection devices and education of the side effects. Findings agree with Lie *et al.* (2016) and Thepaksorn *et al.* (2018). The latter authors found that not using hearing protective devices (HPD) for sawmill workers may increase their risk perception. However, there is no provision for residents in sawmill areas to use HPD. This is not a good practice and may not encourage safer behaviour.

Table 2. Emerged major hazards in sawmill associated with near residents

Categorisation		
Physical	Health	Environmental
Noise	Headache	Property value decline
Pollution (smoke from burnt dust)	Sleeping disturbance	Damage roads
	Respiratory disease	Enhance flooding and erosion
	Hearing challenge	Decline in environmental quality

Health hazard is one of the major perceived threats to near residents of the sawmill. Participant P22, a medical expert says:

> [. . .] we cannot rule out the possibility of health challenges of near residents to the sawmill because of the frequent degree of noise and burning of dust/wood waste all through the year. One of the reasons is that there is empirical evidence that these sawmills' inhalable and respirable fractions are significant. This implies that it has exceeded the limit set by the National Ambient Air Quality Standard [. . .].

The health of residents around these areas may be affected depending on individual body systems (Participant P23). Examples of "health hazards" that emerged from this study are headache, sleeping disturbance, respiratory disease and hearing challenges. Participants across the board agree that frequent exposure to sawmill activities such as noise generated from machines (day and night) and burning of dust or waste timber near residents without safety measures may enhance the above health issues. Participant P7 says:

> [. . .] the negative impact of sawmill factories on my vicinity is enormous. This includes noise nuisance, aesthetic insult, contribute to the frequent headache of my son because one of the machines is directly adjacent to his room, amongst others[. . .]to make matter worse, many of these machines are old with obsolete technology that does not fit urban or semi-urban vicinity like ours [. . .].

Viewpoint from Participant P8 says:

> [. . .] I would have relocated a long time ago but as the eldest son, this building was inherited and tradition demands I remain here. So, based on my background as a medical officer, I developed an internal mechanism for my household. We maintain indoors during burning and closes all openings during their working hours. These measures have helped us [. . .].

Findings agree with Ediagbonya *et al.* (2013), Tobin *et al.* (2016), Thepaksorn *et al.* (2017) and Olalekan *et al.* (2020). Ediagbonya *et al.* (2013) and Tobin *et al.* (2016) found that Nigeria's sawmill employees had a high prevalence of respiratory symptoms such as cough because of exposure to inhalable dust. Also, Olalekan *et al.* (2020) found mean concentrations of volatile organic compounds and combustible, high than the National and International standards. This is attributed to the number of pollutants that emerged from sawmill activities. Concerning "environmental hazard", findings identify property value decline, damage existing road, flooding and erosion and decrease in environmental quality, as the hazards connected with "environmental hazard". Amongst the environmental hazards, property value decline and flooding and erosion are graded with the highest frequencies in this study. Participant P8 says:

> [. . .] the value of house rent has fallen in my vicinity because of the noise and dust from the sawmills. Intending tenants try to avoid my area because of the regular burning of waste/dust and noise from the machines.

The issue of saw-dust flooded over the earth road during rainfall is usually "ill-sighted" (Participants P1, P3, P6 and P8). Findings agree with Charis *et al.* (2019) and it was found that unused sawmill waste over 20 years could create major environmental challenges in the area.

4.2 Theme 2: Fourth industrial revolution technologies usage in the sawmill industry

This sub-section offers a platform to the participants to examine how 4IR technologies usage can promote a healthy and environment-friendly timber sawmill industry across Nigeria's cities. This has become pertinent because to cope with the imminent difficulties associated with sawmill waste across the residential locations, appropriate sawmilling practices with the feasible policy that will promote and encourage high conversion efficiency are needed (Participants P14 and P15). Findings across the board agree that 4IR technology is feasible but stakeholders have a lot to do regarding the enabling environment and policy to drive the change. One of the germane ideas which emerge from this theme is the identified 4IR technologies that can be used in sawmills and their possible functions. Digital technology supports the visualisation of the smart sawmill factory (Participant P10). This includes robots, modularisation (prefabricated construction), cyber-physical systems, internet of things and services (IoT and IoS) and human-computer interaction (HCI) (Participants P12, P20 and P21).

