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Ergonomics, Health and Safety Challenges in the Construction Industry and the Role of Industry 4.0

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ABSTRACT

Construction is a physically demanding process, and its activities entail exposure to a range of health and safety (H&S) and ergonomics hazards and risks. Inadequate H&S and ergonomics in turn negatively impact the health and wellbeing of workers and overall project and business performance. Given these realities and the persistence of H&S and ergonomics hazards and risks, a quantitative study was conducted to interrogate the related issues and evolve a response, including the potential of Industry 4.0 (4IR) technologies to contribute to an improvement in related performance. The study included members of the Association of Construction Health and Safety Management (ACHASM) who completed a self-administered questionnaire. The findings indicate: industry is still focused on the traditional parameters of cost, productivity, and time; workers are exposed to H&S and ergonomics hazards and risks; H&S- and ergonomics-related performance impact on overall project and business performance, and 4IR technologies have the potential to contribute to improving H&S- and ergonomics-related performance. Conclusions include: the construction process and its activities entail exposure to ergonomic hazards and risks; the construction process and its activities are physically demanding and militate against the health and well-being of workers; H&S plays a synergistic role in overall organisational and project performance, and there is a low level of awareness of the potential of 4IR technologies to improve H&S and ergonomics performance. Recommendations include: the holistic benefits arising from optimum H&S and ergonomics should be documented; designers should consider the impact of design, details, and specifications on construction H&S and ergonomics; contractors should interrogate the methods adopted to undertake construction activities to mitigate hazards and risks, and awareness with respect to the potential of 4IR technologies to contribute to improving H&S and ergonomics performance should be raised.

Keywords: Construction, Ergonomics, Health and safety, Industry 4.0

INTRODUCTION

The construction industry suffers from a poor image due to its association with non-conforming work, and poor schedule and H&S performance. Poor H&S performance has been reported in multiple studies globally (van de Molen, Lehtola, Lappalainen, Hoonakker, Hsiao, Haslam, Hale & Verbeek, 2007). The International Labour Organization (ILO) in Construction

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Industry Development Board (cidb) (2009) states that 60 000 fatal accidents occur on construction sites annually, which equates to approximately one accident every ten minutes. Furthermore, one in every six work-related fatal accidents occurs on a construction site despite the industry only employing 6% of the global labour force. In terms of ergonomics, approximately 30% of construction workers suffer from musculoskeletal diseases. The physically demanding nature of construction work poses significant risk to the body, and often requires repetitive movements, adopting of awkward postures and handling heavy or inconveniently sized materials (Smallwood & Haupt, 2005).

REVIEW OF THE LITERATURE

H&S legislation is balanced between self-regulation by employers and an enforced regulation approach (Rikhotso, Morodi & Masekameni, 2022). The general practice in the South African construction industry is that employers employ H&S practitioners that are registered and in good standing with the South African Council for the Project and Construction Management Professions) (SACPCMP).

According to the cidb (2009), construction workers are exposed to more H&S risks than workers in many other industries. The tasks and activities carried out by construction workers in the workplace are physically demanding thus increasing the chance of exposure to H&S risks (Deacon & Smallwood, 2010; Anwer *et al.,* 2020; Ishwarya & Rajkumar, 2020). These tasks and activities demand physical labour to be performed for prolonged periods in static positions, under harsh weather conditions, and where there is exposure to dust and excessive noise (Deacon, Haupt & Smallwood, 2005). Sustained exposure to physical labour can lead to bodily injuries to workers, which negatively affects cost, time, and productivity (Lopez-Garcia, Garcia-Herrero, Gutierrez & Mariscal, 2019).

The number of working days lost in the construction industry has been an ongoing problem and has been worsened by the prevalence of occupational diseases (ODs) (Deacon, Haupt & Smallwood, 2005). Gebremeskel, and Yimer (2019) determined that the prevalence of occupational injuries among construction workers in Egypt was 46.2% and in Kenya, 75%. In terms of the impact of ODs, a study conducted in South Africa by Moyo (2021) identified a significant positive correlation between absenteeism and pain induced by pushing tasks. However, failure to report injuries and ODs can result in the understating of the status quo. Agyekum, Simons & Botchway (2018) emphasise the effects of under-reporting as a factor that influences H&S performance on construction projects. Consequently, H&S culture has often been described as the 'bedrock' of H&S performance on construction projects as it promotes transparency and openness, which are necessary to facilitate reporting (Haruna & Keftin, 2016).

