# FACTORS CAUSING FATIGUE AND SAFETY-RELATED ERRORS ON CONSTRUCTION SITES IN BLOEMFONTEIN

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Fatigue is experienced as mental and muscular (physical) exhaustion that obstructs actual work performance. The factors that contribute to fatigue which, in turn, leads to errors on construction sites, were explored in the reported study. Using a case study approach, semi-structured, face-to-face interviews were conducted to obtain responses to "What factors cause fatigue that leads to human errors in construction?" Data were collected from construction sites in Bloemfontein to examine the phenomenon through the lived experiences of people in construction. The interviews were conducted with site management, professionals and craft workers in the frontline of physical site construction work. The interviews were audio-recorded and transcribed before being analysed. The results affirmed the notion that fatigue could lead to human errors through muscular and mental exhaustion that reduces alertness and, then, impede the ability to complete tasks correctly. A fatigued worker would have reduced mental alertness that increases the likelihood of unintentional errors (slips and lapses) which, in turn, could lead to accidents. The origins of fatigue cited by the interviewees included: long hours of work, lack of comfort or rest breaks in between shifts, dehydration while working, excessive heat or cold, and lack of food. The various on-site activities during which incidents occurred, where fatigue was implicated, included: loading and offloading materials, digging trenches, brickwork and plastering. Therefore, there is a need to rethink work procedures on sites where fatigue plays a leading role in the manifestation of errors with safety implications. The results from this case study provide the impetus for further research into the mental and physical factors that cause fatigue and the practices that perpetuate it on construction sites. Reducing fatigue supports fairness and social justice in promoting the Common Good agenda on sites.

Keywords: errors, fatigue, safety, site work

## INTRODUCTION

Fatigue is a feeling of mental and physical exhaustion that leads to the inability to perform work effectively. A fatigued person will be less alert, less able to process information, and slow to react to events when compared with a person who is not fatigued (Zhang *et al.,* 2015a). Fatigue can lead to errors in task performance (Techera *et al.,* 2016). Human error leads to injuries and fatalities, including a

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reduction in the quality of work and productivity of workers (Hagan, Montgomery and O'Reilly, 2015).

The most significant outcomes of fatigue include short-term, cognitive and physical degradation and, to a lesser extent, error, injury, and illness (Techera *et al.,* 2016). Performance and productivity also suffer in construction when people are fatigued (Aryal, Ghahramani and Becerik-Gerber, 2017). The drivers of fatigue include sleep deprivation and work environment factors such as noise, vibration, and temperature.

In this paper, a descriptive study is presented to respond to the question "What factors cause fatigue that leads to human errors in construction?" The purpose of the research was to determine factors that contribute to fatigue that leads to errors committed by people in construction. The study is critical because an association between reported fatigue and difficulties with physical and cognitive functions experienced by workers in construction has been established elsewhere (Zhang *et al.,* 2015a) with limited awareness of the phenomenon in South Africa.

Strategies such as job rotation, stabilising shifts, controlled overtime, exercise, and maintaining healthy eating habits that enhance scheduled performance are deployed in a work environment to prevent the eventuality of fatigue (Hagan *et al.,* 2015). However, the successful use of the above interventions relies on the identification of the type of fatigue to be addressed. There are two types of fatigue: mental fatigue and localised, muscular fatigue (which is physical fatigue). Mental fatigue is associated with the weariness of thought and decision processes, while localised muscular fatigue is the reduction in a specific muscle's ability caused by prolonged, excessive use (Phillips, 2014). Mental fatigue is likely to contribute significantly to slips or lapses (unintentional errors), which are problems of task execution (Reason, 2008) caused by cognitive processes during specific instances in time. The execution problems can be the result of recognition failures, memory failures and attention failures (Reason, 2008).

