Article

Effect of Fourth Industrial Revolution's Biological Driver on Construction Occupational Related Diseases in Gauteng, South Africa

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Abstract: The persistence of diseases that affect construction workforce as a result of activities on construction sites poses a danger to the sustainable development of the industry. This resulted to a huge loss of skilled labour and economic development of the industry and the entire country. The arrival of the fourth industrial revolution (4IR) technologies urges an urgent need to assess the effect of the technology's biological driver on the construction occupation related diseases. Therefore, this study is aimed at assessing the effect of 4IR on the construction occupation related diseases in Gauteng, South Africa. The study is quantitative in design and questionnaire survey were administered to project and Health and Safety (H&S) managers in Gauteng, South African construction sector using a proportionate simple random sampling technique. For data analysis, the Warp PLS-SEM 8.0 software algorithm was used for the analysis of the collated data. The study found that the effects of the 4IR's biological driver variables ranges between moderate to high effects for genome sequencing (GENSE) and Neurotechnology (NEURO) respectively. The combined predictive relevance of the two (2) variables predicts 64% of the construction occupation related diseases. This implies that the adoption of the driver would help reduce the causes of construction-related diseases. Hence, implies that continuous deployment of 4IR technologies would ensure that construction occupation related diseases are easily identified and put on alert.

Keywords: South Africa, fourth industrial revolution's biological drivers, health and safety, construction occupations, construction-related diseases

1. Introduction

Health and safety measures on construction sites have taken on a new dimension. The construction industry has always put a high value on the H&S of workforce as a central tenet of project performance [1]. It has been evidenced by several studies that the construction industry is one of the most hazardous industries with high rates of fatalities, injuries, and health associated problems [2,3]. It has been observed that the workforce illness caused by the occupation related diseases causes more deaths than any other H&S violation. Health problems due to occupation related diseases cause many problems for a project in terms of productivity and performance. Past studies have shown that heatstroke, eye strain, lung irritation, skin disease, backache, musculoskeletal disorders, hearing loss, skin problems, breathing problems, occupational lung diseases, and cancer are the major types of H&S ailments in the construction industry [1,2]. Generally, Baxter et al., [4] classified the occupational related diseases in the construction industry into six (6) categories: Asbestos-related diseases, silica-related diseases, noise-induced hearing loss, hand-arm vibration syndrome, musculoskeletal disorders, and dermatitis

Moreover, the studies by Stucken and Hong [5] and that of Dobie [6] described that the occupational hearing loss is the most common occupational disease in the United States (US), and it is often accepted as a normal consequence of employment. More than 30 million workers are exposed to hazardous noise, and an additional nine 9 million are at risk from other traumatic agents. On the other hand, in the United Kingdom (UK), the issue of musculoskeletal disorders (MSD) is the main occupational ailment [7]. This is a serious condition because muscle and joint problems compromise workers' ability to work and live well. Contrarily, in South Africa, Theodore et al., [8] described cardio-respiratory tuberculosis (CRTB) as the most prevalent occupational disease at 40.55%. The second most prevalent occupational disease was noise-induced hearing loss, with a reported prevalence rate of 32.36%. The prevalence of pneumoconiosis was 15.37%. The prevalence of silicosis was 14.51% [9].

Pega et al., [10] and Teixeira et al., [9] stated that occupational related diseases labeled all health problems in the work environment that includes other health issues a workforce brings to the workplace including the health issues that are triggered or made worse by work. While Pega et al., [10] viewed occupational disease as any disease contracted primarily as a result of exposure to risk factors arising from work activity. The work-related diseases have multiple causes, where factors in the work environment may play a role, together with other risk factors, in the development of such diseases. The issues of poor management, the human element, and poor working conditions were identified as the main factors triggering occupational related diseases [7]. Karthick et al., [1] further observed that the shortage in the supply of the proper technological tools and equipment, lack of responsibility, negligence of safety precautions among workforce, and workforce resistance to safety practices are the main factors triggering occupational related diseases.

Breakthroughs in biotechnological development driven by the 4IR are centered around genetic technology and neurotechnology [11]. Genetic study is one of the vibrant branches of biological research. With the advancements in computing supremacy, significant development has been achieved in reducing the cost and increasing the ease and efficiency of genetic sequencing, activating, and editing [12]. Li et al., [11] reported that previously it took more than a decade and $2.7x10^9$ USD to complete the Human Genome Project (HGP) but recently, with the advancement in computer technology, a genome can be sequenced in a few hours for less than 1000 USD. For the treatment of construction occupation related diseases, IBM's Watson supercomputer system is used provide personalized treatment plans for cancer patients by comparing the historical data obtained from the worker and treatments is made. This gives the genetic information with updated medical knowledge in just a moment. In addition, progress in genetic engineering helps the workforce towards achieving higher productivity yields by enhancing the robustness, effectiveness, and productiveness of a work site.

On the other hand, neurotechnology is used to monitor brain activity and study how the brain changes and interacts with complex working environments like construction sites. The goal of neurotechnology is to confer the performance edge of human systems on robotic machines [13].

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Floreano et al., [14] revealed that recently, the combination of information and artificial intelligence technology applications in brain sciences has been increasing gradually. There are neuroimaging and neurostimulation devices that enhance disease treatments [11]. The application of neurotechnology by the construction industry is used to treat occupation related ailments such as paralysis and control the activities of prosthetic limbs with minds for productivity improvement at the site [15]. Neurofeedback, the technology to monitor brain activity in real-time, offers countless opportunities to help fight addictions, regulate food behavior, and improve performance in a work environment. As for medical treatment, being able to collect, process, store, and compare large amounts of brain activity-related data allows the improvement of diagnosis and treatment efficiency of occupation related brain disorder and mental health-related issues [16].

Therefore, there is a need to assess the effect of the 4IR biological driver on construction occupation related diseases in the Gauteng, South African construction sector of the economy.

The objectives of this study were to:

1. To identify main factors triggering construction occupation related diseases among the workforce in Gauteng.
2. To assess the effect of 4IR biological driver on the construction occupation related diseases among the workforce in Gauteng.