According to Sutherland (2009), the general culture of construction work and other heavy industries that are predominantly male, short-cuts, and cover-ups are very common, and often play a role in whether accidents are reported, or not. Furthermore, construction workers fail to report the problems they face concerning H&S to management.

One of the most important goals of developing and implementing an H&S management system is to reduce the number of work-related injuries and to provide healthy and safe workplaces (ISO 45001). During, recent years H&S management systems have been recognised as a moral issue and as an approach to improve the transparency, productivity, and competitiveness in the business market (Yoog, Lin, *et al.,* 2013).

Many challenges confront H&S management in South Africa. Some of these challenges, according to Thwala and Mvubu (2009), include the lack of appropriate application of scientific knowledge, insufficient professional knowledge, inability to contain unusual complications and risks on contracts, poor management, poor business control, poor documentation, a lack of practical scientific skills, and poor resource control.

H&S on construction projects is a shared responsibility that should be managed by clients, construction project managers, designers, construction managers, and H&S personnel (Rantsatsi, Musonda & Agumba, 2020). H&S personnel contribute to H&S during different stages of projects, however, they may be involved in multiple construction projects at a time. Furthermore, stakeholder participation in H&S should not only be limited to some professionals, as clients also have a role to play in assessing exposure to ergonomic risks (Smallwood & Deacon, 2010; Anwer, Li, Antwi-Afari & Wong, 2021). From a client-centred approach, it is important to understand the psychosocial risk factors that affect workers during construction projects. Compressed project schedules, which may be client originated, result in work pressure and stress. Smallwood and Haupt (2005) determined that client satisfaction is the most important project parameter followed by quality, cost, and time indicating less consideration towards H&S, which is underscored by Aghimein *et al*., (2019) who contend clients do not engender H&S performance. Unmanned aerial vehicles (UAVs) are aircraft that are not controlled by a human on board (Zhou and Gheisari, 2017). According to Beale and Smallwood (2019), UAVs are being increasingly used to improve construction H&S, productivity, and quality. UAVs can gather multiple images from various angles enabling counting of hardhats, identifying workers adopting awkward postures while working, and locating movable assets such as plant and machinery (Alizadehsalehi, Asnafi, Yitmen & Celik, 2021). Furthermore, the ineffectiveness of manual H&S management due to human error, time required, high labour costs, and subjective judgement, further hinder H&S performance and H&S management (Zhang *et al.,* 2015). However, using novel technologies could generate new issues technically, economically, and socially, which must be solved for practical application. Although the adoption of real-time H&S management technologies does not ensure error-free H&S management, it will provide easier and more accurate measures (Dekker, 2015).

RESEARCH METHOD AND SAMPLE

The quantitative research method was adopted for the study, which entailed the completion of a self-administered questionnaire. The questionnaire consisted of primarily Likert scale type questions.

The sample population consisted of members of ACHASM who are registered as professional and candidate Construction H&S Agents (PrPrCHSAs and CanCHSAs), Construction H&S Managers (CHSMs), and Construction H&S Officers (CHSOs), registered with the SACPCMP.

A total of 516 members of ACHASM were sent the questionnaire on behalf of the lead author as ACHASM fulfilled the function of 'gatekeeper' in terms of the research ethics requirements. A total of 124 questionnaires were returned to the lead author, of which 21 were disqualified due to incompleteness, which resulted in a net response rate of 20.0% (103 / 516).

RESULTS

In terms of the gender of the respondents, 64.1% were male, and 35.9% were female.

Table 1 indicates that National Diploma (35.9%) predominates in terms of the highest level of education of the respondents, followed by Other (23.3%), which included SAMTRAC, and BA / BSc / BTechnology (21.3%). This finding is consistent with recent studies that demonstrate that a substantial portion of H&S personnel in the construction industry did not undertake tertiary education, and in general, have completed short courses and other forms of training.