Robotic is one of the digital concepts that can automate the sawmill industry process and create a "smart sawmill factory (SSF)" if driven with an all-inclusive feasible policy (Participant P17). Participant P11 says, "[. . .] robot has been tested and proven successful in some manufacturing industries, making work more efficient, safer, reduce wastage, easier and more attractive". This same mechanism can be repeated in the sawmill industry but the policy and enabling environment to drive this is presently missing. Findings agree with Son *et al.* (2010) and affirmed that few approaches have been projected to use robotics technology in the construction industry. Note, the sawmill industry is a component of the construction industry. Participants P10 and P21 opine that robots if used can sort through timber waste to seek recyclable materials and reuse them for new products. This process will mitigate the burning of waste timber and make the environment friendly. From the viewpoint of Participant P13, robotics technology has not been used in the sawmill and related construction activities because of the financial implication, inadequate technical staff to manage the equipment and absence of enabling environment for investors. Training and retraining of key technical experts are germane too.

Modularisation also known as prefabricated construction, is another concept of the 4IR (Participant P12). Findings show that prefabrication has been part of the construction industry, including the sawmill industry but the digitisation to meet the advanced growth is missing in the conventional sawmill factories across the cities. Participant P15 says:

> [. . .] the practice of modularisation in the sawmill industry will bring about reduced timber waste and costs to the sawmill owners, enhance the quality to the client satisfaction and safety of the workplace and environment [. . .].

Findings agree with Hong *et al.* (2016) and it was discovered that several construction companies, especially the multi-national, adopt the prefabrication mechanism using a crane. Also, CPS is one of the approaches to promote a "smart sawmill industry", if well integrated with other components (Participant P21). Participant P11 says, "[. . ..] some factories in the developed countries use CPS as part of a real-time monitoring mechanism to check the practice of personal protective equipment during construction processes [. . .]". There is nothing wrong if the same principle is applied to the proposed smart sawmill factory with the integration of the hardware to track if the workers are wearing their PPE. This can be achieved but the stakeholders need to create the enabling environment to actualise this vision "smart sawmill factory" across Nigeria's cities.

The identified 4IR technologies used in the sawmill industry will be incomplete without evaluating the advantages of IoT and IoS. This is another central concept to the vision of the digital smart sawmill industry. Participants P19, P20 and P21 affirm that IoT and IoS can create virtual networks to encourage smart sawmill factories. This can be informed of sensors embedded in machines with the capability to connect to the internet. This can be used to check and analyse the rate of timber waste (Participants P12 and P21). They also affirm that IoT and IoS can be used to predict when maintenance of the machines should be conducted. This indicates that the breakdown of machines will be minimised and in principle save cost. Findings agree with Manyika *et al.* (2015) and it was discovered that IoT technology can save above $930bn annually on construction and other related sites work sites as reported by McKinsey & Company. Last but not least is the concept of HCI. Participants P12, P19, P20, P21 and P23 assert that the presence of humans to interact with the technology cannot be over-emphasis for a successful implementation of digitalisation of the sawmill factory.

An increased upgrading of the sawmill across the cities is desirable from a national economic viewpoint and strengthened by feasible government policy. One of the ways is to procure kiln drying equipment to manage the sawmill waste via collaboration with relevant stakeholders (Participants P12 and P21). This is presently missing because the majority of them incinerate the sawdust. Participant P20 says, "[. . ..] the Nigerian policymakers and lawmakers should come up with policies that will promote 'smart sawmill industry' via advanced technology [. . .]". Findings suggest education and training programmes for near residents on personal protective approach that can be used whilst the sawmill industry is working towards the smart industry. The proposed digitalised industry will mitigate and eliminate many of the physical, health and environmental hazards.