1.1. Literature Review

Occupation related diseases are responsible for the deaths of about thousands of workforce in 2016, of which the construction industry in the developing countries had the largest share [17]. The majority of occupation related deaths were due to respiratory and cardiovascular diseases [18] then non-communicable diseases accounted for 81% of occupation related deaths. According to Herbert and Landrigan [18] the greatest causes of death in the UK construction industry are chronic obstructive pulmonary diseases. Moreover, in 2019, the United States experienced rise in the death figure of occupation related diseases [19]. Additionally, in South Africa, Hnizdo et al., [20] reported that the issue of ill health kills and ruins lives in the construction industry and described that a construction workforce is at least 100 times more likely to die from a disease that has been caused or exacerbated by the work than from a fatal accident. Construction work itself is regarded as stressful, tough and hazardous, highly manual, and transient in nature. Further to the conditions, approximately 30% of the workforce are transient in nature [17].

Bowen et al., [21] considered the main causes of occupational related diseases that includes exposure to long working hours and workplace exposure to air pollution, asthma agents, carcinogens, ergonomic risk factors, and noise. While [22] identified that the key risk factor triggering diseases in the construction industry is the exposure to long working hours and exposure to air pollution [23]. Occupation related diseases strain health systems, affect productivity, and ultimately affect the economy of a nation [24].

1.2. **Causes of construction occupation related diseases**

The common construction occupation related diseases are asbestosis, respiratory ailments such as silicosis, asthma, etc. Previous studies revealed that heatstroke, eye strain, lung irritation, and skin disease are found to be the major types of health problems in the construction industry [24, 25]. A construction occupation related disease is any disorder of structure or function in the body of a construction workforce especially one that produces specific symptoms or that affects a specific location and is not simply a direct result of physical and mental related injuries [26]. McTernan et al., [24] further define a "occupation related disease" as any illness caused or made worse by workplace factors. This includes many diseases that have more complex causes involving a combination of occupational and non-work-related factors. Burdorf, et al., [25] stated that the major occupation related diseases in the construction industry are dermatitis, respiratory illnesses, MSDs, hearing loss, cancer, stress, mental health disorders, etc.

The main causes of construction occupation related diseases are effect of hazardous substances such as dust that emanates from certain types of construction activities, chemicals, and potentially harmful mixtures that are common in construction sites [27]. McTernan et al., [24] identifies work processes that emit dust, fumes, vapours, or gases into the air that affects lungs as the main cause of construction occupation diseases. However, Kamardeen [27] asserted that the majority of ill health in the construction industry are as a result of overworking and unacceptable pressures. But Burdorf et al., [25] opposed and stated that the main causes of diseases in construction sites are maltreatment and intimidation of workforce, while Kamardeen [27] added that frequent harassment of workforce is the main cause of stress among the construction workforce. In addition, Chung [28] argued that other major causes of diseases in construction sites arise from use of long-time operation of vibratory equipment, effect of noise, and heavy manual work. Moreover, Gupta [29] showed that construction occupation related diseases are mostly caused by exposure to a variety of agents, including primary irritants or sensitizers, physical agents, and mechanical trauma caused by repetitive movement. McTernan et al., [24] viewed the biological agents (bacteria, fungi etc.} are the main causes of diseases in construction sites. Kamardeen [27] stated that occupational MSDs are the major illnesses among construction workers in South Africa that are caused by common repetitive movements, which include injuries such as carpal tunnel syndrome and medial or lateral epicondylitis.

1.3. **4IR's Biological drivers**

The 4IR's biological driver is centered around genome sequencing and neurotechnology [28]. Genome sequencing is the process of using recombinant DNA (rDNA) technology to alter the genetic makeup of an infected workforce. The application of genetic technologies in the areas of stem cells, cloning, gene therapy, genetic manipulation, gene selection, sex selection, and preimplantation diagnosis has created a significant opportunity for improved H&S of construction workforce [30]. Genetically engineered bacteria and other microorganisms are currently used to produce human insulin, human growth hormone, and a protein used in blood clotting for injured construction workforce [31]. One of the first cases of human benefit from genome sequencing was the production of human insulin in bacterial cells [30]. With the successful production of genetically engineered insulin, many other human proteins have been produced in this manner. This technology improved millions of workforce lives [31]. More recently, it has become possible to develop therapeutic molecules that can target occupation related diseases such as cancer by genome sequencing of naturally-occurring antibodies [28]. These antibodies may have toxic molecules attached to kill cancer cells or may be modified to improve their sticking to the cancer cells and activate the patient's immune system to destroy cancer [31].

1.4. **Factors Influencing genome sequencing 4IR biological driver**

A breakthrough in genome sequencing has been the ability to sequence the DNA in cancer cells of a construction workforce [32]. The process of genome sequencing entails the identification of which genes and mutations aids in developing medicines for cure of certain occupation related ailments. Recently, genome sequencing impacted stratification of cancer, characterization of genetic diseases, and providing information about a workforce likely response to treatment. In addition, construction workforce experiencing ill health condition, DNA sequencing provided a precise diagnosis that might affect the medical management of symptoms or provide treatment options [33]. Generally, genome sequencing provided information concerning drug efficacy or its effects. Similarly, through the analysis of workforce DNA, a specific gene variant that predispose workforce to certain ailments based on working conditions were identified and treated [34]. However, the high cost of establishing and maintaining a sequencing facility, the lack of skilled personnel, limited access to tools for genomic data manipulation and analysis, and a lack of a regulatory framework are some of the major factors influencing the establishment of genetic engineering laboratories on construction sites [33]. Land et al. [32] stated that the main factors influencing genome sequencing in construction sites are obtaining scientific information with potential medical implications, technical accuracy of the system, and protection of information. Quainoo et al. [34] argued that lifetime use of the system and cascading testing to other family members are the major factors influencing genome sequencing of workers in the construction environment. Similarly, Quainoo et al. [34] viewed that information of value to future generations in workforce families as well as staying ahead of nongenetic healthcare providers as the most important factors influencing genome sequencing at the construction sites. However, Land et al., [32] added that the sense of empowerment, psychological benefits, and cost-saving are the major factors influencing genome sequencing in the construction industry.