The respondents' mean years of work experience in the construction industry is 11.7 years or 11 years and 8 months, which indicates that they can be deemed relatively experienced.

Table 2 indicates the SACPCMP registration category of the respondents. CHSOS (49.5%) predominated, followed by CHSMs. PrCHSAs and CanCHSAs collectively constituted 19.5% of the respondents.

Table 3 presents the importance of six project parameters during construction projects in terms of percentage responses to a scale of 1 (not important) to 5 (very important), and means scores (MSs) between 1.00 and 5.00. It is notable that all the MSs are > 3.00, which indicates that in general, the respondents perceive the project parameters to be more than important as opposed to less than important. However, 4 / 6 (66.7%) MSs are > 4.20 ≤ 5.00, which indicates the parameters are perceived to be between more than important to very / very important. The remaining 2 / 6 (33.3%) MSs are > 3.40 ≤ 4.20, which indicates the parameters are perceived to be

Table 1. Highest education level of the respondents.

Education level	Response (%)
National Diploma	35.9
Other	23.3
BA / BSc / BTechnology	21.3
Matric (Grade 12)	10.7
Honours	7.8
Masters	1.0
Total	100.0

Table 2. Registration category of the respondents.

Registration Category	Response (%)
CHSO	49.5
CHSM	31.1
PrCHSA	11.7
CanCHSA	7.8
Total	100.0

Table 3. Importance of six project parameters during construction projects.

Parameter	Response (%)						MS	Rank
	Un-sure	Not ....Very						
		1	2	3	4	5		
Productivity	0.0	1	0.0	9.7	46.6	42.7	4.30	1
Time	0.0	0.0	0.0	4.9	66	29.1	4.24	2
Cost	0.0	3.9	2.9	4.9	42.7	45.6	4.23	3
Environment	0.0	2.9	4.9	16.5	19.4	56.3	4.21	4
H&S	2.9	3.9	9.7	34	45	44.7	4.08	5
Quality	0.0	0.0	8.7	22.3	31.1	37.9	3.98	6

between important to more than important / more than important. It is notable that H&S, which includes ergonomics, and which is the subject of the study is ranked fifth.

Table 4 presents the likelihood relative to ergonomic risks on construction projects in terms of percentage responses to a scale of 1 (very unlikely) to 5 (very likely), and MSs between 1.00 and 5.00. It is notable that all the MSs are > 3.00, which indicates that in general, the respondents perceive the likelihood to be more than likely, as opposed to less than likely. Given that the MS is > 4.20 ≤ 5.00, 'Ergonomic risks arise from the work on construction projects' is perceived to be between more than likely to very / very likely. Then, the MSs of 'Ergonomic risks are encountered on projects' and 'Ergonomic risks are considered by the principal contractor' are > 3.40 ≤ 4.20, which indicates they are perceived to be between likely to more than likely / more than likely.

Table 5 presents the likelihood of six ergonomic hazards leading to the development of MSDs in terms of percentage responses to a scale of 1 (very unlikely) to 5 (very likely), and MSs between 1.00 and 5.00. It is notable that all the MSs are > 3.00, which indicates that in general, the respondents perceive the likelihood to be more than likely, as opposed to less than likely. However, 4 / 6 (66.7%) MSs are > 4.20 ≤ 5.00, which indicates the likelihood is perceived to be between more than likely to very likely / very likely. The remaining 2 / 6 (33.3%) MSs are > 3.40 ≤ 4.20, which indicates the likelihood is perceived to be between likely to more than likely / more than likely.

Table 6 presents the likelihood of physical and psychosocial stressors being encountered by construction workers in terms of percentage responses to a scale of 1 (very unlikely) to 5 (very likely), and MSs between 1.00 and 5.00.

Table 4. Likelihood relative to ergonomic risks on construction projects.

Likelihood	Response (%)						MS	Rank
	Unsure	Very unlikely ……Very likely						
		1	2	3	4	5		
Ergonomic risks arise from the work on construction projects	1.9	0.0	1.0	19.2	25.0	52.9	4.23	1
Ergonomic risks are encountered on projects	0.0	0.0	1.9	13.6	63.1	21.4	4.04	2
Ergonomic risks are considered by the principal contractor	0.0	1.9	8.7	13.6	51.5	24.2	3.87	3

Table 5. Likelihood of six ergonomic hazards leading to the development of MSDs.