5. Implication and benefit of this research

As part of this paper's implications, promoting healthy and environment-friendly timber sawmill industry across Nigerian cities via 4IR technologies roles have far-reaching advantages to the sawmill industry, policymakers and near residents in sawmill vicinity. Apart from the developmental benefits of the 4IR technologies, such as mitigating wastage, efficiency, improving product output and improving collaboration and quality, the application of the technologies in the sawmill industry can promote the smart sawmill industry. One of the outcomes will be eradication or reduction of physical, health and environmental hazards. Examples are robots, modularisation (prefabricated construction), cyber-physical systems, IoT and IoS and HCI. These are some of the technologies that promote smart digitalisation and visualisation of industry. The literature on the role of 4IR technologies regarding mitigating hazards from sawmills with a focus on near residents has been strangely quiet and this gap filled in this research. The paper's results will strengthen and offer awareness of the impact of the sawmill industry on near residents. Also, the usage of 4IR technologies in the sawmill industry can be successful if the stakeholders are enlightened concerning creating an enabling environment. Thus, the usage of 4IR technologies in the sawmill industry can assist to mitigate hazards because the digital mechanism will eliminate waste and minimise open burning of dust. The paper intends to stir up stakeholders, especially sawmill owners and the government regarding creating feasible policy and the enabling environment for the conversion of conventional sawmills across the cities to smart sawmill industries. The emerged recommendations from this paper are enlightening to the major stakeholders.

Regarding the benefits of this study, the research intends to stir policymakers in government and sawmill owners to re-examine the long-time benefits of the use of 4IR technologies as one of the possible methods to mitigate hazards associated with sawmills via robotic, CPS, IoT and IoS and HCI. Therefore, mitigating the hazards (physical, health and environmental) on a sawmill industry is a component of mitigating social and health issues. This is achievable in the Nigerian sawmill industry but the import of this study shows that to harvest these advantages, factors hindering the use of 4IR should be addressed. Oesterreich and Teuteberg (2016) and Ebekozien and Aigbavboa (2021) identified some of them. This includes resistance to change, high implementation cost, inadequate knowledge management, reluctance to adopt, amongst others. These issues should be addressed via pragmatic policies because 4IR can promote the building of stronger infrastructure, generate economic wealth via converting timber waste to other products and reduce environmental degradation. These are catalysts of transformative revolution if positively implemented. The implementation has to be all-inclusive and the two key stakeholders (governments and sawmill owners) should be willing to make a sacrifice for the benefit of the future.

6. Policy and recommendation

Evidence shows that timber sawmills are located across Nigeria and may have contributed to the physical, health and environmental challenges of the people living in the neighbourhood. The government attitude to enforcement and implementation of regulatory rules and policies may have hindered advanced digitalisation usage in the construction industry, including the sawmill section. The few positive impacts of the 4IR in Nigeria come from the private organisation (ICT industry-related, banks and manufacturing). The sawmill industry, a sub-sector of the construction sector is backward when it comes to the smart industry. Findings from previous studies such as Oesterreich and Teuteberg (2016) and Ebekozien and Aigbavboa (2021) show that advanced technology can mitigate waste in construction, thus, smart sawmill factories should be encouraged. Apart from mitigating the hazards to mankind and the environment, the digitalisation and smart industry will save operational time and cost, promote workers and environment safety, improve the quality of the final product and collaboration, amongst others. The establishment of a sustainable institutional framework to drive the different phases of the process via pragmatic policies emerged as one of the feasible solutions. This includes reviewing and upgrading the existing operational policies of the sawmill factory across the cities to meet the international standard with a focus on the safety and health of the workers and near residents.

Collaboration with relevant stakeholders has been identified as one of the feasible policies. The transformation from a conventional sawmill factory to a smart sawmill factory is impossible if there is no collaboration with the relevant stakeholders, including the electricity distributor. Changing from conventional to digital industry involves huge investment. The sawmill owners should be willing to invest in this sub-sector whilst the government needs to provide the enabling environment to access interest-free loans or grants to boost the process. This will encourage more sawmill owners to kick start the process of converting their sawmills to smart sawmills. New technology comes with new training. So, re-training of technical workers, including new staff cannot be over-emphasised. Finally, findings suggest that changing from the conventional sawmill to a smart sawmill factory requires all-inclusive policies (federal, state and local governments) and is backed with commitment from policymakers and ruling political leaders.

7. Conclusion

This paper highlights the perceived hazards associated with residents living near sawmills and the role of 4IR technologies used to promote a healthy and environment-friendly sawmill industry across Nigeria's cities. The study discusses the three main groups of perceived hazards from sawmills (physical, health, environmental hazards) and the main 4IR technologies (robotic, CPS, IoT and IoS and HCI) that can be used to support the smart sawmill industry. This paper contributes towards enlightening sawmill owners, policymakers, NGOs on environmental issues and political leaders in power that converting from conventional sawmills to smart sawmills across cities is feasible but requires a collaborative effort from them.