1.5. **Factors Influencing neurotechnology of 4IR biological driver**

Neurotechnology refers to any technology that provides greater insight into brain or nervous system activity and affects brain or nervous system function [35]. Based on the nature of the construction working environment, workforces most likely to experience brain cancer and other types of mental diseases. Neurotechnology is purely based on research purposes that experiment brain imaging to gather information about mental illness or the sleep patterns of the workforces [36]. The common goals of neurotechnology are neural activity readings that controlled external devices such as neuroprosthetics, altering neural activity via neuromodulation that restored or normalized functions affected by neurological disorders because of poor site conditions or augmenting cognitive abilities [37]. The application of natural sensors in the body of construction workforce were degenerated by diseases or decoupled by traumatic injuries, muscles, or organs that no longer obtain neural input, neurotechnology offers alternatives to pharmaceutical approaches and devices for diseases that have been fatal [35]. The pharmaceutical products that contain nanoparticles, which improve absorption within the bodies of workforces provided remedy for this

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situation. Neurotechnology provided means of using chemotherapy drugs on the affected cancer cells [38]. Teigland et al., [39] stated that neurotechnology allowed stimulation of deeper regions of the brain than other techniques of treatment for workforce with good spatial resolution. This system is cheap and portable and also provided good signal quality for easy identification of diseases. While McKiernan [38] stated that the system is used to diagnose and screen different mental illnesses and causes, Moreover, Yang et al., [36] stated that the system provided an easy drug delivery system, health monitoring, and the production of vaccines. Also, Xing et al., [35] stated that neurotechnology provided an interface between the brain of a workforce and a computer for easy control of assistive devices, phrenic and bladder pacemakers, spinal cord stimulators to treat pain, vision prostheses, grasp, and gait neuroprostheses after a stroke or spinal problem.

2. Materials and Methods

This study reviewed past literature on the 4IR biological driver and construction occupation related diseases. In addition, the study was aimed at assessing the effect of 4IR biological driver on the construction occupation related diseases. Subsequently, the variables identified from previous literature were used to adapt a structured questionnaire that was used to collect data on the three (3) study constructs, consisting of two (2) constructs of the 4IR biological driver (independent variables) and one (1) construct on the construction occupation diseases (dependent variable). Thus, the study design was quantitative [40].

A total subject of 650 4IR experienced project and H&S managers working with the construction industry in Gauteng Province, South Africa were asked to complete the adapted structured questionnaire. The questionnaires were administered to the respondents through the WhatsApp handle platform. About 462 completed questionnaires were returned and 400 selected for further consideration and analysis. Sixty-two (62) of the returned questionnaires were rejected because of inconsistencies in the responses. The analysis represented 71% and 61% return and response rates, respectively.

The primary research tool for the study were WhatsApp administered questionnaires. Questionnaires had only closed ended questions [41]. The questions used in this study were captured by the three (3) constructs namely: construction occupation related diseases (CORED) as the dependent variable, while the genome sequencing (GENSE), and the neurotechnology (NEURO) were factors of 4IR biological driver (independent variables) respectively. All the variables were measured on a 5-point Likert scale. Through the development of a model, partial least squares structural equation modeling (PLS-SEM) was used to analyze the data obtained and to examine the effects of the path model between the constructs. Hair et al., [42] suggested that PLS-SEM facilitates theory building in studies that seek to explore causal relationships between latent variables rather than the covariance based structural equation modelling (CB-SEM) that is generally used to confirm theories [42]. Moreover, PLS-SEM was employed for the analysis because of its high predictive ability and for examining the validity of reflectively measured constructs [42]. The measurement model of the conceptual framework is depicted in Figure 1, and it shows the number of items in each construct. Table 1 indicates the sources from which the items of each construct were adapted.

This study adopted two (2) theories: the Scientific Management Theory and Schumpeter's Innovation Theory. The two (2) theories tend to explain the relationship between the application and use of technology in H&S services i.e., the application of technology for the identification, controlling, and curing of certain kinds of occupation related diseases.

The scientific management theory was developed by Frederick Taylor [43] which posits that a scientific method should be used to perform tasks in the workplace, as opposed to the leader relying on their judgment or the personal discretion of team members. The theory explains that scientific and technological methods like the 4IR's biological driver to reduce occupation related diseases. On the other hand, Schumpeter's [44] Theory of Innovation is in line with other business investment theories, which assert that the change in business investment accompanied by monetary expansion is the major factor behind business improvement, Schumpeter's Theory posits that business innovation is the major reason for minimizing cause-effect relationships, hence improving productivity in investments and business success. The two theories explain the relationship between the study constructs, i.e., two dimensions of the 4IR's biological driver and the construction occupation related disease were considered in this study. Hence, the theories advocate the adoption of technology to minimize the cause-effect relationship and improve business productivity.

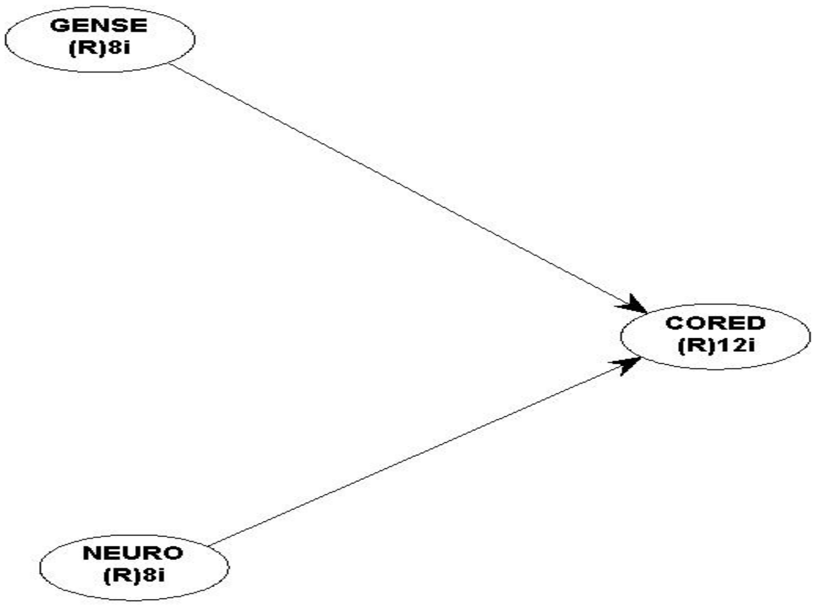

Figure 1: Measurement Model

Based on the measurement model in figure 1, the following directional alternate hypotheses were developed:

H_{A1}: There is a significant high effect between the genome sequencing of the 4IR biological driver (GENSE) and the construction occupation related diseases in Gauteng.