Ergonomic hazard	Response (%)						MS	Rank
	Unsure	Very unlikely ……Very likely						
		1	2	3	4	5		
Handling heavy machinery	1.0	0.0	0.0	11.6	29.9	57.7	4.42	1
Excessive use of body force	1.9	1.0	1.9	4.8	29.8	60.6	4.41	2
Repetitive movements	1.9	0.0	1.0	19.2	25.0	52.9	4.23	3
Handling heavy equipment	1.0	0.0	0.0	5.8	60.6	32.7	4.22	4
Working in an awkward posture	1.9	0.0	1.0	9.7	68.3	19.2	3.99	5
Bending and twisting the back	1.9	0.0	1.0	27.9	29.8	38.5	3.98	6

It is notable that all the MSs are > 3.00, which indicates that in general, the respondents perceive the likelihood to be more than likely, as opposed to less than likely. However, all the physical and 2 / 3 (66.7%) psychosocial stressors' MSs are > 4.20 ≤ 5.00, which indicates the likelihood is perceived to be between more than likely to very likely / very likely. The remaining 1 / 3 (33.3%) psychosocial stressor MSs is > 3.40 ≤ 4.20, which indicates the likelihood is perceived to be between likely to more than likely / more than likely.

Table 7 presents the likelihood of the impact of absenteeism in terms of percentage responses to a scale of 1 (very unlikely) to 5 (very likely), and MSs between 1.00 and 5.00. It is notable that both the MSs are > 3.00, which indicates that in general, the respondents perceive the likelihood to be more than likely, as opposed to less than likely. However, both MSs are > 3.40 ≤ 4.20, which indicates the likelihood is perceived to be between likely to more than likely / more than likely.

Table 6. Likelihood of physical and psychosocial stressors being encountered by construction workers.

Physical	Response (%)						MS	Rank
	Unsure	Very unlikely ……Very likely						
		1	2	3	4	5		
Exposure to dust	0.0	0.0	0.0	1.9	16.5	81.6	4.80	1
Prolonged static work	0.0	0.0	1.0	4.9	47.6	46.6	4.40	2
Excessive noise	0.0	0.0	0.0	3.9	56.3	39.8	4.36	3
Physical labour	0.0	0.0	0.0	4.9	64.1	31.1	4.26	4
Psychosocial								
Work pressure	0.0	1.0	0.0	1.9	26.2	70.9	4.66	1
Work stress	0.0	0.0	1.0	5.9	53.4	39.8	4.32	2
Stakeholder disinvolvement	0.0	0.0	2.9	36.9	46.6	13.6	3.71	3

Table 7. Likelihood of the impact of absenteeism.

Likelihood	Response (%)						MS	Rank
	Unsure	Very unlikely ……Very likely						
		1	2	3	4	5		
Absenteeism impacts costs through hiring	7.8	6.8	11.7	21.4	15.5	36.9	3.71	1=
Absenteeism impacts H&S performance	3.9	2.9	6.8	26.2	25.2	35	3.71	1=

Table 8. Likelihood of H&S to impact on three organisational factors.

Factor	Response (%)						MS	Rank
	Unsure	Very unlikely ……Very likely						
		1	2	3	4	5		
Productivity	1.9	5.8	7.8	22.3	11.7	50.4	3.95	1
Competitiveness in the business market	5.8	1.0	9.7	16.5	42.7	24.3	3.85	2
Transparency	7.8	9.7	13.6	11.7	22.3	35.0	3.65	3

Table 8 presents the likelihood of H&S to impact on three organisational factors in terms of percentage responses to a scale of 1 (very unlikely) to 5 (very likely), and MSs between 1.00 and 5.00. It is notable that the MSs are > 3.00, which indicates that in general, the respondents perceive the likelihood to be more than likely, as opposed to less than likely. However, all the MSs are > 3.40 ≤ 4.20, which indicates the likelihood is perceived to be between likely to more than likely / more than likely.