This study can guide the academicians, policymakers and sawmill owners in Nigeria and other developing nations regarding how 4IR technologies usage can mitigate hazards associated with residents living near the timber sawmill industry. This research is not short of some restrictions such as the qualitative method used but does not affect the strength of the work. Creswell and Creswell (2018) and Ebekozien *et al.* (2019) emphasised on generalisability of findings, thus, this study recommended exploratory sequential mixed methods, a type of research design for future study. The authors affirmed that this approach aids scholars to confirm and validate the qualitative results. This is missing in earlier related works concerning sawmill hazards associated with residents and the role of 4IR to the best knowledge of this study. From an empirical perspective, future research can be conducted to identify in-depth challenges that may be confronted in converting the orthodox sawmill to a smart sawmill factory. From a practice point, the proposed smart sawmill industry can be used as a framework for the digitalisation of other sub-industries, such as the concrete industry and block industry, under the Nigerian construction industry.

References

Abdul-Aziz, A.R., Suresh, S. and Renukappa, S. (2020), "The conundrum of professionalising building surveying in Malaysia", *International Journal of Building Pathology and Adaptation*, Vol. 38 No. 5, pp. 621-634, doi: 10.1108/IJBPA-10-2019-0086.

Anavberokhai, I.O. (2008), "Environmental aspect review – a case study of two sawmills in Etuko-West, Edo state, Nigeria", *The Quantity Surveyor*, Vol. 2, pp. 12-15.

Arimoro, F.O., Ikomi, B.R. and Osalor, C.E. (2006), "The impact of sawmill wood wastes on the water quality and fish communities of Benin river, Niger Delta area, Nigeria", *World Journal of Zoology*, Vol. 1 No. 2, pp. 94-102.

Awosan, J.K., Ibrahim, O.T.M., Yunusa, U.E., Isah, A.B., Ango, M.U. and Michael, A. (2018), "Knowledge of workplace hazards, safety practices and prevalence of Workplacerelated health problems among sawmill workers in Sokoto, Nigeria", *International Journal of Contemporary Medical Research*, Vol. 5 No. 10, pp. J5-J12.

Babatunde, T.O., Babatunde, O.O., Adejumo, A.A. and Okeleke, S.O. (2017), "Cost and return structure in sawmill industry in Ijebu ode, Ogun state, Nigeria", *Journal of Research in Forestry, Wildlife and Environment*, Vol. 9 No. 3, pp. 12-18.

Batidzirai, B., Smeets, W.M.E. and Faaij, C.P.A. (2012), *Bioenergy for Sustainable Development in Africa*, Springer, Berlin, pp. 117-130.

Bogue, R. (2018), "What are the prospects for robots in the construction industry?", *Industrial Robot: An International Journal*, Vol. 45 No. 1, pp. 1-6, doi: 10.1108/IR-11-2017-0194.

Briggs, B. and Buchholz, S. (2019), *Tech Trends 2019: Beyond the Digital Frontier*, Deloitte Insights, New York, NY.

Caldera, S.T.H. and Amarasekera, S.H. (2015), "Investigation of sawmill management and technology on waste reduction at selected sawmills in Moratuwa, Sri Lanka", *Journal of Tropical Forestry and Environment*, Vol. 5 No. 1, pp. 71-82.

Chandra, Y. and Shang, L. (2019), *Qualitative Research Using R: A Systematic Approach*, Springer Nature Singapore Pte, Singapore.

Charis, G., Danha, G. and Muzenda, E. (2019), "A review of timber waste utilization: challenges and opportunities in Zimbabwe", *Procedia Manufacturing*, Vol. 35, pp. 419-429.

Corbin, J. and Strauss, A. (2015), *Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory*, 4th ed., Sage, Thousand Oaks, CA.

Creswell, J.W. and Creswell, D.J. (2018), "*Research Design: Qualitative, Quantitative and Mixed Methods Approaches*, 5th ed., Sage, London.

Crouch, M. and McKenzie, H. (2006), "The logic of small samples in interview-based qualitative research", *Social Science Information*, Vol. 45 No. 4, pp. 483-499.