To understand the connection between fatigue and adherence to a safe working procedure (SWP) better, it is essential to observe the effects of mental fatigue and muscular fatigue on human error (Fang *et al.,* 2015). According to the literature, human errors are caused by deficiencies in mental functions that are accelerated as mental and physical fatigue increase. Studies of the causes of accidents show how organisational factors, local workplace conditions, and unsafe acts of people can compromise precautions in a system to produce adverse outcomes (Reason, 2016). Hallowell (2010) observed that the frequency and severity of injury increased during overtime work in construction because of a surge in human error caused by weariness in cognitive processes (mental fatigue). Typically, errors are detected through self-monitoring of formal processes in the human body. As mental fatigue increases, the workers' ability to perform mental checks decreases and the speed at which decision processes are executed is reduced. This behaviour is notable among workers (such as general workers in construction) who perform repetitive tasks for an extended time (Zhang *et al.,* 2015b). In summary, the effects of mental and muscular fatigue on people in construction are the immediate reduction in safe work behaviour, productivity, teamwork and morale (Fang *et al.,* 2015; Zhang *et al.,* 2015a). Additional effects include physical weakness, reduced production, mistakes, slips, lapses, weariness, memory loss, sleepiness, discomfort, and illnesses (Hallowell, 2010).

## METHOD

The reported study was conducted on construction sites in Bloemfontein, South Africa, as the location for primary data collection. The interpretive perspective of the study helped the researchers to collect data that were closely related to the social and contextual beliefs of the participants. The study conformed to the notion that qualitative research is a situated activity that locates the researcher in the field (construction sites served as the field in this case study) (Denzin and Lincoln, 2008). The data collection exercise provided a view of the world through interviews and field notes (Denzin and Lincoln, 2008). The data collection tools used in the study were semi-structured interviews and field notes. The interviews were conducted with a semi-structured protocol that elicited information from site management. The face-to-face interviews were used to obtain responses to "What factors cause fatigue that leads to human errors in construction?"

Multiple researchers were used in the study to collect the primary data from several construction sites in Bloemfontein, South Africa, to allow for the possible convergence of observations to improve confidence in the results and to promote a more reliable substantiation of constructs (Huberman and Miles, 2002). A purposive sampling strategy was used to select construction sites and, ultimately, interviewees. The main criteria for selection were involvement in physical work on-site and prior experience of the interplay between fatigue and safety errors in construction. Three field workers were used to collect the primary data, which was textual. The field workers were registered, construction management students who were knowledgeable about fatigue concerning safety. They were trained in interviewing techniques before data collection commenced in 2018. All the interviews were audio-recorded and transcribed before being analysed thematically in line with the open-ended questions. Before the start of the fieldwork, informed consent was obtained from participants. Other ethical considerations that were applied in the study included confidentiality, the anonymity of data and voluntary participation. A covering letter and the field workers informed the participants of the purpose and benefits of the study. An option to sign a confidentiality agreement was also available to the participants, although none of them exercised the right.

The data analysed thematically, gave insight into the phenomenon of fatigue and errors as a lived experience of the interviewees. The strategy used to analyse the data relied on theoretical propositions informed by the central research question. The question, in turn, influenced the literature that was reviewed, and which guided the compilation of the questions used in the interviews. The analysis was organised by using the central research question to identify relevant, contextual statements that were collated to form specific themes.

Although 30 potential interviewees were approached on different construction sites, only 20 of them took part in the study. The interviewees have cognate on-site working experience in construction. Their education levels ranged from a Secondary School Certificate to a Postgraduate Diploma, and their construction work experience ranged from two to more than 18 years. The interviewees had various job titles, which included: engineer, foreman, site supervisor, and construction manager. Detailed demographic information of the interviewees is not provided here due to page number limitations.

## FINDINGS

The 20 interviewees were requested to use yes, no, or unsure options to respond to fatigue-related questions, to gauge their perceptions of the phenomenon. Table 1 shows that 18 of the interviewees concurred with the definition of fatigue extracted from the literature, while two were not sure of the definition. This observation implies that most of the interviewees agreed with the description of fatigue in the context of the study. Most of the interviewees were also in agreement with the notion that fatigue is linked to incidents that influence productivity negatively despite the belief that it can be prevented. More importantly, all the interviewees agreed that fatigue influences productivity on sites.