Table 9 presents project stakeholders' commitment to construction H&S in terms of percentage responses to a scale of 1 (very unlikely) to 5 (very likely), and MSs between 1.00 and 5.00. It is notable that 2 / 4 (50.0%) MSs are > 3.00, which indicates that in general, the respondents perceive the commitment to be more than likely, as opposed to less than likely as in the

Table 9. Project stakeholders' commitment to construction H&S.

Stakeholder	Response (%)						MS	Rank
	Unsure	Very unlikely ……Very likely						
		1	2	3	4	5		
Contractors	0.0	4.9	15.5	15.5	18.5	45.6	3.84	1
Engineers	0.0	6.8	13.6	9.7	32	37.9	3.81	2
Architects	4.9	14.6	28.2	16.5	10.7	25.2	2.89	3
Clients	6.8	13.6	26.2	18.5	19.4	15.5	2.77	4

Table 10. Likelihood of 4IR technologies to mitigate H&S risks on construction projects.

Technology	Response (%)						MS	Rank
	Unsure	Very unlikely ……Very likely						
		1	2	3	4	5		
UAVs (Drones)	10.7	6.8	11.7	10.7	21.4	38.9	3.42	1
Virtual Reality	10.7	17.5	17.5	21.4	19.4	13.6	2.83	2
Wearable tech	9.7	18.5	16.5	7.8	38.8	8.7	2.74	3

case of MSs ≤ 3.00. However, all the MSs are > 3.40 ≤ 4.20, which indicates the likelihood is perceived to be between likely to more than likely / more than likely. Given the H&S requirements of the Construction Regulations relative to clients, designers, and contractors, these findings are notable.

Table 10 presents the likelihood of 4IR technologies to mitigate H&S risks on construction projects in terms of percentage responses to a scale of 1 (very unlikely) to 5 (very likely), and MSs between 1.00 and 5.00. It is notable that only 1 / 3 (33.3%) MSs is > 3.00, which indicates that in general, the respondents perceive the likelihood to be more than likely, as opposed to less than likely as in the case of MSs ≤ 3.00. The MS relative to UAVs (Drones) is > 3.40 ≤ 4.20, which indicates the likelihood is perceived to be between likely to more than likely / more than likely. The MSs relative to virtual reality, and wearable tech are > 2.60 ≤ 3.40, which indicates the likelihood is perceived to be between less than likely to likely / likely.

Table 11 presents the likelihood of using drones for three types of H&S inspections in terms of percentage responses to a scale of 1 (very unlikely) to 5 (very likely), and MSs between 1.00 and 5.00. It is notable that 2 / 3 (66.7%) of the MSs are > 3.00, which indicates that in general, the respondents perceive the likelihood to be more than likely, as opposed to less than likely as in the case of a MS ≤ 3.00. The MS relative to 'counting hardhats' is > 3.40 ≤ 4.20, which indicates the likelihood is perceived to be between likely to more than likely / more than likely. The MS relative to 'locating plant and machinery' is > 2.60 ≤ 3.40, which indicates the likelihood is perceived to be between less than likely to likely / likely. The MS of the remaining term 'identifying workers working in awkward postures' is > 1.80 ≤ 2.60, which indicates the likelihood is perceived to be between very unlikely to less than likely / less than likely. The level of unsure response relative to 'locating plant

Table 11. Likelihood of using drones for three types of H&S inspections.

Type of inspection	Response (%)						MS	Rank
	Unsure	Very unlikely ……Very likely						
		1	2	3	4	5		
Counting hardhats	2.9	5.8	11.7	22.3	24.3	33.0	3.58	1
Locating plant and machinery	13.6	9.7	17.5	7.8	21.4	30.1	3.04	2
Identifying workers working in awkward postures	17.5	15.5	18.5	12.6	12.6	23.3	2.57	3

Table 12. Likelihood of 4IR technologies to impact H&S on construction projects.

Technology	Response (%)						MS	Rank
	Unsure	Very unlikely ……Very likely						
		1	2	3	4	5		
Wearable tech / Smartwatches can detect dangerous workspaces	2.9	8.8	20.4	16.5	22.3	29.1	3.34	1
VR can improve H&S training on construction projects	6.8	16.5	29.1	18.5	11.7	17.5	2.64	2

and machinery', and 'identifying workers working in awkward postures' is notable.