H_{A2}: There is a significant moderate effect between the neurotechnology of 4IR biological driver (NEURO) and the construction occupation related diseases in Gauteng.

Table 1. Development of the construct for the study

S/N	CONSTRUCTS	SOURCE
CORED	**Factors Reducing Construction Occupational-Relative Diseases**	
CORED 1	Easing repetitive movement	McTernan et al., (2013); Burdorf et al., (2003)
CORED 2	Improving setting up of workstations	Hämäläinen et al., (2007); Kamardeen, (2021)
CORED 3	Improve sanitary condition	Burdorf, et al., (2003), Chung (2021)
CORED 4	Correcting poor design of tools	Kamardeen, (2021); Chung (2021)
CORED 5	Eliminating hazardous dust	Chung (2021); Gupta (2021)
CORED 6	Eliminating hazardous chemicals	Gupta (2021); Takala et al., (2017)
CORED 7	Controlling biological agents (insects, reptiles, animals)	Bowen et al., (2013); Kamardeen, (2021)
CORED 8	Controlling working temperature	Takala et al., (2017); Gupta (2021)
CORED 9	Minimizing unacceptable pressure and attacks	Baxter, et al., (2010); Bowen et al., (2013)
CORED 10	Heavy overwork	Wang, (2021); Kamardeen, (2021)
CORED 11	Minimizing maltreatment of worker	Lopes, Haupt, & Fester, (2011); Gupta (2021)
CORED 12	Elimination of heavy noise	Al-Kindi et al., (2020); Kamardeen, (2021)
GENSE	**GENOME SEQUENCING**	
GENSE 1	Analyzing of worker's DNA for a specific gene variant that may predispose workers to certain ailment as a result of working condition	Land et al., (2015); Quainoo et al., (2017)
GENSE 2	Precise diagnosis of occupationally related diseases	Punina et al., 2015); Chung (2021)
GENSE 3	Characterization and stratification of occupationally related disease	
GENSE 4	Information on workers' likely response to diseases	Quainoo et al., (2017) Chung (2021)
GENSE 5	Information on drug efficacy or its effects	Greenhill et al., (2021); Quainoo et al., (2017)
GENSE 6	Advancement in the development of medicines for workers	Chung (2021); Quainoo et al., (2017)
GENSE 7	Access to scientific information on different occupational diseases	Lund (2021); Chung (2021)
GENSE 8	Technical accuracy of the system	Chung (2021); Quainoo et al., (2017)
NEURO	**NEUROTECHNOLOGY**	
NEURO 1	Provides brain imaging for information relating to the mental health of workers	Xing et al., (2020); Umer et al., (2018)
NEURO 2	Controlling external devices (neuroprosthesis) to aid workers	Yang et al., (2021); McKiernan, (2017)
NEURO 3	Augmenting cognitive abilities	Umer et al., (2018); Lund (2021)
NEURO 4	Aiding natural sensors of the body of workers	McKiernan, (2017); Lund (2021)
NEURO 5	Nanoparticles aid infected workers to discharge their duties	Teigland et al., (2018); McKiernan, (2017)
NEURO 6	Chemotherapy improves workers' damaged cells	Lund (2021); Chung (2021)
NEURO 7	The good signal quality output of information	Chung (2021); Xing et al., (2020);
NEURO 8	Provides an interface between worker's brain and the controlling computer	Greenhill et al., (2021); Xing et al., (2020);

The research constructs cover the construction occupation related diseases in Gauteng, South Africa, and the two (2) dimensions of the biological driver of the 4IR were all measured using the 5-point Likert scale. The Likert scale is concerned with one-dimensionality and is also the most popular scaling procedure that is commonly used in engineering management research [42]. The construction occupation related diseases were dependent variable and was operationalized from very low severe to very high severe. The independent constructs (dimensions), i.e., the genome

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sequencing and neurotechnology dimensions of 4IR, were operationalized using very low effect to very high effect. The operationalization process was adapted from the studies of Gambo and Musonda [45].

3. Results

3.1. Respondents' demographic information

Table 2 shows the respondents' demographic information. The results in table 2 indicated that about 58.25% of the respondents were 4IR experienced project managers working in the construction sector in the Gauteng. While, about 41.75% of the respondents were 4IR experienced H&S managers working in the province. The project and H&S managers were also managed the H&S practices of the construction firms in the province. All the respondents hold at least a bachelor's degree in construction-related disciplines. Only about 10% of the respondents are Ph.D. holders, and about 44% have Master's degrees, while almost 46% of the respondents hold Bachelor's degrees as their highest educational qualification. This shows that all the respondents are educationally qualified to respond to the questionnaire of this nature, and as such, enhanced the validity of the research data. Also, Table 2 revealed that the study respondents have an average of 12 years of working experience in the H&S practice; this implies that the professionals are very experienced in the area of this research.