*Table 1: Perceptions of interviewees on fatigue in construction*

| Perception | No | Yes | Unsure |
|---|---|---|---|
| Fatigue is described as a state of physical and mental exhaustion, which reduces a person's ability to perform work safely and effectively by reducing alertness that leads to errors, which increases workplace incidents. | - | 18 | 2 |
| Fatigue can be prevented. | 4 | 14 | 2 |
| Fatigue affects productivity on a construction site. | - | 20 | - |
| Fatigue has been linked to accidents on construction sites. | - | 14 | 2 |

The causes of fatigue among construction workers

In responding to the opening set of questions, the interviewees identified factors that were influencing fatigue and errors on their construction sites. The factors mentioned included: long hours of work, excessive heat, lack of breaks between tasks, sleeping problems, dehydration (not getting enough water while working), hunger, and lifting of heavy materials and equipment (Figure 1). In Figure 1, the size of the words reflects their representation within the data. In the literature reviewed, these factors were deemed to be leading indicators of cognitive and localised muscular fatigue. Some factors are unique to either cognitive or muscular fatigue, while others, such as extended work periods and heat, are linked to both cognitive and muscular fatigue.

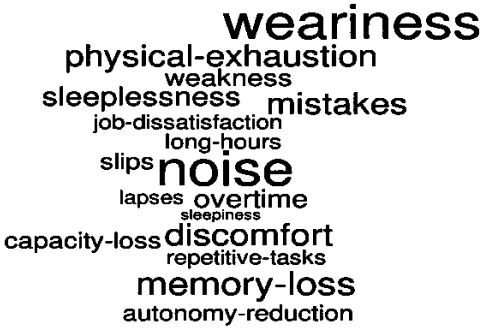


*Figure 1: Factors contributing to fatigue on construction sites*

To follow-up the question that checked whether the interviewees concurred with the definition of fatigue, the researchers asked them to describe fatigue on the worksite from their experience. The feedback indicated that the interviewees regard fatigue to be the feeling of physical tiredness, loss of concentration while working, and evidence of mental exhaustion. The interviewees also mentioned that workers work slowly when fatigued. In particular, explanations based on physical and mental tiredness were mentioned by 12 interviewees, loss of concentration while working was mentioned by four of them and working slowly with less productivity was mentioned

by four interviewees. Given the recognition of the manifestation of fatigue in their worksites, the interviewees were requested to indicate whether their firms informed workers to be aware of fatigue. It was notable that 12 interviewees indicated that there was no awareness of fatigue on their sites because their firms were not aware of the risk associated with fatigue, while eight of them indicated that there was an awareness of fatigue on their worksites because of the mindfulness of the risk associated with fatigue. The feedback implies that the employers of the 12 interviewees did not pay attention to the signs and effects of fatigue in their workplaces.

The participants were asked, next, to mention site activities that lead to fatigue. Brickwork and plastering were mentioned by three interviewees, working with shovels and spades were mentioned twice, digging trenches was mentioned by four of them, erecting and working around scaffolding was mentioned by two interviewees, loading and offloading of heavy materials was mentioned by four, while using vibrating equipment and working in the office the whole day were mentioned once. Some of these activities are highlighted in Figure 2, where they have been categorised under equipment, process, people, materials, environment, and management causes. In summary, the interviewees cited the lack of quality work produced on-site, workers sleeping on-site during working hours, workers having low morale, lack of productivity on site, increased risk of injuries and accidents on site, increased absenteeism, and poor housekeeping as the effects of fatigue observed in construction. Figure 2 shows that, where the outlined causes predominate in construction, fatigue-induced errors are a possible event on a site.