Table 12 presents the likelihood of 4IR technologies to impact H&S on construction projects in terms of percentage responses to a scale of 1 (very unlikely) to 5 (very likely), and MSs between 1.00 and 5.00. It is notable that only 1 / 2 (50.0%) MSs is > 3.00, which indicates that in general, the respondents perceive the likelihood to be more than likely, as opposed to less than likely as in the case of MSs ≤ 3.00. However, both the MSs are > 2.60 ≤ 3.40, which indicates the likelihood is perceived to be less than likely to likely / likely.

Table 13 presents the likelihood of the consideration of 4IR and the impact of 4IR on construction H&S in terms of percentage responses to a scale of 1 (very unlikely) to 5 (very likely), and MSs between 1.00 and 5.00. It is notable that only 1 / 2 (50.0%) MSs is > 3.00, which indicates that in general, the respondents perceive the likelihood to be more than likely, as opposed to less than likely as in the case of MSs ≤ 3.00. However, the MS relative to '4IR can impact ergonomic risks' is > 3.40 ≤ 4.20, which indicates the likelihood is perceived to be between likely to more than likely / more than likely. The MS relative to '4IR is considered on construction projects' is > 2.60 ≤ 3.40, which indicates the likelihood is perceived to be less than likely to likely / likely, which militates against potential impact.

Table 13. Likelihood of the consideration of 4IR and the impact of 4IR on construction H&S.

Aspect	Response (%)						MS	Rank
	Unsure	Very unlikely ……Very likely						
		1	2	3	4	5		
4IR can impact ergonomic risks	0.0	6.8	18.5	23.3	20.4	31.1	3.50	1
4IR is considered on construction projects	8.7	14.6	17.5	16.5	15.5	27.2	2.97	2

CONCLUSION

Given the importance of six project parameters it can be concluded that the industry is still focused on the traditional parameters of cost, productivity, and time, except for quality, at the 'expense' of H&S.

The likelihood relative to ergonomic risks on construction projects leads to the conclusion that the construction process and its activities entail exposure to ergonomic hazards and risks.

Given the likelihood of six ergonomic hazards leading to the development of MSDs, workers encountering physical and psychosocial workplace stressors, it can be concluded that the construction process and its activities are physically demanding and militate against the health and wellbeing of workers.

The likelihood of H&S impacting on three organisational factors leads to the conclusion that H&S plays a synergistic role in overall organisational and project performance.

Given the project stakeholders' likely commitment to construction H&S, it can be concluded that construction H&S is not receiving the necessary and potential multi-stakeholder support.

The likelihood of 4IR technologies to mitigate H&S risks on construction projects, the likelihood of using drones for three types of H&S inspections, the likelihood of 4IR technologies to impact H&S on construction projects, and the likelihood of 4IR to impact ergonomic risks leads to the conclusion that the responding H&S practitioners are not fully aware of the potential of 4IR technologies to improve H&S and ergonomics performance.

RECOMMENDATIONS

The industry needs to make a paradigm shift in terms of the importance of the respective project parameters. This can be engendered by investigating and documenting the holistic benefits arising from optimum H&S and ergonomics.

Designers should consider the impact of design, details, and specifications on construction H&S and ergonomics. Contractors in turn should highlight design originated H&S and ergonomics hazards and risks and provide feedback to designers. Furthermore, contractors should interrogate the methods adopted to undertake construction activities to mitigate such hazards and risks.

Multi-stakeholder support for H&S and ergonomics should be engendered by developing project H&S plans, which include all stakeholders' planned H&S and ergonomics-related interventions, as opposed to merely contractor H&S plans.

Awareness with respect to the potential of 4IR technologies to contribute to improving H&S and ergonomics performance should be raised among H&S practitioners and other stakeholders.

REFERENCES

Aghimien, D. O., Oke, A. E. and Aigbavboa, C. O. (2018) Barriers to the adoption of value management in developing countries. Engineering, Construction and Architectural Management Volume 25 No. 7.

Agyekum, K, Simons, B, and Botchway, S. Y. (2018) Factors influencing the performance of safety programmes in the Ghanaian construction industry. Acta Structilia Volume 25 No. 2.