Table 2: Respondents Demographic Information

Project Managers	**No.**	**%**	**Cumulative %**	
Project Managers	233	58.25	58.25	
H&S Managers	167	41.75	100	
Total	**400**	**100**		
		Educational Qualifications		
PhD	38	10.00	10.00	
MSc	178	44.00	54.00	
BSc	184	46,00	100	
Total	**400**	**100**		
		Years of Experience		
Years	**Mid Value (x)**	**Frequency (f)**	**% of Frequency**	**fx**
5-10	7.5	126	31.50	945.00
10-15	12.5	147	36.75	1837.50
15 and above	15.0	127	31.75	1905.00
Total		**400**	**100**	**4687.50**

Mean of years of experience Σfx/Σf = 4687.50/400 = 12 years' mean experience

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3.2. Indicators of model fit

Past studies provided basic sets of guidelines on the information that should be included in the reports on the confirmatory factor analysis as the primary statistical analysis technique. Such indices include Chi-square 2, Alike Information Criteria (AIC), Comparative fit, Parsimonious fit, Goodness-of-fit index, Standardized root mean square residual (SRMR), Bentler-Bonett or Normed fit index, and Root mean square error (RMSE) [42]. However, Kock, [41] stated that there is a theoretically straightforward differences between CB-SEM and PLS-SEM. When the research objective is theory testing and confirmation, then the best method is to use CB-SEM. In contrast, if the research objective is prediction and theory development, then the suitable method is to use PLS-SEM. Conceptually and practically, PLS-SEM is similar to multiple regression analysis. On the interpretation of the model fit, if the goal is to only test hypotheses, where each arrow represents a hypothesis, then the model fit indices are of little importance. However, if the goal is to find out whether one model has a better fit with the original data than another, then the model fit indices are useful sets of measures related to model quality (Kock, 2017).

However, PLS-SEM software algorithms reported the following indices: The fit indices are used to compare the indicator correlation matrices such as the standardized root mean squared residual (SRMR), standardized mean absolute residual (SMAR), standardized chi-squared (SChS), standardized threshold difference count ratio (STDCR), and standardized threshold difference sum ratio (STDSR). As with the classic model fits and quality indices, the interpretation of these indices depends on the goal of the SEM analysis. Since these indices refer to the fits between the model-implied and empirical indicator correlation matrices, they become more meaningful when the goal is to find out whether one model has a better fit with the original data than another, particularly when used in conjunction with the classic indices [41]. When assessing the model's fit with the data, several criteria are recommended as follows. The average path coefficient (APC) was 0.436 with a P-value ≤ 0.001, the average R-squared was 0.637 with a P-value ≤ 0.001, and the average adjusted R-squared (AARS) was 0.635 with a P-value ≤ 0.001. The average block VIF (AVIF) = 1.633, acceptable if ≤ 5, ideally ≤ 3.3 hence regarded as ideally. The average full collinearity VIF (AFVIF) = 2.402, acceptable if ≤ 5, ideally ≤ 3.3 hence regarded as ideally. The VIF is used when indicators are formative. Tenenhaus GoF (GoF) = 0.527, small ≥ 0.1, medium ≥ 0.25, large ≥ 0.36, then GoF is regarded as large, The GoF is the geometric mean of the average communality (outer measurement model), and the average R^2 of endogenous latent variables represents an index for validating the PLS model globally, as it looks for a compromise between the performance of the measurement and the structural model, respectively. The Sympson's paradox ratio (SPR) = 1.000, acceptable if ≥ 0.7, ideally = 1 and regarded as ideally. Therefore, all the fits indices are acceptable in this study. The R-squared contribution ratio (RSCR) = 1.000, acceptable if ≥ 0.9, ideally = 1, is regarded as ideal in this study. The statistical suppression ratio (SSR) = 1.000, which is acceptable if ≥ 0.7, so it is acceptable in this study. Nonlinear bivariate causality direction ratio (NLBCDR) = 1.000, acceptable if ≥ 0.7, which is regarded as acceptable in this study. The standardized root mean square residual (SRMR) value for this model was 0.07, which indicated a good fit [46]. The Bentler-Bonett

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or Normed fit index was 0.98, which was considered good [47]. The root mean square error (RMSE) for this model was 0.05 and was regarded as good according to [48]. Therefore, this model has a good fit index.

3.3. Measurement Model

Table 2 shows the assessment of the model by WarpPLS 8.0 algorithm which typically follows two steps, namely: the assessment of the reflective measurement and structural models [42]. The assessment of the measurement model examines the validity and reliability of the measurement instrument and the relationship among the constructs. The mssodel for this study has 3 reflective constructs namely: construction occupation related diseases CORED as dependent variable and the independent variables comprises of 4IR biological genome sequencing GENSE and 4IR biological neurotechnology NEURO. The reflective measurement model evaluates the reliability and validity of the model. The two criteria are composite reliability and the average variance extracted, AVE [42]. This study used the internal consistency in testing the reliability of the research instrument. According to Benjamin et al., [49] the Cronbach's alpha (α) testis used for the questionnaire's construct consistency and level of random error. The use of Cronbach's alpha allows the negative construct to be detected and positive to be accepted ranging from 0.0 to 1.0 scales. The minimum acceptable value for Cronbach’s alpha is from 0.6 scale [50]. Once, an item is to be used together as a scale in this study, the item must be within the benchmark value of reliability indicators. Ho, [50] stated that the reliability of a measuring instrument is defined as its ability to consistently measure the phenomenon it is designed to measure. Reliability, therefore, refers to test consistency. The importance of reliability lies in the fact that it is a prerequisite for the validity of a test. The internal consistency tests comprise of split-half technique, item analysis, and Cronbach's alpha method. One of the shortcomings of Cronbach's alpha is that it usually under-estimates the reliability of a construct with a small sample size (<100), but construct with a large sample size (>100) Cronbach alpha is used to estimates the internal consistency of the construct [42]. However, Ho, [50] recommended Cronbach's alpha test as the most reliable among others.

Therefore, the indicator and construct reliability were assessed to evaluate the reliability of the reflective measurement model for structural equation modeling. The indicator reliability was evaluated by cross-checking the loading of each indicator variable on its associated latent construct, and the loading should be higher than 0.70 before accepting the reliability of the indicator variable [42]. For the assessment of construct reliability, two coefficients are considered, i.e., composite reliability and Cronbach's alpha [51]. Hair et al. [42] recommended CR for PLS-SEM.