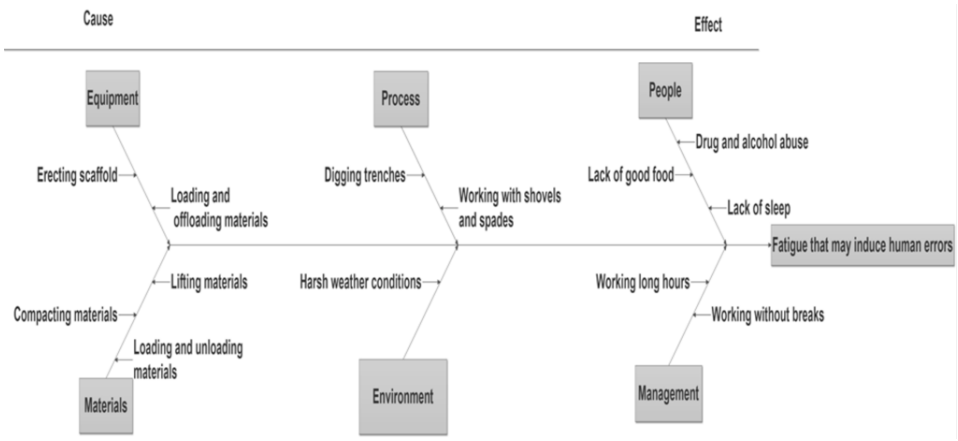


*Figure 2: Illustrated cause and effect factors contributing to fatigue on construction sites*

The data also revealed the factors contributing to fatigue shown in Table 2.

*Table 2: Factors contributing to fatigue*

| Factor | Frequency |
|---|---|
| Long hours | 5 |
| Harsh environmental conditions | 5 |
| Working without breaks | 2 |
| Lack of sleep | 2 |
| Alcohol abuse | 2 |
| Lack of proper nutrition | 2 |
| Lifting heavy materials and equipment | 2 |

In addition, 12 interviewees contended that scorching temperatures were a principal cause of fatigue on their sites, while four of them also noted extreme cold weather as a

contributing environmental condition. Two interviewees commented that it was difficult for them to work in dusty areas and wet conditions without significant errors. Another interviewee responded that it was also challenging to work in steep and mountainous environments. Another interviewee observed that exposure to rapid changes in environmental conditions could make workers uncomfortable to the extent that their biological rhythms and physiological functioning might be altered.

When the interviewees were asked whether they could link human error on their projects sites to fatigue based on their lived experiences, 18 of them responded with a strong affirmative, while only two said 'no'. An interview cited one accident as a case in point. The interviewee said that a truck driver hit electric poles, which caused an explosion due to lack of concentration. Although other work-related factors may cause a lack of concentration, fatigue was flagged as a primary reason in this cited example. In this study, the assumption is made that the factors that were identified as causing fatigue are the same that lead indirectly to human error, given the complexity of fatigue aetiology. The following are some of the interviewees' verbatim remarks:

> Yes, because most workers get injured when they are tired.
>
> Yes, I would link it. When project deadlines are near, employees are overworked... failures.
>
> If people are overworked on a project, they are bound to make a human failure.
>
> A worker is highly adaptable but not without end. There should be limits for any activity. Fatigue can lead to poor decision-making and poor performance on a project that requires attention or high levels of skills. Fatigue disrupt physiological functioning.
>
> The effectiveness of mitigation strategies

The comments of the interviewees, quoted verbatim below, suggest an over-reliance on breaks and availability of water as interventions. The breaks include 15-minute tea break twice a day with 30 minutes for lunch. Exchange in working shifts and awareness helps to limit fatigue among the workers. The provision of clean drinkable water and a place to rest also serve as a mitigation strategy. A paid weekend reportedly gives the workers enough time to relax and rest. Managing fatigue with rest is one of the most effective fatigue management strategies. However, when it is used within-shift and between-shift breaks, it might not be useful in all situations. Beyond breaks, workers are advised on how to take care of their health through text and visual while the use of equipment is deployed to reduce manual labour that could lead to physical fatigue.