Dovetail Partners (2012), "Utilisation of harvested wood by the Nort American forests products industry", National Alliance of Forest Owners, Vol. 91 No. 3, pp. 474-489.

Dwivedi, K.Y., Hughes, D.L., Coombs, C., Constantiou, I., Duan, Y., Edwards, J.S., Gupta, B., Lal, B., Misra, S., Prashant, P. and Raman, R. (2020), "Impact of COVID-19 pandemic on information management research and practice: transforming education, work and life", *International Journal of Information Management*, Vol. 55, p. 102211, doi: 10.1016/j.ijinfomgt.2020.102211.

Ebekozien, A. (2020a), "Home ownership in a Sub-Saharan Africa city: exploring self-help via qualitative insight to achieve sustainable housing", *Advances in 21st Century Human Settlements (A21CHS): Housing and SDGs in Africa*, 1st series, Springer, London, pp. 1-15, available at: www.springer.com/series/13196

Ebekozien, A. (2020b), "A qualitative approach to investigate low-cost housing policy provision in Edo state, Nigeria", *International Planning Studies*, Vol. 26 No. 2, pp. 165-181, doi: 10.1080/13563475.2020.1779671.

Ebekozien, A. (2021), "Construction companies' compliance to personal protective equipment on junior staff in Nigeria: issues and solutions", *International Journal of Building Pathology and Adaptation*, National Alliance of Forest Owners, pp. 1-18, doi: 10.1108/IJBPA-08-2020-0067.

Ebekozien, A. and Aigbavboa, C. (2021), "COVID-19 recovery for the Nigerian construction sites: the role of the fourth industrial revolution technologies", *Sustainable Cities and Society*, Vol. 69, p. 102803, doi: 10.1016/j.scs.2021.102803.

Ebekozien, A., Abdul-Aziz, A.R. and Jaafar, M. (2019), "Housing finance inaccessibility for low-income earners in Malaysia: factors and solutions", *Habitat International*, Vol. 87, pp. 27-35, doi: doi.10.1016/j.habitantint.2019.03.009.

Ediagbonya, T.F., Tobin, A.E., Ukpebor, E.E. and Okieimen, F.E. (2014), "Prevalence of respiratory symptoms among adults from exposure to particulate matter in rural area of Niger delta region of Nigeria", *Biological and Environmental Sciences Journal for the Tropics*, Vol. 11, pp. 463-466.

Ediagbonya, T.F., Tobin, A.E., Olumese, E.E., Asagba, E.U., Uwidia, E.I. and Osarumwensee, P.O. (2013), "Spatial distribution of respirable and inhalable particulate matter concentration in sawmills of South-South region of Nigeria", *Environmental Skeptics and Critics*, Vol. 2 No. 2, pp. 63-72.

Effah, B., Antwi, K., Boampong, E., Asamoah, N.J. and Asibey, O. (2015), "The management and disposal of small scale sawmills residues at the Sokoban and Ahwia wood markets in Kumasi – Ghana", *International Journal of Innovative Science and Research Technology*, Vol. 19 No. 1, pp. 15-23.

Ekpe, S. (2011), "Comparative study of activities of sawmilling industry on the environment of two selected locations within Southern Nigeria", available at: www.grin.com/document/176081

Eziyi, J., Akinwumi, I.O., Olabanji, I.O., Ashaolu, O.O. and Amusa, Y.B. (2015), "Noise pollution: knowledge, attitudes and practice of sawmill workers in Osun state, Nigeria", *Nigerian Journal of Health Sciences*, Vol. 15 No. 1, pp. 36-39.

Garcia, D. and Gluesing, J.C. (2013), "Qualitative research methods in international organisational change research", *Journal of Organizational Change Management*, Vol. 26 No. 2, pp. 423-444, doi: 10.1108/09534811311328416.

Goulding, J.S., Pour Rahimian, F., Arif, M. and Sharp, M. (2015), "New offsite production and business models in construction: priorities for the future research agenda", *Architectural Engineering and Design Management*, Vol. 11 No. 3, pp. 163-184.

Hirschi, A. (2018), "The fourth industrial revolution: issues and implications for career research and practice", *The Career Development Quarterly*, Vol. 66 No. 3, pp. 192-204.