Alizadehsalehi, S., Yitmen, I., Celik, T. and Arditi, D. (2020) The effectiveness of an integrated BIM/UAV model in managing safety on construction sites. International Journal of Occupational Safety and Ergonomics Volume 26 No. 4.

Anwer, S., Li, H., Antwi-Afari, M. F., Umer, W. and Wong, A. Y. L. (2021) Evaluation of physiological metrics as real-time measurement of physical fatigue in construction workers: State-of-the-art review. Journal of Construction Engineering and Management, Volume 147 No. 5.

Beale, J., and Smallwood, J. J. (2019). "The potential of industry 4.0 to enhance construction health and safety (H&S) performance", proceedings 14th International postgraduate research conference: Contemporary and Future Directions in the Built Environment.

Construction Industry Development Board (cidb) (2009). Construction health & safety in South Africa: Status & recommendations. Pretoria: cidb.

Deacon, C., Smallwood, J., and Haupt, T. (2005) "The health and well-being of older construction workers", in International Congress Series Volume 1280, pp. 172–177, Elsevier.

Dekker, S. (2014) Safety differently. London: CRC Press.

Gebremeskel, T. G. and Yimer, T. (2019) "Prevalence of occupational injury and associated factors among building construction workers in Dessie town, Northeast Ethiopia; 2018", in BMC research notes, Volume 12 No. 1, pp. 1–6.

International Standards Organization (ISO) (2018) Occupational Health and Safety Management: ISO 45001:2018. Geneva: ISO.

Irizarry, J. and Costa, D. B. (2016) Exploratory study of potential applications of unmanned aerial systems for construction management tasks. Journal of Management in Engineering, Volume 32 No. 3.

López-García, J. R., García-Herrero, S., Gutiérrez, J. M., and Mariscal, M. A. (2019). Psychosocial and ergonomic conditions at work: influence on the probability of a workplace accident. BioMed research international, 2019.

Moyo, L. (2021) Occupational Health and Safety Factors Influencing Absenteeism Among Construction Workers in Johannesburg, South Africa. University of Johannesburg (South Africa).

Rantsatsi, N., Musonda, I. and Agumba, J. (2020) Identifying factors of collaboration critical for improving health and safety performance in construction projects: A systematic literature review, Acta Structilia Volume 27 No. 2, pp. 120–150.

Rikhotso, O., Morodi, T. J., and Masekameni, D. M. (2022) The Extent of Occupational Health Hazard Impact on Workers: Documentary Evidence from National Occupational Disease Statistics and Selected South African Companies' Voluntary Corporate Social Responsibility Disclosures. Sustainability, Volume 14 No. 17, 10464.

Smallwood, J. and Haupt, T. (2005) The need for construction health and safety (H&S) and the Construction Regulations: engineers' perceptions, Journal of the South African Institution of Civil Engineering Volume 47 No. 2, pp. 2–8.

Sutherland, V., Makin, P. J. and Cox, C. J. (2000) The management of safety: The behavioural approach to changing organisations. London: Sage.

Thwala, W. D. and Mvubu, M. (2009). Problems facing small and medium size contractors in Swaziland, Journal of Service Science and Management Volume 2 No. 4van der Molen, H., Lehtola, M. M., Lappalainen, J., Hoonakker, P. L. T., Hsiao, H., Haslam, R. A., Hale A. R., and Verbeek, J. H. (2007) "Interventions for preventing injuries in the construction industry", Cochrane Database of Systematic Reviews.

Yoon, S. J., Lin, H. K., Chen, G., Yi, S., Choi, J. and Rui, Z. (2013) Effect of occupational health and safety management system on work-related accident rate and differences of occupational health and safety management system awareness between managers in South Korea's construction industry, Safety and Health at Work Volume 4 No. 4, pp. 201–209.

Zhang, S., Sulankivi, K., Kiviniemi, M., Romo, I., Eastman, C. M., and Teizer, J. (2015) BIM-based fall hazard identification and prevention in construction safety planning Volume 72, pp. 31–45.

Zhou, S. and Gheisari, M. (2018) Unmanned aerial system applications in construction: a systematic review. Construction Innovation October 2018.