However, six interviewees said that their firms did not have mitigation strategies for fatigue. Among this group of interviewees, three of them perceived that contractors do not address fatigue because they did not see anything happening on-site to mitigate fatigue. However, seven other interviewees said that contractors allowed workers enough time to rest during lunchtimes, encouraged workers to eat healthy food and drink lots of water. These interventions were combined with the provision of machines to undertake heavy tasks. For example, excavators were used in place of people to dig trenches. One interviewee cited a common practice on a site where job rotation was implemented so that workers who required a break could rest. Contractors who are mindful of the need to reduce the manual labour required by specific tasks, even when there is time pressure to end the project, promote such a practice. Ways to mitigate fatigue were mentioned by 14 interviewees who confirmed that their firms gave workers enough time for breaks and did not allow workers to

carry heavy materials on-site; a machine would be used instead to transport the load for workers.

When the interviewees were asked to indicate whether mitigation strategies led to practical changes to ease fatigue on their sites, only one interviewee responded with confidence. In contrast, most interviewees were not convinced of the impact of mitigation strategies. Some of the interviewees were sceptical because of the view that workloads often make workers miss rest opportunities available through either tea or lunch break. One interview opined that when the workers carry on working without eating and breaks, the likelihood of fatigue increases. Mitigation strategies are also not practical due to the improper attitude of workers and poor reporting of fatigue risks. The views of the interviewees imply that the implementation of mitigation strategies to prevent fatigue had to be intentional and monitored on sites. If the implementation is left to chance, the desired results might not be forthcoming.

## DISCUSSION

The results corroborate the notion that measurable factors can predict construction worker fatigue (Techera *et al.,* 2018). The findings and interpretations, in the section above, indicate that a range of factors, some of which are latent, contribute to the manifestations of fatigue which, in turn, increase the likelihood of errors that could be blamed on people in the frontline of construction. This line of thought is the basis of the person model of unsafe acts (Reason, 2008). Reason (2008) explains that, in the person model, unsafe acts are viewed as the result of disorderly mental processes observed as forgetfulness, inattention, distraction, carelessness, culpable negligence and recklessness. The focus of this paper was on the person model of unsafe acts because of its relation to mental and physical (muscular) fatigue.

In addition, the causes and effects of fatigue mentioned by the interviewees the previous section make it mandatory for a contractor to find ways to prevent it. The factors that contribute to the cause and outcomes of fatigue could have a profound impact on the well-being, work performance and safety of workers (Powell and Copping, 2010). The primary outcomes of fatigue include a reduction in short-term, cognitive and physical alertness, and errors to some extent, not to mention accidents, injuries, and illnesses (Techera *et al.,* 2016). When lax attention is paid to workload, Fang *et al. (*2015) observed that there is a linear relationship between fatigue levels and human errors. Fatigue is a significant driver of human error (Techera *et al.,* 2018).

In terms of accidents, fatigue either might reduce the ability to process information concerning a hazard (error linked to fatigue) or might limit the ability to respond to the hazard and its manifestations adequately (error linked to fatigue) (Fang *et al.,* 2015). The error is the outcome of the impact of cognitive fatigue on humans. In literature about social psychology, deficiencies in mental function that increase in tandem with mental and physical fatigue, lead to errors (Reason, 2008). Human errors and the likelihood of their occurrence as a result of fatigue should encourage site management personnel to implement effective programmes. Low productivity, injuries and fatalities, and rework result from errors in judgment, decisions, and physical actions (Hallowell, 2010). Physical actions, such as digging trenches for extended periods, mentioned by an interviewee, could lead to low productivity and human errors with implications for safety. For example, Fang *et al. (*2015) noted that, when the fatigue level is low, human errors are caused by failure to perceive hazards because of cognitive challenges (low information-processing abilities) and, when the

fatigue level is high, the level of motor control failure increases (low response abilities). Motor control failure often happens during prolonged physical actions.

Mental fatigue increases the possibility of human errors, so it must be mitigated in workplaces (Hallowell, 2010). In the central region of South Africa, two interviewees, mentioned by Emuze (2017), said long working hours are a risk because people make mistakes when they are fatigued. The interviewees in the previous section of this paper also identified long working hours, as illustrated in Figure 1. In effect, long working hours, work pressures and the poor working conditions of workers on some project sites in South Africa provide a platform for the proliferation of the causes of fatigue (Emuze and Mollo, 2019). Emuze and Mollo (2019) also observed how poor working conditions and evident [dis]respect for people severely limit the promotion of HSW on construction sites, citing a requirement to work in severe weather conditions without adequate protection as an example.