Table 2.0 shows the results of the measurement model for this study, which indicated high internal consistency and reliability. The indicator loadings were all well > 0.70 and both the CR and Cronbach’s ranged from 0.899-0.846 and 0.873-0.791, respectively. This shows that all the indicators and constructs' reliability are acceptable. Convergent and discriminant validity are also considered in the validation of the reflective measurement model [42]. The average variance extracted (AVE) values of the constructs must be greater than 0.5 for an acceptable convergent validity [42]. The AVE is only applicable to models with reflective indicators. AVE measures the total variance of a construct through its indicators [50]. The AVE values for this study ranged between 0.556-0.510, all higher than the benchmark of 0.500. Therefore, the convergent validity of the measurement model is highly acceptable [52].

Table 3: Results of the measurement model evaluation

Construct	Items	Factor Loading	CR	Cronbach's α	AVE
CORED	CORED 1	0.937	0.899	0.873	0.544
	CORED 2	0.922			
	CORED 3	0.878			
	CORED 4	0.778			
	CORED 5	0.912			
	CORED 6	0.728			
	CORED 7	0.931			
	CORED 8	0.742			
	CORED 9	0.959			
	CORED 10	0.749			
	CORED 11	0.781			
	CORED 12	0.832			
GENSE	GENSE 1	0.911	0.846	0.791	0.510
	GENSE 2	0.754			
	GENSE 3	0.711			
	GENSE 4	0.977			
	GENSE 5	0.758			
	GENSE 6	0.739			
	GENSE 7	0.831			
	GENSE 8	0.934			
NEURO	NEURO 1	0.781	0.867	0.823	0.556
	NEURO 2	0.922			
	NEURO 3	0.758			
	NEURO 4	0.774			
	NEURO 5	0.954			
	NEURO 6	0.838			
	NEURO 7	0.766			
	NEURO 8	0.821			

Note: α-alpha; CR-composite reliability; AVE- average variance extracted

Table 4 indicates the discriminant validity of the measurement model. Discriminant validity is the extent to which a construct is distinguished from other constructs in the model [42]. This is achieved through checking of the AVE of each construct and must be higher than the highest squared correlation of the construct with any other construct in the model, or the loading of an indicator with its associated construct must be higher than that with other constructs [53]. The results indicated that the square root of AVE for each construct with its correlation to another construct is acceptable discriminant validity of the measurement model.

Based on the results of the measurement model, the questionnaires were recognized to be reliable and valid for the assessment of the study constructs.

Table 4: Results for discriminant validity

	CORED	GENSE	NEURO
CORED	**0.768**		
GENSE	0.667	**0.640**	
NEURO	0.648	0.623	**0.676**

Note: Discriminant validity showing AVE

3.4. **Measures and Path Coefficients of the Model**

Figure 2 indicates the R^2 measure of endogenous latent variables (constructs) and the path coefficients of the model. The model is evaluated as a part of a preliminary assessment of structural relationships, i.e., inner model and hypothetical framework [42]. Therefore, Chin [54] suggested 0.67, 0.33, and 0.19 as substantial, moderate, and weak measures for R^2 respectively. The R^2 for this study was 0.64, which indicates moderate relationships exist between criterion and predictor variables. The path coefficient between GENSE on CORED also had a β-value of 0.60 with a P-value of < 0.01 significant at a P-value 0.05 level of significance. Similarly, the path coefficient between NEURO and CORED had a β-value of 0.28 with a P-value of < 0.01, which is significant at a P-value 0.05 level of significance.

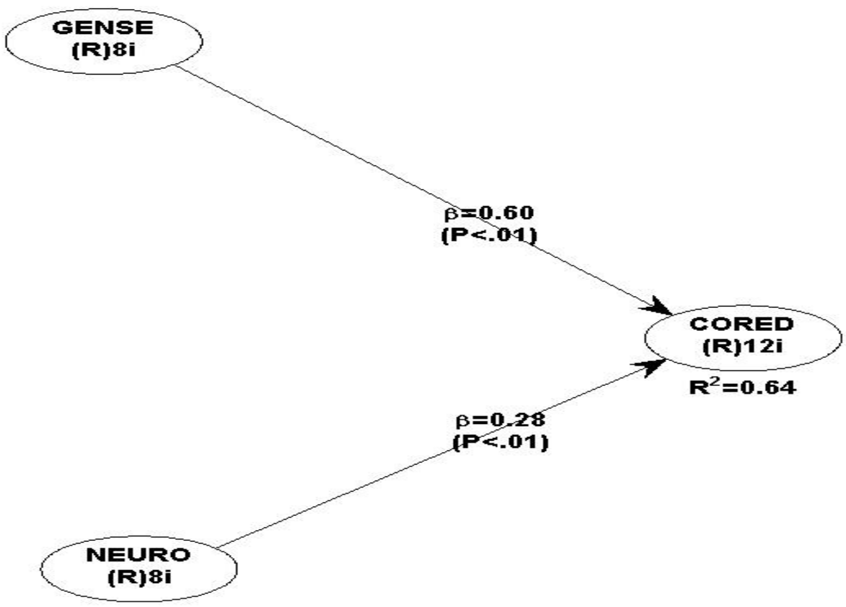

Figure 2: Assessment results for the structural model

Table 5 indicates the effect size (f^2), which is a measure that confirms whether the effects indicated by the path coefficients are low, moderate, or high for the values of f^2 of 0.02, 0.15, and 0.35, respectively [55]. Effect size (f^2) indicates the effect of a certain construct

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on the dependent latent variable is substantial [54]. The f^2 between GENSE and CORED was 0.46, which indicated a high effect size. The f^2 between NEURO and CORED was 0.18 indicating a moderate effect size, respectively. The predictive competency of each endogenous construct in the model was determined by Stone-Geisser's (cross-validated redundancy) (Q^2) [42]. The predictive skill of this model was 0.64, and WarpPLS-SEM automatically generates Q^2 [41]. Hair et *al., [42]* reported that Q^2 values indicate the predictive relevance as either weak (0.02), moderate (0.15), or strong (0.35). Therefore, this model exhibits strong predictive relevance because of $Q^2 > 0$, i.e., about 0.64 [41]. As a result, Hair et al., [42] concluded that the path model's predictive relevance on the endogenous construct is strong. This implies that the two predictors of CORED (GENSE and NEURO) predict 64% of the variance of the dependent variable.