Hong, J., Shen, Q.G., Mao, C., Li, Z. and Li, K. (2016), "Life-cycle energy analysis of prefabricated building components: an input? Output-based hybrid model", *Journal of Cleaner Production*, Vol. 112 No. 4, pp. 2198-2207.

IEA (2010), "SuStainable production of second generation biofuels", *Renew Energy*, Vol. 3, pp. 1-39.

Lemieux, V.L. and Lemieux, V.L. (2016), "Trusting records: is blockchain technology the answer?", *Records Management Journal*, Vol. 26 No. 2, pp. 110-139.

Lie, A., Skogstad, M., Johannessen, H.A., et al. (2016), "Occupational noise exposure and hearing: a systematic review", *International Archives of Occupational and Environmental Health*, Vol. 89 No. 3, pp. 351-372, doi: 10.1007/s00420- 015-1083-5.

Manyika, J. (2017), *Technology, Jobs and the Future of Work*, McKinsey Global Institute, San Francisco, CA.

Manyika, J., Chui, M., Bisson, P., Woetzel, J., Dobbs, R., Bughin, J. and Aharon, D. (2015), *The Internet of Things: Mapping the Value beyond the Hype*, McKinsey and Company, New York.

Marshall, C. and Rossman, G.B. (2006), *Designing Qualitative Research*, 4th ed., Sage, Thousand Oaks, CA.

Neale, B. (2018), *What is Qualitative Longitudinal Research*?, Bloomsbury Academic, London.

Nwosu, E.E. and Pepple, T.G. (2016), ""Site selection and analysis of solid waste dumpsites in Ile-Ife, Nigeria (8363)", *Presented in FIG Working Week 2016 Recovery from Disaster Christchurch*, New Zealand.

Obiebi, P.I., Ibekwe, U.R. and Eze, U.G. (2017), "Lung function impairment among charcoal workers in an informal occupational setting in Southern Nigeria", *African Journal of Respiratory Medicine*, Vol. 13 No. 1, pp. 8-13.

Occupational Safety and Health Administration (OSHA) (2017), "U.S. Department of labor. Guide for protecting workers from woodworking hazards", available at: www.osha.gov/Publications/woodworking_hazards/osha3157.html

Oesterreich, D.T. and Teuteberg, F. (2016), "Understanding the implications of digitisation and automation in the context of industry 4.0: a triangulation approach and elements of a research agenda for the construction industry", *Computers in Industry*, Vol. 83, pp. 121-139, doi: 10.1016/j.compind.2016.09.006.

Ogunbode, E.B., Fabunmi, F.O., Ibrahim, S.M., Jimoh, I.O. and Idowu, O.O. (2013), "Management of sawmill wastes in Nigeria: case study of Minna, Niger state", *Greener Journal of Science, Engineering and Technological Research*, Vol. 3 No. 2, pp. 34-41.

Ogundari, K. (2010), "Estimating and analysing cost efficiency of sawmill industries in Nigeria: a stochastic frontier approach", *China Agricultural Economic Review*, Vol. 2 No. 4, pp. 420-432, doi: 10.1108/17561371011097731.

Ogunwusi, A.A. (2014), "Wood waste generation in the Forest industry in Nigeria and prospects for its industrial utilisation", *The Journal of Civil and Environmental Research*, Vol. 6 No. 9, pp. 62-69.

Okedere, B.O., Fakinle, S.B., Sonibare, A.J., Elehinafe, B.F. and Adesina, A.O. (2017), "Particulate matter pollution from open burning of sawdust in Southwestern Nigeria", *Cogent Environmental Science*, Vol. 3 No. 1, pp. 1-11, doi: 10.1080/23311843.2017.1367112.

Olalekan, R.M., Oluwatoyin, O. and Olalekan, A. (2020), "Health impact assessment: a tool to advance the knowledge of policy makers understand Sustainable development goals: a review", *ES Journal of Public Health*, Vol. 1 No. 1, pp. 1002-1010.

Paley, J. (2016), *Phenomenology as Qualitative Research: A Critical Analysis of Meaning Attribution*, Routledge, Abingdon, Oxon.

Raimi, M.O., Adio, Z.O., Odipe, O.E., Timothy, K.S., Ajayi, B.S. and Ogunleye, T.J. (2020), "Impact of sawmill industry on ambient air quality: a case study of Ilorin metropolis, Kwara state, Nigeria", *Energy and Earth Science*, Vol. 3 No. 1, pp. 1-25.