There is a need to address the gaps in the work environment where general workers and artisans struggle to have enough rest on site. Based on their experiment, Fang *et al. (*2015) affirmed that the effects of fatigue could be mitigated and one of the practical ways is to ensure that it does not accumulate. However, the insights from fatigue-related experiments must be accepted with caution because of the inability of laboratory-based research to be directly applied to field conditions in construction (Techera el al., 2018). Beyond organisational approaches to fatigue management, such as rest between breaks, mentioned by the interviewees, contractors must embrace technology-based countermeasures to ensure successful detection, prevention and mitigation of fatigue (Horrey *et al.,* 2011). For example, a recent approach to monitoring physical fatigue in real-time among construction workers using wearable sensors has been reported by Arya *et al. (*2017). The high accuracy level of wearable sensors makes using technology for fatigue management an approach that contractors should explore.

Apart from the multiple causal factors that should not be treated in isolation, it notable that the type of worker or trade is a predictor of fatigue manifestation (Techera *et al.,* 2018). The above narrative shows that construction workers are exposed to fatigue, which has multiple causal pathways. The textual data presented in this paper require analytic generalisation as opposed to statistical generalisation. In terms of analytic generalisation, the results which shed empirical light on the central question of this case study can be generalised beyond construction sites in Bloemfontein to similar work settings. It can be argued that the results presented in this paper corroborate the underlying ideas about the causes of fatigue (Techera *et al.,* 2016; 2018). For example, while several authors, such as Hallowell (2010), have confirmed that fatigue remains a problem in developed countries, this paper has reinforced analytically the notion that fatigue confronts construction in developing countries as well, especially among general workers.

## CONCLUSION

This paper presents factors that cause construction worker fatigue. The paper further demonstrates how fatigue could lead to human errors in construction. The interview technique provided perceptions of the phenomenon based on the lived experiences of people who have encountered fatigue in the frontline of construction. An attempt to answer the question, “What are the causes of fatigue that lead to human errors in construction?”, shows that the causes of fatigue can be categorised under equipment, process, people, materials, environment, and management-related causes, as illustrated

in Figure 2. However, it is noted that the causality illustrated in Figure 2 is not linear because the factors relate to each other and can lead to pervasive manifestations of fatigue if left unchecked. The inter-connected factors that predict fatigue could be conceived as a "recipe". An example of a causal recipe would be the combined influence of working long hours, harsh environmental conditions, and alcohol and drug abuse. While the factors mentioned in this example contribute to fatigue (mental and physical), their effects vary.

One significant insight from this study was the realisation that not all contractors give due attention to fatigue and its consequences on the sites visited. This inadequate attention to the causes of fatigue and their links to human errors require further inquiry. The findings showed that contractors who promote awareness of fatigue tend to implement preventive measures, while contractors who do not promote awareness fail to implement preventive measures.

Some preventive measures include the intentional monitoring of continuous work hours and the periods for breaks on a site and the inclusion of fatigue-related topics in inductions and toolbox talks on site. However, the research results presented in this paper are not exhaustive. There is a need to conduct further research that would establish the strength of the causal factors and the magnitude of their influence on errors committed by construction workers. The robustness of the fatigue management model by Hallowell (2010) in the context of a developing country needs to be tested in a future study. The limitations of the primary data sources presented, in the form of small sample size and the work type (a higher number of managers than general workers in the sample) do not permit statistical generalisation of the results. The insights provided in this paper, as a case study, are framed as a call for more research involving larger projects, higher sample sizes and varied worker types that serve as predictors of fatigue. Such a study will be able to test predictive fatigue models with well-known factors and emergent factors from the field. Comparative studies to further interrogate the predictive power of the factors across multiple trades should also be considered.

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