Table 5: Hypotheses-Testing Results

Hypotheses	**Path coefficient**	**P-value**	**Effect size (f^2)**	**Stone-Geisser's (Q^2**	**R^2**	**Supported**
GENSE→CORED	0.60	<0.01	0.46	0.64	0.64	Yes
NEURO→CORED	0.28	<0.01	0.18			Yes

Note: Level of significance (p) ≤ 0.05; Q^2-cross-validated redundancy

Graphical relationships amongst the study constructs

Figure 3 presents a graph of the relationship between the adoption of GENSE and CORED. The graph indicates that a linear relationship exists between the two (2) constructs. The relationship implied a positive relationship, which means that the adoption of GENSE would improve the construct CORED. The coordinates' points (x_o, y_o and x_1, y_1) and the regression line of the graph were (2.00, 2.83 and 4.85, 4.64). The mean score value of CORED was 4.09 with a standard deviation (SD) of 0.55. On the other hand, the construct GENSE had a mean score value of 3.97 and a SD of 0.82.

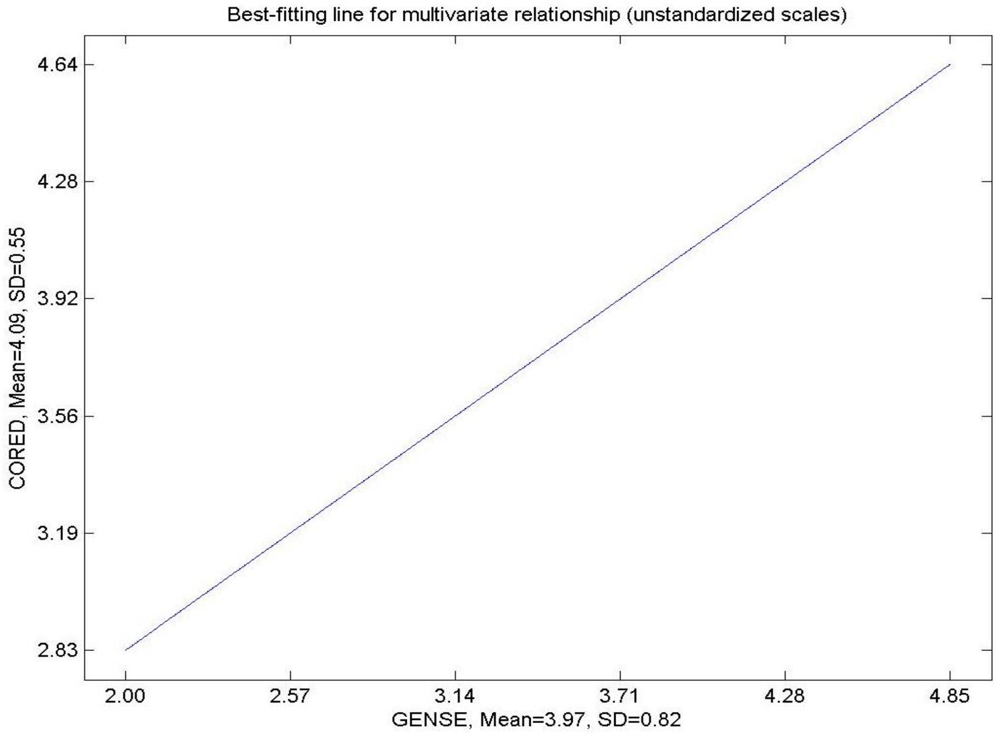

Figure 3: Relationship of GENSE and CORED

Figure 4 presents a graph of the relationship between the adoption of NEURO and CORED. The graph indicates that a linear relationship exists between the two (2) constructs. The relationship implied a positive relationship, which means that the adoption of NEURO would improve the construct CORED. The coordinates' points (x_o, y_o and x_1, y_1) and the regression line of the graph were (1.94, 3.54, and 5.00, 4.31). The mean score value of CORED was 4.09 with the standard deviation (SD) of 0.55. On the other hand, the construct GENSE had a mean score value of 4.13 and a SD of 0.93.