Reyes, R., Nelson, H., Navarro, F. and Retes, C. (2015), "The firewood dilemma: human health in a broader context of well-being in Chile", *Energy for Sustainable Development*, Vol. 28, pp. 75-87.

Rotatori, D., Lee, J.E. and Sleeva, S. (2021), "The evolution of the workforce during the fourth industrial revolution", *Human Resource Development International*, Vol. 24 No. 1, pp. 92-103, doi: 10.1080/13678868.2020.1767453.

Saldana, J. (2015), *The Coding Manual for Qualitative Researchers*, 3rd ed., Sage, London.

Schmidt, R., Mohring, M., Härting, R.C., Reichstein, C., Neumaier, P. and Jozinovi, P. (2015), "Industry 4.0 – potentials for creating smart products: empirical research results", *International Conference on Business Information Systems*, Vol. 27.

Schwab, K. (2018), *Towards a Reskilling Revolution: A Future of Jobs for All*, World Economic Forum, Zurich.

Schwartz, J., Hatfield, S., Jones, R. and Anderson, S. (2019), *What is the Future of Work*?, Deloitte Insights, New York, NY.

Sekaran, U. and Bougie, R. (2016), *Research Method for Business, a Skill Building Approach*, 7th ed., John Wiley and Sons, West Sussex.

Shakor, P., Nejadi, S., Paul, G. and Sanjayan, J. (2020), "Dimensional accuracy, flowability, wettability and porosity in inkjet 3DP for gypsum and cement mortar materials", *Automation in Construction*, Vol. 110, p. 102964.

Son, H., Kim, C., Kim, H., Han, H.S. and Kim, K.M. (2010), "Trend analysis of research and development on automation and robotics technology in the construction industry", *KSCE Journal of Civil Engineering*, Vol. 14 No. 2, pp. 131-139.

Stecher, K., Brosowski, A. and Thran, D. (2013), *Biomass Potential in Africa*, Irena, Abu Dhabi, p. 44.

Stysko-Kunkowska, M. (2014), *Interviews as a Qualitative Research Method in Management and Economics Sciences*, Warsaw School of Economics, Warsaw.

Tansey, O. (2007), "Process tracing and elite interviewing: a case for non-probability sampling", *PS: Political Science and Politics*, Vol. 40 No. 4, pp. 765-772.

Thepaksorn, P., Koizumi, A., Harada, K., Siriwong, W. and Neitzel, R.L. (2017), "Occupational noise exposure and hearing defects among sawmill workers in the South of Thailand", *International Journal of Occupational Safety and Ergonomics*, Vol. 23, pp. 1-23.

Thepaksorn, P., Siriwong, W., Neitzel, L.R., Somrongthong, R. and Techasrivichien, T. (2018), "Relationship between noise-related risk perception, knowledge and the use of hearing protection devices among Para rubber wood sawmill workers", *Safety and Health at Work*, Vol. 9 No. 1, pp. 25-29.

Thepaksorn, P., Thongjerm, S., Siriwong, W. and Ponprasit, P. (2019), "Occupational hazard exposures and health risks at wooden toys industry in Southern Thailand", *Human and Ecological Risk Assessment: An International Journal*, Vol. 26 No. 8, pp. 1-12, doi: 10.1080/10807039.2019.1656053.

Thurston, G. and Lippmann, M. (2015), "Ambient particulate matter air pollution and cardiopulmonary diseases", *Seminars in Respiratory and Critical Care Medicine*, Vol. 36 No. 3, pp. 422-432, doi: 10.1055/s-0035-1549455.

Tobin, E.A., Ediagbonya, T.F., Okojie, O.H. and Asogun, D.A. (2016), "Occupational exposure to wood dust and respiratory health status of sawmill workers in South-South Nigeria", *Pollution Effects and Control*, Vol. 4 No. 1, pp. 1-6.

van der, M.H.F., de Vries, S.C., Stocks, S.J., Warning, J. and Frings-Dresen, M.H. (2016), "Incidence rates of occupational diseases in the Dutch construction sector, 2010–2014", *Occupational and Environmental Medicine*, Vol. 73 No. 5, pp. 350-352, doi: 10.1136/oemed-2015-103429.

Appendix. Face-to-face interview questions

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