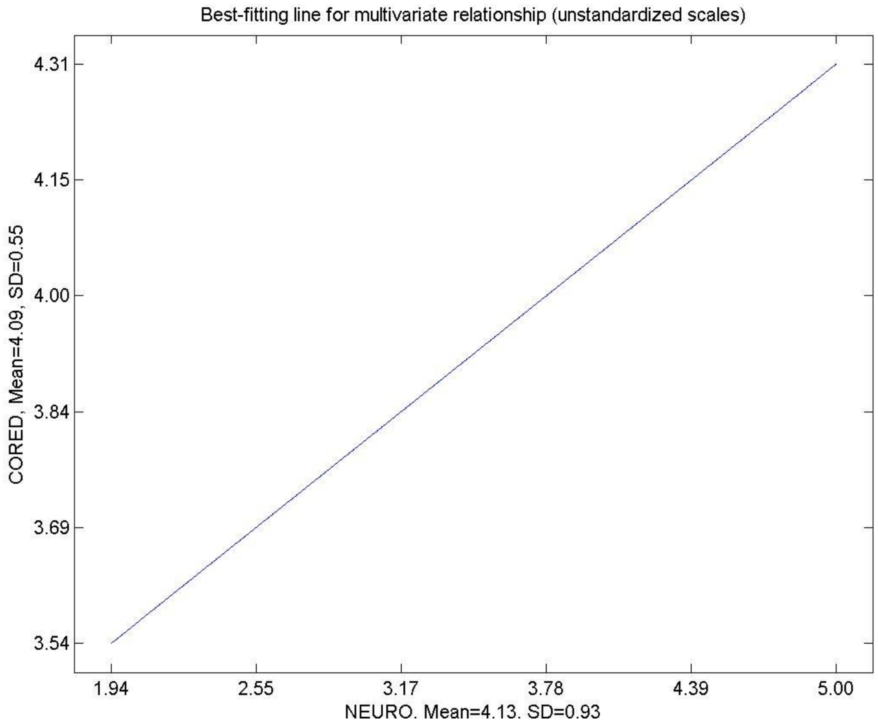

Figure 4: Relationship of NEURO and CORED

Discussion of Results

This study assessed the effect of the 4IR biological driver on the construction occupation related diseases in Gauteng. Two constructs were considered as predictor variables i.e., genome sequencing and neurotechnology and the outcome variable was construction occupation related diseases. The constructs were identified from past studies. The predictor constructs were chosen based on the classification of Li et al., [11] that categorized the biological driver of the 4IR as genome sequencing and neurotechnology. The 4IR was built on the previous revolutions and used biological driver for identification and treatment of diseases among workforce. This is characterized by the fusion of technologies that is clouding the lines between genome sequencing and neurotechnology spheres, enabling industrial organizations to rapidly diagnose and treat patients.

The results of the measurement model indicates that the research instrument is highly reliable and valid for the intended purpose. Hence, indicating the reliability and validity of the results. The study found that the major construction occupation related diseases affecting workforce on the construction sites are pulmonary disease, stroke, ischemic heart disease, asthma, muscular diseases, mental disorders, stress, biological diseases, etc. [1,2].

The results indicate that the adoption of genome sequencing of the 4IR biological driver had a high effect on the construction occupation related diseases in Gauteng. This result supported the study by Abas et al., [56]on a survey on work-related musculoskeletal disorders (WMSDs) among construction trades in Malaysia and suggested the use of advanced technology and proper observation of the H&S regulatory framework for the construction industry. Similarly, the finding supports that of Biswas et al., [57] on the occupational health status of construction workers, which indicated that construction workers are commonly faced with physical, chemical, biological, mechanical, and psychosocial hazards during their daily working schedules, and the study paper suggested the application of sophisticated methods of monitoring the occupational health of workers on sites. The finding contradicts the research paper by Ng and Chan [58], which considered the workability of Hong Kong construction workers based on individual and work-related factors. The study concluded that the shortage of skilled construction workers in Hong Kong had worsen further because of the aging population coupled with increasing construction activities. This is because the study considered the effect age of workforce on performance. Hence, the finding supported the first hypothesis, which stated that there is a significant high effect between the genome sequencing of the 4R biological driver (GENSE) and the construction occupation related diseases in Gauteng.

Moreover, the results of this study further indicated that the neurotechnology by the 4.R biological driver had a moderate effect on the construction occupation related diseases in Gauteng. This is in line with the finding of Lee, Lin, Seto, and Migliaccio [59] on the examination and reliability of the use of wearable sensors for monitoring on-duty and off-duty worker physiological status and activities in construction. The results found very high correlation between the wearable sensors and the medical condition of workers for heart rate, energy expenditure, metabolic equivalents, and sleeping efficiency. The study participants exhibited significant variations in their physical responses, health status, and safety behaviors. Equally, this study supported that of Liao et al., [60] that explored construction workers' brain connectivity during hazard recognition and found that workers' brain connectivity supplements new evidence underpinning parallel distributed

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processing theory for workplace hazard recognition. On the other hand, the results contradict that of MacDuffie et al., [61] because the study only compared neural device industry representatives and the general public on ethical issues and principles in neurotechnology, which relates to the potential ethical challenges related to agency, identity, privacy, equality, normality, and justice for workers. Therefore, this study supported the second hypothesis, which stated that there is a significant effect between neurotechnology of 4IR biological driver and the construction occupation related diseases in Gauteng.

4. Conclusions

The study is aimed at assessing the effect of 4IR biological driver on the construction occupation related diseases in Gauteng, with the view of improving the H&S of workforce on the construction sites. The adoption of the 4IR biological driver is a valuable tool for improving the H&S of workforce on the site and improving labor productivity. The results identified two dimensions of the 4IR biological driver thus: genome sequencing and neurotechnology. The two (2) dimensions of the biological driver of the 4IR are vital and effective ways of improving the H&S of workforce. The results indicated that 4IR biological driver had a high and moderate effects on the construction occupation related diseases for genome sequencing and neurotechnology, respectively. Hence, it is implied that the 4IR biological driver had 60% and 28% effects on genome sequencing and neurotechnology dimensions respectively. Moreover, the results indicated that about 64% of the predictor variable was explained by the model.

Similarly, the two graphs for the relationships between genome sequencing and construction occupation related diseases and that of neurotechnology and the construction occupation related diseases had straight line graphs. The study is limited to the biological driver of 4IR and the construction occupation related diseases in Gauteng. Therefore, the study recommends the adoption of the 4.0IR biological driver for the management of construction occupation related diseases on the construction sites for the proper transformation of construction sites. Consequently, the study recommends further and continuous studies on the potential of 4IR drivers for management of H&S performance of workforce.

Limitations

- This paper used a Likert scale approach for it analysis, relying on the personal experiences of respondents in primary healthcare building delivery rather than actual surveys of the facilities in the buildings, and participants may be reluctant to express their true views due to social expectations and moral pressures; therefore, findings should be treated with caution.
- The survey design used a cross-sectional approach, so it is only able to capture experience, beliefs and behavioural intentions at a single point in time. Given that experience, beliefs and behavioural intentions change over time, future research could explore this from a para-experimental perspective or use a longitudinal approach or time series data for follow-up studies.
- This study is based on the assessment of the effect of biological driver of 4IR on the construction occupation related diseases, but 4IR is not the only technology used for the assessing occupation related diseases. Other technologies such as artificial intelligence (AI) and virtual and augmented realities should also be applied in further

studies to consider the effects of different technologies on assessing construction occupation related diseases. s.

Supplementary Materials: The following supporting information can be downloaded at: www.mdpi.com/xxx/s1.

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